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# Automatic identification and data capture techniques — Bar code print quality test specification — Linear symbols

*Techniques automatiques d'identification et de capture des données — Spécifications pour essai de qualité d'impression des codes à barres — Symboles linéaires*



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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

This second edition cancels and replaces the first edition (ISO/IEC 15416:2000), which has been technically revised with the following changes, as well as minor editorial modifications:

— the computation of "Defects" was modified in this revision of ISO/IEC 15416 (see Note 3 in 5.4.8); and

— sharp boundaries between grade levels are avoided by assigning grades within grade boundaries to the first decimal place (see the Notes in 6.2.2 and 6.2.3).



# Introduction

The technology of bar coding is based on the recognition of patterns encoded in bars and spaces of defined dimensions according to rules defining the translation of characters into such patterns, known as the symbology specification.

The bar code symbol is produced in such a way as to be reliably decoded at the point of use, if it is to fulfil its basic objective as a machine readable data carrier.

Manufacturers of bar code equipment and the producers and users of bar code symbols therefore require publicly available standard test specifications for the objective assessment of the quality of bar code symbols, to which they can refer to when developing equipment and application standards or determining the quality of the symbols. Such test specifications form the basis for the development of measuring equipment for process control and quality assurance purposes during symbol production, as well as afterwards.

The performance of measuring equipment is the subject of a separate standard, ISO/IEC 15426-1.

This document is to be read in conjunction with the symbology specification applicable to the bar code symbol being tested, which provides symbology-specific detail necessary for its application.

This methodology provides symbol producers and their trading partners a universally standardized means for communicating about the quality of bar code symbols after they have been printed.

# Automatic identification and data capture techniques — Bar code print quality test specification — Linear symbols

## 1 Scope

This document:

— specifies the methodology for the measurement of specific attributes of bar code symbols;

— defines a method for evaluating these measurements and deriving an overall assessment of symbol quality; and

— provides information on possible causes of deviation from optimum grades to assist users in taking appropriate corrective action.

This document applies to those symbologies for which a reference decode algorithm has been defined, and which are intended to be read using linear scanning methods, but its methodology can be applied partially or wholly to other symbologies.



## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**bar reflectance**
lowest reflectance value in the scan reflectance profile of a bar element

**3.2**
**decode**
determination of the information encoded in a bar code symbol

**3.3**
**edge contrast**
difference between *bar reflectance* (3.1) and *space reflectance* (3.14) of two adjacent elements

**3.4**
**element reflectance non-uniformity**
reflectance difference between the highest *peak* (3.9) and the lowest *valley* (3.16) in the scan reflectance profile of an individual element or quiet zone

**3.5**
**global threshold**
reflectance level midway between the maximum and minimum reflectance values in a scan reflectance profile used for the initial identification of elements

**3.6**
**inspection band**
band (usually from 10 % to 90 % of the height of a bar code symbol) across which measurements are taken

Note 1 to entry: See Figure 2.

**3.7**
**measuring aperture**
opening which governs the effective *sample area* (3.10) of the symbol, and the dimensions of which at 1:1 magnification is equal to that of the sample area

**3.8**
**modulation**
ratio of minimum *edge contrast* (3.3) to *symbol contrast* (3.15)

**3.9**
**peak**
point of higher reflectance in a scan reflectance profile with points of lower reflectance on either side

**3.10**
**sample area**
effective area of the symbol within the field of view of the measurement device

**3.11**
**scan path**
line along which the centre of the *sample area* (3.10) traverses the symbol, including quiet zones

**3.12**
**show-through**
property of a substrate that allows underlying markings or materials to affect the reflectance of the substrate

**3.13**
**space**
light element corresponding to a region of a scan reflectance profile above the *global threshold* (3.5)

**3.14**
**space reflectance**
highest reflectance value in the scan reflectance profile of a space element or quiet zone

**3.15**
**symbol contrast**
difference between the maximum and minimum reflectance values in a scan reflectance profile

**3.16**
**valley**
point of lower reflectance in a scan reflectance profile with points of higher reflectance on either side



# 4 Symbols and abbreviated terms

## 4.1 Abbreviated terms

| | |
|---|---|
| EC | edge contrast |
| $EC_{min}$ | minimum value of EC |
| ERN | element reflectance non-uniformity |
| $ERN_{max}$ | maximum value of ERN |

| | |
|---|---|
| GT | global threshold |
| MOD | modulation |
| PCS | print contrast signal |
| RT | reference threshold |
| SC | symbol contrast |

### 4.2 Symbols

| | |
|---|---|
| A | average achieved width of element or element combinations of a particular type |
| c | defect adjustment constant |
| e | width of widest narrow element |
| E | width of narrowest wide element |
| $e_i$ | i'th edge to similar edge measurement, counting from leading edge of symbol character |
| F | factor used to soften the effect on defect grades derived from small changes peaks and valleys within an element |
| K | smallest absolute difference between a measurement and a reference threshold |
| k | number of element pairs in a symbol character in a (n, k) symbology |
| M | width of element showing greatest deviation from A |
| m | number of modules in a symbol character |
| N | average achieved wide to narrow ratio |
| n | number of modules in a symbol character in a (n, k) symbology |
| $R_b$ | bar reflectance |
| $R_D$ | dark reflectance |
| $R_L$ | light reflectance |
| $R_{max}$ | maximum reflectance |
| $R_{min}$ | minimum reflectance |
| $R_s$ | space reflectance |
| $RT_j$ | reference threshold between measurements j and (j + 1) modules wide |
| S | total width of a character |
| V | decodability value |
| $V_C$ | decodability value for a symbol character |
| Z | average achieved narrow element dimension or module size, as measured |

# 5 Measurement methodology

## 5.1 General requirements

The measurement methodology defined in this document is designed to maximize the consistency of both reflectivity and bar and space width measurements of bar code symbols on various substrates. This methodology is also intended to correlate with conditions encountered in bar code scanning hardware.

Measurements shall be made with a defined light source (such as a single light wavelength) and a measuring aperture of dimensions defined by the application specification or determined in accordance with 5.2.1 and 5.2.2. A circular aperture is defined by its diameter in accordance with Table 1. Application specifications may define other aperture diameters or shapes.

Whenever possible, measurements shall be made on the bar code symbol in its final configuration, i.e. the configuration in which it is intended to be scanned. If this is impossible, refer to Annex C for the method to be used for measuring reflectance for non-opaque substrates.

The sampling method should be based on a statistically valid sample size within the lot or batch being tested. A minimum grade for acceptability shall be established prior to quality control inspection. In the absence of a sampling plan defined in formal quality assurance procedures or by bilateral agreement, a suitable plan may be based on the recommendations in ISO 2859-1.

## 5.2 Reference reflectivity measurements

### 5.2.1 General

Equipment for assessing the quality of bar code symbols in accordance with this document shall comprise a means of measuring and analysing the variations in the diffuse reflectivity of a bar code symbol on its substrate along a number of scan paths which shall traverse the full width of the symbol including both quiet zones. The basis of this methodology is the measurement of diffuse reflectance from the symbol.

All measurements on a bar code symbol shall be made within the inspection band defined in accordance with 5.2.4.

The measured reflectance values shall be expressed in percentage terms by means of calibration and reference to recognized national standards laboratories, where 100 % should correspond to the reflectance of a barium sulphate or magnesium oxide reference sample.



### 5.2.2 Measurement light source

The light source used for measurements should be specified in the application specification to suit the intended scanning environment. When the light source is not specified in the application specification, measurements should be made using the light source that approximates most closely to the light source expected to be used in the scanning process. Light sources may include narrow band or broad band illumination. Refer to Annex E for guidance on the selection of the light source.

### 5.2.3 Measuring aperture

The nominal diameter of the measuring aperture should be specified by the user application specification to suit the intended scanning environment. When the measuring aperture diameter is not specified in the application specification, Table 1 should be used as a guide. In an application where a range of X dimensions will be encountered, all measurements shall be made with the aperture appropriate to the smallest X dimension to be encountered.

In the absence of a defined X dimension, the Z dimension shall be substituted.

The effective measuring aperture diameter may vary slightly from its nominal dimension due to manufacturing tolerances and optical effects. Note that the measured width of some of the narrow elements may be smaller than the measuring aperture diameter.

**Table 1 — Guideline for diameter of measuring aperture**

| X Dimension (mm) | Aperture diameter (mm) | Reference number |
|---|---|---|
| 0,100 ≤ X < 0,180 | 0,075 | 03 |
| 0,180 ≤ X < 0,330 | 0,125 | 05 |
| 0,330 ≤ X < 0,635 | 0,250 | 10 |
| 0,635 < X | 0,500 | 20 |
| NOTE The aperture reference number approximates to the measuring aperture diameter in thousandths of an inch. | | |

NOTE The measuring aperture is not to be confused with the F-number of a lens.

### 5.2.4 Optical geometry

The reference optical geometry for reflectivity measurements shall consist of the following:

a) a source of incident illumination which is uniform across the sample area at 45° from a perpendicular to the surface, and in a plane containing the illumination source that shall be both perpendicular to the surface and parallel to the bars;

b) a light collection device, the axis of which is perpendicular to the surface.

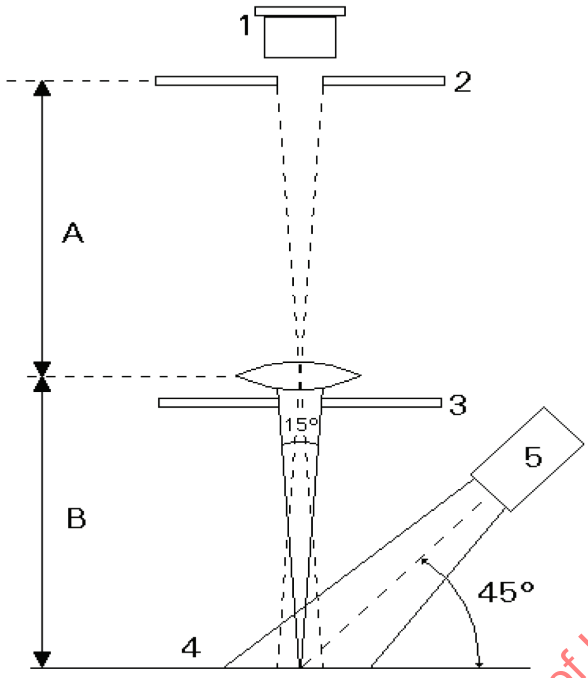
The light reflected from a circular sample area of the surface shall be collected within a cone; the angle at the vertex of which is 15°, centred on the perpendicular to the surface, through a circular measuring aperture, the diameter of which at 1:1 magnification shall be equivalent to that of the sample area.

NOTE Figure 1 illustrates the principle of the optical arrangement, but is not intended to represent an actual device.

This reference geometry is intended to minimize the effects of specular reflection and to maximize those of diffuse reflection from the symbol. It is intended to provide a reference basis to assist the consistency of measurement. It may not correspond with the optical geometry of individual scanning systems. Alternative optical geometries and components may be used, provided that their performance can be correlated with that of the reference optical arrangement defined in this subclause.






**Key**

1 light sensing element

2 aperture at 1:1 magnification (measurement A = measurement B)

3 baffle

4 sample

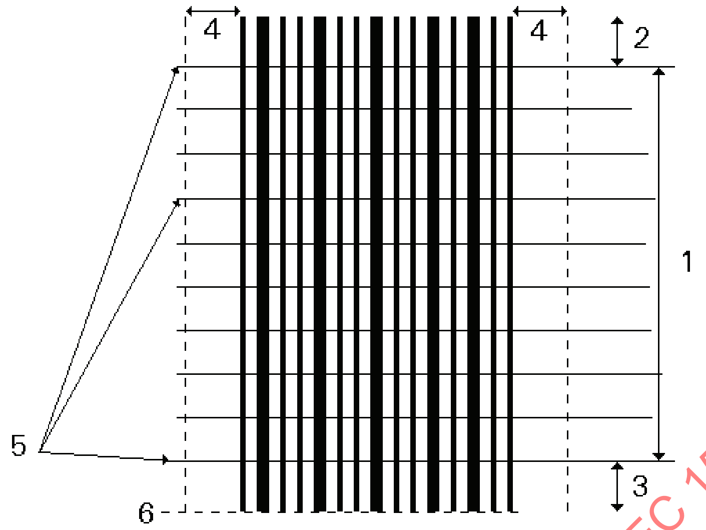
5 light source

**Figure 1 — Reference optical arrangement**



### 5.2.5 Inspection band

The area within which all measurement scan paths shall lie shall be contained between two lines perpendicular to the height of the bars of the symbol, as illustrated in Figure 2. The lower line shall be positioned at a distance above the average lower edge of the bar pattern of the symbol while the upper line shall be positioned at the same distance below the average upper edge of the bar pattern of the symbol. This distance shall be equal to 10 % of the average bar height or the measuring aperture diameter, whichever is greater. The inspection band shall extend to the full width of the symbol including quiet zones.




**Key**

1 inspection band (normally 80 % of average bar height)

2 10 % of average bar height, or aperture diameter if greater, above inspection band

3 10 % of average bar height, or aperture diameter if greater, above average bar bottom edge

4 quiet zones

5 scanning lines

6 average bar bottom edge

**Figure 2 — Inspection band**

### 5.2.6 Number of scans

In order to provide for the effects of variations in symbol characteristics at different positions in the height of the bars, a number of scans shall be performed across the full width of the symbol including both quiet zones with the appropriate measuring aperture and a light source of defined nominal wavelength. These scans shall be approximately equally spaced through the height of the inspection band. The minimum number of scans per symbol should normally be 10 or the height of the inspection band divided by the measuring aperture diameter, whichever is lower. Refer to Annex F for guidance on the number of scans.

The overall quality grade of the symbol is determined by averaging the quality grades of the individual scans, in accordance with Clause 6.

## 5.3 Scan reflectance profile

Bar code symbol quality assessment shall be based on an analysis of the scan reflectance profiles. The scan reflectance profile is a plot of reflectance against linear distance across the symbol. If scanning speed is not constant, measuring devices plotting reflectance against time should make provision to compensate for the effects of acceleration or deceleration. If the plot is not a continuous analogue profile, the measurement intervals should be sufficiently small to ensure that no significant detail is lost and that dimensional accuracy is adequate.

Figure 3 is a graphical representation of a scan reflectance profile. The vertical axis represents reflectance and the horizontal axis linear position. The high-reflectance areas are spaces and the low-reflectance areas are bars. The high-reflectance areas on the extreme left and right are the quiet zones. The important features of the scan reflectance profile can be determined by manual graphical analysis or automatically by numerical analysis. For example, the highest reflectance point on the scan reflectance profile in Figure 3 is approximately 82 % and the lowest is approximately 10 %.

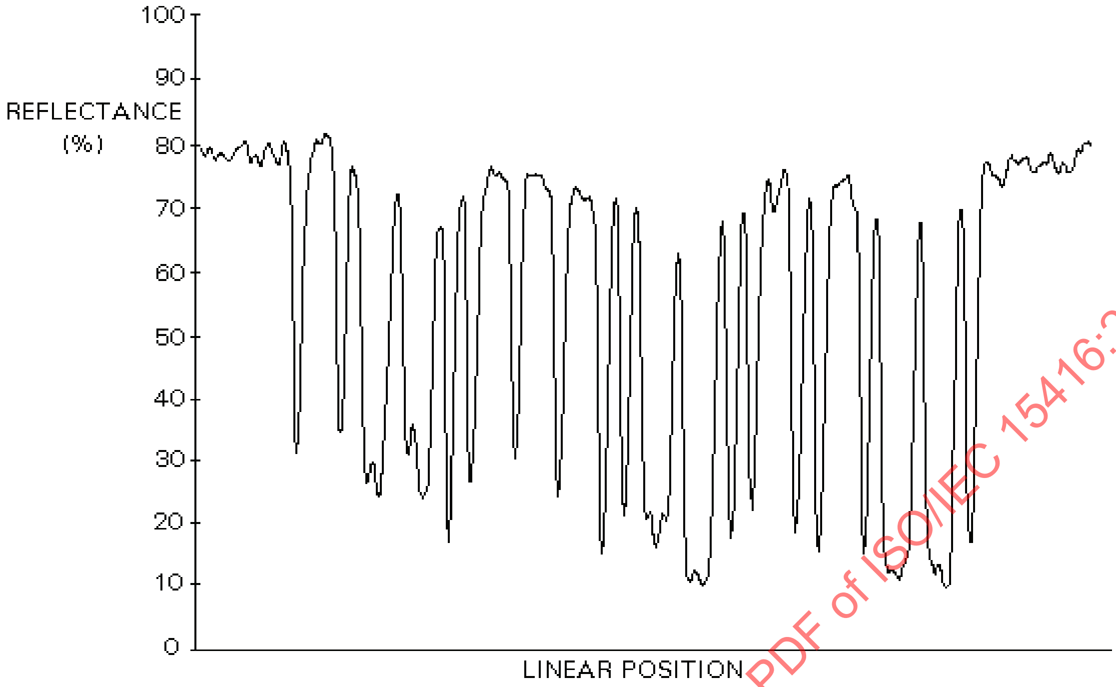



**Figure 3 — Scan reflectance profile**

## 5.4 Scan reflectance profile assessment parameters

### 5.4.1 General

The scan reflectance profile parameters described in 5.4.2 to 5.4.9 shall be assessed for compliance with this document. Grading of the scan reflectance profile parameters is described in 6.2. Figure 4 is the same scan reflectance profile as Figure 3 with certain features indicated.



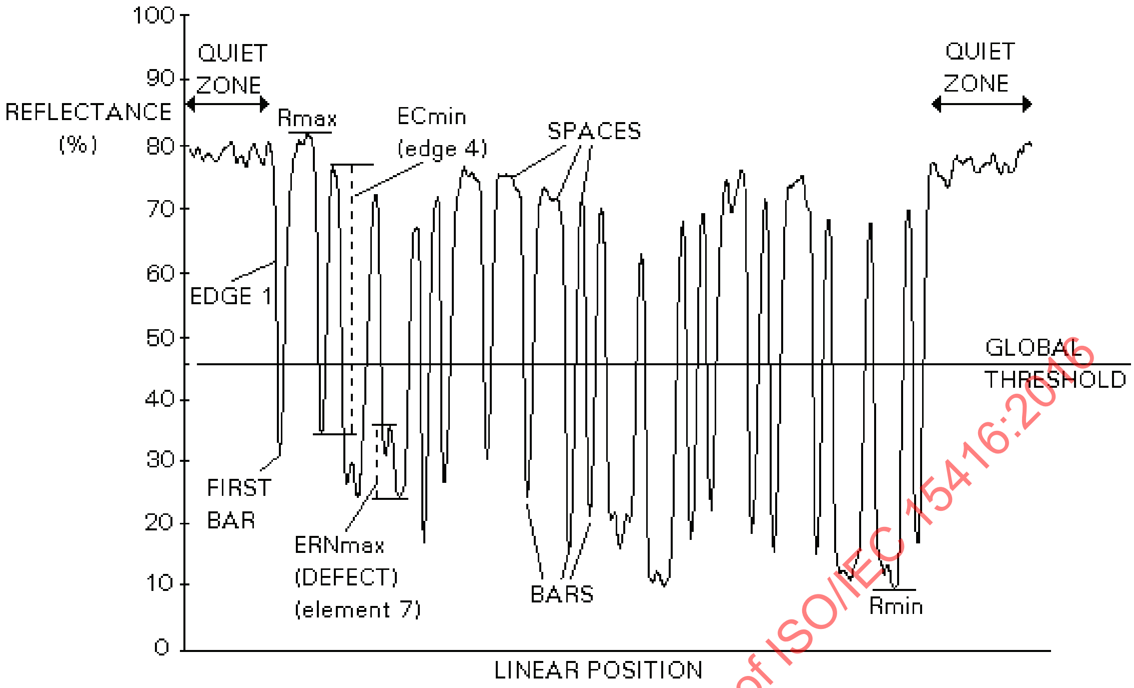



**Figure 4 — Features of scan reflectance profile**



### 5.4.2 Element determination

To locate the bars and spaces, a global threshold shall be established. The global threshold shall be the reflectance value midway between the highest and lowest reflectance values measured in the scan reflectance profile, or:

$$GT = (R_{max} + R_{min})/2$$

where

$R_{max}$ is the highest reflectance value;

$R_{min}$ is the lowest reflectance value.

Each region above the global threshold shall be regarded as a space and the highest reflectance value in the region shall be designated the space reflectance, $R_s$. Similarly, the region below the global threshold shall be regarded as a bar and the lowest reflectance in the region shall be designated the bar reflectance, $R_b$.

For each space, $R_s$ − GT represents its reflectance margin above the global threshold. For each bar, GT − $R_b$ represents its reflectance margin below the global threshold. A warning should be issued when the minimum reflectance margin for any element is less than 5 % of the SC of a symbol. This warning should caution users to consider the possibility that this symbol is close to an F grade for edge determination.

NOTE This warning is not required and this recommendation is newly introduced in this revision of this document.

### 5.4.3 Edge determination

An element edge shall be defined as being located at the point where the scan reflectance profile intersects the mid-point between $R_s$ and $R_b$ of two adjacent regions, i.e. where the reflectance value is $(R_s + R_b)/2$. If more than one point satisfying this definition exists between adjoining elements, then the edge position and the element widths will be ambiguous and the scan reflectance profile shall fail the decode parameter. The quiet zones and intercharacter gaps, if any, are considered to be spaces.

### 5.4.4 Decode

The symbology reference decode algorithm shall be used to decode the symbol using the element edges determined in 5.4.3. This algorithm may be found in the symbology specification.

### 5.4.5 Symbol contrast (SC)

Symbol contrast is the difference between the highest and lowest reflectance values in a scan reflectance profile.

$$SC = R_{max} - R_{min}$$

### 5.4.6 Edge contrast (EC)

Edge contrast is the difference between the $R_s$ and $R_b$ of adjoining elements including quiet zones. The lowest value of edge contrast found in the scan reflectance profile is the minimum edge contrast, $EC_{min}$.

$$EC = R_s - R_b$$

### 5.4.7 Modulation (MOD)

Modulation is the ratio of the minimum edge contrast to symbol contrast.

$$MOD = EC_{min}/SC$$

### 5.4.8 Defects

Defects are irregularities found within elements and quiet zones, and are measured in terms of element reflectance non-uniformity.

Element reflectance non-uniformity within an individual element or quiet zone is the difference between the reflectance of the highest peak and the reflectance of the lowest valley. When an element consists of a single peak or valley, its reflectance non-uniformity is zero. The highest value of element reflectance non-uniformity found in the scan reflectance profile is the maximum element reflectance non-uniformity. Defect measurement is expressed as the ratio of the maximum element reflectance non-uniformity ($ERN_{max}$) to symbol contrast.

a) Define the defect adjustment constant “c” equal to 0,075.

NOTE 1 “c” corresponds to the following:

— a small amount of “noise” to be reduced to eliminate instability in measurement;

— an amount of contrast difference that is small enough for scanners to ignore.

NOTE 2 If “c” would be defined as 0, the method described here is equivalent to the defect grade specified in the previous edition of this document in all cases (because the factor, F, defined below, would always be equal to 1).

b) For each bar element.

1) For each positive Peak Maxima in the element:

i) find the lowest valley to the left of it within the element, called $R_{minLeft}$;

ii) find the lowest valley to the right of it within the element, called $R_{minRight}$;

iii) calculate $ERN_{left}$ as the Peak Maximum − $R_{minLeft}$;



iv) calculate $ERN_{right}$ as the Peak Maximum − $R_{minRight}$;

v) take the lesser of $ERN_{left}$ and $ERN_{right}$ as ERN′ (ERN prime);

vi) set F to the value 1 if ERN′ ≥ c. If ERN′ < c, then calculate F = ERN′/c;

vii) calculate the provisional ERN for this peak (and only this peak) as F × MAX ($ERN_{left}$, $ERN_{right}$).

2) Take the maximum of the provisional ERN values from all iterations of the previous step as the ERN of this element.

c) Same as b) for each space element, and as follows.

1) For each negative Valley Minima (a local minima):

i) find the highest peak to the left of it within the element, called $R_{maxLeft}$;

ii) find the highest peak to the right of it within the element, called $R_{maxRight}$;

iii) calculate $ERN_{left}$ as $R_{maxLeft}$ − the Valley minimum;

iv) calculate $ERN_{right}$ as $R_{maxRight}$ − the Valley minimum;

v) take the lesser of $ERN_{left}$ and $ERN_{right}$ as ERN′ (ERN prime);

vi) set F to the value 1 if ERN′ ≥ c. If ERN′ < c, then calculate F = ERN′/c;

vii) calculate the provisional for this valley (and only this valley) as F × MAX ($ERN_{left}$, $ERN_{right}$).

2) Take the maximum of all the provisional ERN values from all iterations of the previous step as the ERN of this element.

d) Take the maximum of all ERN values from b) 2) and c) 2) as $ERN_{max}$ for the overall scan.

Defects = $ERN_{max}$/SC

NOTE 3 The calculation of $ERN_{max}$ described above is modified in this revision of this document.

Three cases are especially useful to illustrate the functioning of this algorithm. The leftmost example shown in Figure 5 is an example of a case that will be affected by this change. The defect will be reduced because $ERN_{left}$ is very small (in particular, it is much less than “c”). The middle example shows a case where many peaks and valleys exist within an element, but $ERN_{left}$ and $ERN_{right}$ are much larger than “c”. The defect measurement will not be affected by this change. The rightmost example is actually equivalent to the middle example in as much as this algorithm is concerned, even though $ERN_{left}$ and $ERN_{right}$ are different for each local maxima.

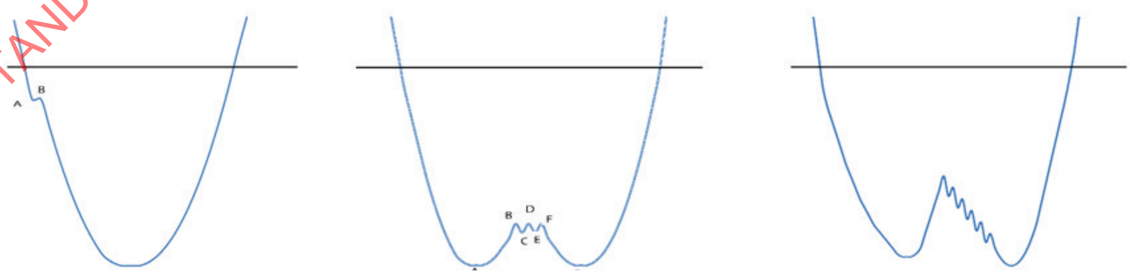


**Figure 5 — Examples to illustrate ERN calculation**

### 5.4.9 Decodability

The decodability of a bar code symbol is a measure of the accuracy of its production in relation to the appropriate reference decode algorithm. Bar code scanning equipment can generally be expected to perform better on symbols with higher levels of decodability than on those with lower decodability.

Rules governing the nominal dimensions for each bar code symbology are given in particular symbology specifications. The reference decode algorithm allows reasonable margin for errors in the printing and reading processes by defining one or more reference thresholds at which a decision is made as to the widths of elements or other measurements.

The decodability of a scan reflectance profile is the fraction of available margin which has not been consumed by the printing process and is thus available for the scanning process. When calculating the decodability value, V, for a scan reflectance profile, regard shall be to the measurements required by the reference decode algorithm in the relevant symbology specification. In the following paragraph, the term “measurement” shall be taken to refer to either to a single element width, in symbologies which use these directly in the reference decode algorithm (e.g. “Code 39”), or to the combined width of two or more adjacent elements, in symbologies using edge to similar edge measurements for decoding (e.g. “Code 128”).

The decodability value is calculated with reference to the following:

a) the average achieved width (referred to in the formula below as A) for measurements of a particular type [e.g. narrow elements, or bar + space combinations nominally totalling 2 (or 3, or 4 ...) modules] in the scan reflectance profile;

b) the reference threshold applicable to measurements of the same type as A (referred to in the formula below as RT);

c) the actual measurement showing the greatest deviation from A in the direction of the reference threshold, (referred to in the formula below as M).

The general form of the formula for calculating V is as follows:

V = absolute value of [(RT − M)/(RT − A)]

where

(RT − M) is the remaining margin not used by printing variation;

(RT − A) is the total theoretical margin based on the ideal measurement of the element(s).

Figure 6 illustrates this principle. The shaded area represents the range of measurements of the same type as A (e.g. narrow elements). All measurements are taken from 0.

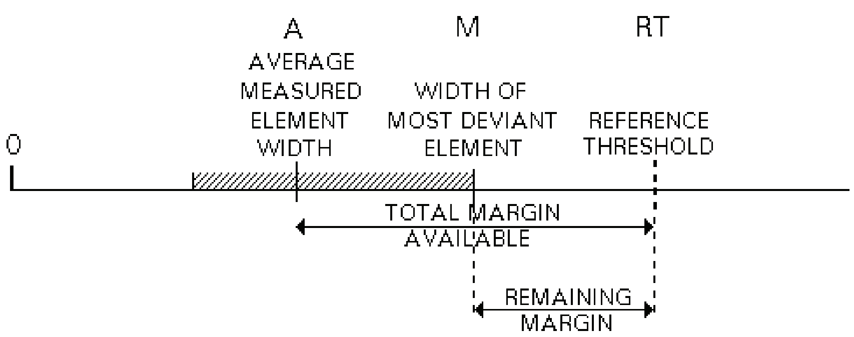



**Figure 6 — Principle of decodability measurement**

More specific formulae applicable to either two-width symbologies or (n, k) symbologies are defined in Annex A. Reference should also be made to the symbology specification for the particular computation of decodability unique to each symbology.

#### 5.4.10 Quiet zone check

The average narrow element width, Z, shall be calculated and revised quiet zones determined based on this dimension. $R_{max}$, ERN of the quiet zones and $R_s$ of the quiet zones, as used in the initial scan reflectance profile analysis, shall be compared with new values obtained for the revised quiet zones. If the value(s) differ, then affected portions of the scan reflectance profile analysis shall be repeated.

## 6 Symbol grading

### 6.1 General

As a consequence of the use of different types of bar code reading equipment under differing conditions in actual applications, the level of quality required of a bar code symbol to ensure an acceptable level of performance will differ. Application specifications should therefore define the required performance in terms of symbol grade in accordance with this document, following the guidelines in D.3.

Symbol grading shall be used to derive a relative measure of symbol quality under the measurement conditions used. Each scan reflectance profile shall be analysed and assigned a grade on a descending scale from 4 to 0 in steps of 0,1. The grade 4 represents the highest quality, while the grade 0 represents failure. The scan reflectance profile grade for each scan reflectance profile shall be the lowest grade of any parameter in that scan reflectance profile. The overall symbol grade shall be the arithmetic mean of the scan reflectance profile grades. If any two scans of the same symbol yield different decoded data, then the overall symbol grade, irrespective of individual scan reflectance profile grades, shall be 0. An example of a symbol quality grading is given in Annex B. For the interpretation of the scan reflectance profile and profile grades, see Annex D.

In order to determine the causes of poor quality grades, it is necessary to examine the grades for each parameter in the scan reflectance profile in question as described in D.2. For process control purposes, the averages of the grade for each parameter obtained from all the scan reflectance profiles may provide meaningful guidance (see I.4). If the grades alone do not provide sufficient explanation, it may also be necessary to examine the plot(s) of the scan reflectance profile(s).

### 6.2 Scan reflectance profile grading

The scan reflectance profile grade shall be the lowest grade of the following:

a) decode;

b) symbol contrast (SC);

c) minimum reflectance ($R_{min}$);

d) minimum edge contrast ($EC_{min}$);

e) modulation (MOD);

f) defects;

g) decodability (V);

h) any additional requirements imposed by the application or symbology specification.

It is appropriate to measure these parameters in the sequence given above.

### 6.2.1 Decode

Decodable symbols shall comply with the symbology specification, notably in respect of character encodation, start and stop patterns, symbol check character(s), quiet zones and intercharacter gaps (where applicable). If the scan reflectance profile cannot be decoded using the symbology reference decode algorithm, then it shall receive the failing grade 0. Otherwise, it shall receive the grade 4.

### 6.2.2 Reflectance parameter grading

Depending on their values, symbol contrast, modulation and defects may be graded from 4,0 to 0 in steps of 0,1; minimum reflectance and minimum edge contrast grades may be graded either 4 or 0. These parameters are interdependent and need to be considered together.

Table 2 defines the parameter values corresponding to the various grades.

**Table 2 — Reflectance parameter grading**

| Grade | $R_{min}$ | SC | $EC_{min}$ | MOD | Defects |
|---|---|---|---|---|---|
| 4,0 | ≤0,5 $R_{max}$ | ≥70 % | ≥15 % | ≥0,70 | ≤0,15 |
| 3,0 | | ≥55 % | | ≥0,60 | ≤0,20 |
| 2,0 | | ≥40 % | | ≥0,50 | ≤0,25 |
| 1,0 | | ≥20 % | | ≥0,40 | ≤0,30 |
| 0 | >0,5 $R_{max}$ | <20 % | <15 % | <0,40 | >0,30 |

For SC, MOD and defects, the grade shall be computed as an interpolated value, rounded to the nearest 0,1 in between grade levels. For example, SC of 52 % shall result in a grade of 2,8 and MOD of 0,69 shall results in a grade of 3,9. In the lowest range, the grade shall be interpolated from 1 down to 0, except defect which shall be 0 for all values greater than 0,30. The decimal part of the SC grade is computed as the fraction of the range for the grade of 2 (15 %) that the measured value (52 %) exceeds the minimum value for a grade of 2 (40 %), computed as 2 + [(52 % − 40 %)/15 %].

NOTE The interpolation described above is a new feature in this revision of this document and is introduced as a way of reducing meaningless grade level fluctuations when small changes in measurements cause a grade to transition between grade levels.



### 6.2.3 Decodability

The decodability value, V, for each scan reflectance profile shall be calculated according to the formula for the type of symbology in question set out in Annex A, supplemented where necessary by formulae specific to the symbology in question, contained in the symbology specification. Decodability is graded from 4 to 0, rounded to the nearest 0,1, in between grade levels according to Table 3. For example, for V of 0,56 shall result in a grade of 3,5 and V of 0,20 shall result in a grade of 0,8.

**Table 3 — Decodability grades**

| V | Grade |
|---|---|
| ≥0,62 | 4 |
| ≥0,50 | 3 |
| ≥0,37 | 2 |
| ≥0,25 | 1 |
| <0,25[a] | 0 |

[a] For values less than 0,25, interpolate from 1 down to 0.

NOTE The interpolation described above is a new feature in this revision of this document and is introduced as a way of reducing meaningless grade level fluctuations when small changes in measurements cause a grade to transition between grade levels.

### 6.3 Expression of symbol grade

A symbol grade is only meaningful if it is expressed in conjunction with the measurement light source and aperture used. It should be shown in the format G/A/L, where G is the overall symbol grade, i.e. the arithmetic mean of the scan reflectance profile grades to one decimal place, A is the aperture reference number, from Table 1, and L indicates the light source, by the light peak wavelength in nanometres for narrow band illumination, the letter "W" for white (broad band) illumination, or other designator defined by an application specification.

For example, 2,7/05/660 would indicate that the average of the grades of the scan reflectance profiles was 2,7 when these scan reflectance profiles were obtained with the use of a 0,125 mm aperture (ref. no. 05) and a 660 nm light source.

## 7 Substrate characteristics

Certain characteristics of the substrate, notably gloss, low opacity and the presence of an over-laminate may affect reflectance measurements, and the recommendations in Annex C should be taken into account if any of these factors is present.

# Annex A
(normative)

# Decodability

## A.1 General

This annex defines general formulae for the calculation of the decodability value, V, for symbologies for which the reference decode algorithm defines reference thresholds. These formulae may be supplemented by additional formulae specific to an individual symbology and defined in the relevant symbology specification.



## A.2 Two-width symbologies

In each scan reflectance profile, calculate Z and N for the whole symbol.

For each symbol character or auxiliary pattern, calculate RT in accordance with the reference decode algorithm.

Then,

$V1 = (RT - e)/(RT - Z)$

$V2 = (E - RT)/[(N \times Z) - RT]$

$V_C$ = the lesser of V1 or V2

The decodability value, V, for the scan reflectance profile shall be the lowest value of $V_C$ for any symbol character or auxiliary pattern.

## A.3 Edge to similar edge decodable symbologies [(n, k) symbologies]

If necessary in each scan reflectance profile, calculate Z for the whole symbol:

$Z = (\text{average } S)/n$

where S and n are as defined in 4.2.

For each symbol character, determine a set of reference thresholds $RT_j$:

for all $j = 1$ to $n - 2(k - 1)$

$RT_j = [(j + 0{,}5) \times S]/n$

where S, n and k are as defined in 4.2.

for all $i = 1$ to $2(k - 1)$ and all $j = 1$ to $n - 2(k - 1)$

let K = smaller of absolute value of $(e_i - RT_j)$ or previous K

where $e_i$ is the measurement from leading edge of element i to leading edge of element (i + 2).

Then, $V_C = K/(S/2n)$.

The decodability value, V, for the scan reflectance profile shall be the lowest value of $V_C$ for any symbol character or auxiliary pattern.

# Annex B
(informative)

# Example of symbol quality grading

## B.1 Individual scan reflectance profile grading

This annex illustrates the determination of the grades for the scan reflectance profile shown in Figure 3, assuming measurement using a 900 nm (infrared) light source and a 0,125 mm aperture.

Referring to Figure 3, the actual reflectance values may be determined graphically in order to grade the scan reflectance profile.

Minimum reflectance ($R_{min}$) is 10 % while the maximum reflectance ($R_{max}$) is 82 %. The global threshold is therefore 46 %. $R_{min}$ satisfies the (0,5 × $R_{max}$) test by being less than (0,5 × 82 %) = 41 %.

Symbol contrast (SC) is 82 − 10 = 72.

Minimum edge contrast ($EC_{min}$) occurs on edge 4, where $R_s$ and $R_b$ are 76 % and 34 %, respectively. $EC_{min}$ is 76 − 34 = 42.

Modulation (MOD) is therefore 42/72 = 0,58

Maximum element reflectance non-uniformity ($ERN_{max}$), the largest non-uniformity or defect in a scan reflectance profile, can be found as the result of a void in element 7, a bar. $ERN_{max}$ is equal to 36 − 24 = 12. Note that the $ERN_{max}$ can be in any bar, space or quiet zone. The defects value is therefore

12/72 = 0,17.

Assuming that the symbol has decoded correctly (as characters “Start $ M Stop” in “Code 39”) and that the decodability value, V, has been calculated as 0,58, the following individual parameter grades and the scan reflectance profile grade can be determined for the scan reflectance profile in Figure 3 (see Table B.1).

**Table B.1 — Grades for the scan reflectance profile as shown in Figure 3**

| Parameter | Value | Grade |
|---|---|---|
| Decode | | 4 |
| $R_{max}$ | 82 % | |
| $R_{min}$ | 10 % | 4,0 |
| SC | 82 − 10 = 72 % | 4,0 |
| $EC_{min}$ | 76 − 34 = 42 % | 4,0 |
| MOD | 42/72 = 0,58 | 2,8 |
| Defects | 12/72 = 0,17 | 3,6 |
| Decodability | 0,58 | 3,7 |

Since the lowest individual grade, in this instance the grade for MOD, is 0,28, the scan reflectance profile grade is also 2,8.

See also Annex G.



## B.2 Overall symbol grade

Assuming that a series of 10 scans of the symbol used in Figure 3 gave the following scan reflectance profile grades:

2, 2, 3, 3, 4, 2, 2, 2, 3, 3,

the arithmetic mean of these grades, and hence the overall symbol grade, is 2,6. The result should be reported in the form

2,6/05/900.

For information, this result would be shown, using alphabetic grading as

B/05/900.

# Annex C
(informative)

# Substrate characteristics

## C.1 General

In certain circumstances (for example, the design and production of printed packaging materials incorporating bar code symbols), it is necessary or desirable to assess the acceptability of substrates and/or ink colours for a given bar code application, before a bar code symbol is available, which could be tested in accordance with this document.

## C.2 Substrate opacity

The symbol shall be graded according to the reflectance parameters in 6.1.2 when measured in its final configuration, e.g. final filled package.

If it is not possible to measure the symbol in this configuration, then the effects of show-through of high-contrast interfering patterns may be ignored if when measured as follows, the substrate opacity is 0,85 or greater. If the opacity is less than 0,85, the symbol should be measured when backed by a uniform dark surface the reflectance of which is not more than 5 %.

The opacity of the substrate shall be calculated as follows:

$$\text{Opacity} = R2/R1$$

where

R1 is the reflectance of a sample sheet of the substrate backed with a white surface the reflectance of which is 89 % or greater;

R2 is the reflectance of the same sample sheet backed with a black surface of not more than 5 % reflectance.

## C.3 Gloss

The reference illumination conditions specified for the measurement of reflectance should enable the maximum rejection of specular reflection while giving a representative assessment of the diffuse reflectance of the symbol and substrate. Highly glossy materials and those whose diffuse reflectance characteristics vary with the angle of incident and/or collected light may yield grades differing from those obtained by the use of the reference optical arrangement.

## C.4 Over-laminate

A symbol intended to be covered with a protective lamination should be graded according to the reflectance parameters in 6.2.2 when measured with the laminate in place. The thickness of the laminate including its adhesive should be as small as possible in order to minimize its effects on the reading performance of the symbol.



## C.5 Static reflectance measurements

In some cases, it may be desirable to carry out static reflectance measurements of samples of the substrate on which a bar code is to be printed and on colour patches or ink samples which replicate the colour in which the bar code will be printed. The following guidelines provide a means which, if it is followed, will predict as closely as is generally possible, the results which will be obtained when the symbol is scanned dynamically.

Static reflectance measurements should be made with the wavelength of light, aperture size and optical arrangement which relate to the application and which are specified in accordance with 5.2.1 to 5.2.3.

Where reflectance measurement equipment meeting the requirements of this annex is not available, optical density measurements may be made using a standard densitometer with an appropriate light source and converted to reflectance values; density (D) and reflectance (R) are related as follows:

$R = 100/10^{D}$.

NOTE It is impossible to predict to a high degree of accuracy the symbol contrast and, in particular, the edge contrast which will be achieved in the printed symbol. It is therefore appropriate to allow some safety margin above the minimum values for specified grades.

### C.5.1 Prediction of symbol contrast (SC)

The prediction of SC requires that measurements of reflectance be made on samples which simulate the highest ($R_{max}$) and lowest reflectance ($R_{min}$) areas which will be present in the finished symbol.

It is probable that in most bar code symbols, $R_{max}$ will be found in the quiet zone of the symbol; therefore to simulate the conditions found in the quiet zone, $R_{max}$ should be measured in the centre of a sample area, at least 10× in diameter, of the material on which the symbol is to be printed.

It is probable that in most bar code symbols, $R_{min}$ will be found in the widest bars of the symbol; therefore to simulate the conditions most likely to yield a value of $R_{min}$ consistent with that which would be found in practice, reflectance should be measured in the centre of a strip of material 2× to 3× wide and which matches the colour in which the bars are to be printed.

A predicted value of SC can then be calculated as follows:

$SC' = R_{max} - R_{min}$

### C.5.2 Prediction of minimum edge contrast ($EC_{min}$) and modulation (MOD)

In order to assess the grade for modulation (MOD), it is necessary to predict the minimum value of edge contrast likely to be found in practice. It is best to make measurements of edge contrast on the printed symbol. If that is not possible, the prediction of $EC_{min}$ requires that measurements of reflectance be made on samples which simulate the smallest reflectance difference which will be found between adjacent elements. It is probable that in most bar code symbols, this condition will be found where a light and a dark element which are each 1× in width are adjacent to each other and where the element on the other side of the light element is a wide dark element.

To simulate this condition, a sample of material, which is of the colour in which the bar code symbol will be printed, should be cut to form a mask of the type shown in Figure C.1.




**Figure C.1 — Mask for static reflectance measurements**

The mask shown in Figure C.1 should be made of a material that is as thin as is practical. It will however have some thickness and would therefore be capable of casting a shadow. To ensure that the effects of this are minimized, it is essential that the light source(s) of the instrument used to make the measurements are oriented to be in line with the long axis of the elements in which the measurements are being made. The narrow dark element AA and the narrow light element BB should each be equal in width to the X dimension of the symbol to be printed and the height of BB should be at least 20× or 10 mm, whichever is greater.

The measurement of the reflectance value $R_s$ should be made in the narrow light element which is formed when the mask in Figure C.1 is placed over a background of the material and colour on which the bar code is to be printed.

The measurement of the reflectance value $R_b$ should be made in the narrow dark element which is formed when the mask in Figure C.1 is placed over a background of the material and colour on which the bar code is to be printed.

A predicted value of $Ec_{min}$ can then be calculated as follows:

$$Ec_{min}' = R_s - R_b$$

For materials which do not satisfy the tests for opacity, which are detailed in C.1, the measurements which are made for the purpose of predicting SC and ECmin should be made with the test samples backed by a uniform dark surface, the reflectance of which is not more than 5 %. The same measurements should then be made with the test samples backed by a uniform surface the reflectance of which is not less than 89 %. The calculated values of static SC and ECmin shall be equal to or greater than the minimum values for the grade selected for the application, for tests on both the dark and light backgrounds.

A predicted value of MOD can be calculated as follows:

$$MOD' = Ec_{min}'/SC'$$



### C.5.3 Acceptability of measured and derived values

The grades corresponding to the static values of SC and $EC_{min}$ and to the derived value for modulation (MOD) shall all be equal to or higher than the minimum overall symbol grade specified for the application.

For applications where print contrast signal (PCS) is the preferred method of determining the reflectance characteristics of a bar code symbol, an approximation of the value of PCS can be determined from the values measured for the purpose of predicting SC. Refer to Annex H.

# Annex D
(informative)

# Interpretation of the scan reflectance profile and profile grades

## D.1 Significance of scan reflectance profiles

The scan reflectance profile represents the signal from a typical bar code scanning device. In a bar code reader, this signal is processed by an edge finding circuit prior to arriving at the decoder.

In order to allow a variety of edge finding circuits to find the intended elements, the following reflectance parameters should be considered:

— the global threshold should be traversed by every edge in the symbol;

— symbol contrast, modulation and minimum edge contrast should not be too low;

— defects and minimum reflectance should not be too high.

In addition, to allow a decoder to function, the following parameters should be considered:

— decode;

— decodability.

## D.2 Interpretation of results

When examining a symbol with a view to drawing conclusions about the possible causes of low grades, individual parameter grades should be examined, as well as the overall grade. There is a degree of interdependence between the parameters, but typical causes and effects are listed below. For process control purposes, significant additional information may be derived by averaging the grades obtained for each parameter for all scan reflectance profiles. In particular, the measurement of the average bar width gain or loss may be used for monitoring the performance of a printer or printing press during an extended print run.

Bar width gain:

— may be reported directly (as average);

— reduces EC;

— reduces MOD;

— reduces decodability:

  — if not systematic, decodability will suffer though average bar width gain does not appear excessive;

  — if systematic, decodability will appear low and average bar width gain will be higher;

— may cause decode failure if excessive.

Bar width loss:

— may be reported directly (as average);

— increases EC initially; when excessive, reduces EC;

— increases MOD initially; when excessive, reduces MOD;

— may increase $R_{min}$;

— reduces decodability:

  — if not systematic, decodability will suffer though average bar width loss does not appear excessive;

  — if systematic, decodability will appear low and average bar width loss will be higher;

— may cause decode failure if excessive.

Irregular element edges:

— cause variations in decodability between scan reflectance profiles;

— may cause decode failure if excessive.

Uneven inking:

— decreases EC;

— decreases MOD;

— may increase $ERN_{max}$;

— may cause spurious elements to be detected (decode failure).

Voids and/or specks:

— increase ERN;

— if excessive in size may cause spurious elements to be detected (decode failure);

— may cause edge determination failure.

## D.3 Matching grades to applications

Because of the varying features of bar code systems, notably:

— vertical redundancy;

— tolerances in decoding algorithms;

— ability of operators to rescan in the event of failure to read;

— availability of scanning equipment with multiple scan paths.

Symbols with differing grades may give good performance in practice. Application specifications should specify the minimum acceptable grade (together with aperture size and shape and light wavelength or light source) to suit the characteristics of the scanning environment.

Symbols with an overall grade of 3,5 or better are the best quality and will in principle perform most reliably. This grade should be specified as a minimum where the reader crosses the symbol once only (with little possibility of rescanning in the event of failure to read) or is limited to a fixed single scan path.

A symbol graded between 2,5 and 3,5 if scanned in a single path may require rescanning to decode. A minimum grade of 2,5 is appropriate for systems where the symbol will be read on most occasions in a single scan pass, but which allow for rescanning.

Symbols graded between 1,5 and 2,5 are more likely to require rescans than those with higher grades. For best read performance, devices which provide for multiple scan paths across the symbol should be used or the system should be prepared to allow frequent rescan attempts.

Symbols with grades between 0,5 and 1,5 should be read by equipment providing for multiple, unique scan paths across the symbol. Some readers may fail to scan some such symbols successfully. System designers may therefore wish to provide for alternative means of data entry in such an event. Prior to the acceptance of symbols of this grade for a particular application, it is recommended that the symbols should be tested with the type of bar code reader to be used to determine that the results are within acceptable limits.

Symbols graded below 0,5 will have had a high proportion of "failed" scan reflectance profiles and are unlikely to perform reliably with any reading equipment.

## D.4 Alphabetic grading

In certain application specifications, grades are identified using the letters A, B, C, D and F to correspond to the numeric grades 4, 3, 2, 1 and 0 respectively used in this document.

Overall symbol grading using this scheme is in accordance with Table D.1.

**Table D.1 — Overall symbol grading — Numeric and alphabetical grading equivalence**

| Numeric range | Alphabetic grade |
|---|---|
| 3,5 to 4,0 | A |
| 2,5 to <3,5 | B |
| 1,5 to <2,5 | C |
| 0,5 to <1,5 | D |
| below 0,5 | F |

# Annex E
(informative)

# Guidance on selection of light wavelength

## E.1 General

5.1 and 5.2.2 require measurements to be made using the wavelength of light which the intended scanning environment will use. If, as may happen, an application specification does not specify the light source, a judgment needs to be made in order to determine the most likely wavelength, to enable valid measurements to be made and to be sure that the results will be properly indicative of likely scanning performance in the application.

## E.2 Light sources

Light sources for bar code scanning applications normally fall into two broad areas, namely visible light and infrared light, although a very few highly specialized applications may call for light sources of unusual characteristics such as ultra-violet for fluorescent bar code symbols.

Visible light scanning normally uses light sources with a peak wavelength in the red part of the spectrum, between 620 nm and 700 nm. Infrared scanning uses sources with peak wavelengths between 720 nm and 940 nm.

The most common light sources used for bar code scanning are as follows:

a) helium-neon laser (633 nm);

b) light-emitting diode (numerous wavelengths, both visible and infrared);

c) solid-state laser diode (numerous wavelengths, both visible and infrared);

d) incandescent lamp (nominally white light);

e) white LED.

The key characteristics of these are as follows.

A **helium-neon laser** is a gas-filled laser tube which emits highly monochromatic coherent light at a peak wavelength of 632,8 nm (most usually rounded to 633 nm), in the visible red area of the spectrum.

A **light-emitting diode** is a low-power solid-state component most frequently found as the light source in a light pen (wand) or CCD scanner. Operating wavelengths in the visible spectrum may be from 620 nm to 680 nm; most commonly either 633/640 or about 660 nm. In the infrared spectrum, 880 nm to 940 nm is the most common range of wavelengths.

Typical wavelengths used by **solid-state laser diodes** at the date of publication of this document are 780 nm (infrared) and, in the visible spectrum, 660 nm and 680 nm. They are frequently found in hand-held (laser) scanning equipment and a number of fixed scanners.

In bar code scanning applications, **incandescent lamps** are mainly found in systems using CCD array camera and image processing technology rather than scanning techniques. The light source has a power distribution covering much of the visible spectrum and well into the infrared spectrum; optical characteristics are defined in colour temperature terms rather than in those of peak wavelength, because of the wide bandwidth and relative absence of peaks in the power distribution. When used in conjunction with a Wratten 26 filter, the light characteristics of a 2856°K lamp approximate to those of a 620 nm to 633 nm source.



White LEDs emit a combination of wavelengths that are prominent in the blue and yellow regions. The colour spectrum of white LEDs should be defined within an application.

NOTE Wavelengths stated above can change as the technology evolves.

## E.3 Effect of variations in wavelength

The reflectance of a substrate or bar code symbol element varies with the wavelength of the incident light. A black, blue or green printed area will tend to absorb visible red light strongly (and appear therefore of low-reflectance), whereas a white, red or orange area will reflect most of the incident light. In the infrared spectrum, the apparent colour of the element does not correlate at all with reflectance; it is the nature of the pigmentation used (for example, the proportion of carbon content) which governs reflectance. Taking reflectance measured at 633 nm as a reference, when measured at 660 nm or 680 nm, the results may differ significantly and sufficiently to cause the symbol grade to change by one or two units, or even more in the case of bars printed on some thermal papers.



# Annex F
(informative)

# Guidance on number of scans per symbol

Bar code symbols are designed to provide a considerable degree of vertical redundancy of the information contained in them. Localized defects and variations in symbol characteristics may occur in the height of the symbol, resulting in the likelihood of scan reflectance profiles from different scan paths across the symbol differing significantly. It is therefore necessary to assess the overall symbol quality by averaging scan reflectance profile grades from multiple scan paths.

The minimum number of scans per symbol as defined in 5.2.5 should normally be 10 or the height of the inspection band divided by the measuring aperture diameter, whichever is lower.

Where the production process (in particular, in the circumstances defined in I.1) has been shown to be subject to a relatively low incidence of the defects and variations referred to above through documented formal quality assurance procedures in accordance with ISO 9000 and related standards, the number of scans per symbol may be reduced in order to simplify the process of assessment of large numbers of symbols. Refer to I.2 for details of this reduction.



# Annex G
(informative)

# Example of verification report

There exists a wide range of verification equipment designed to measure the quality of bar code symbols. Table G.1 illustrates an example report produced by one of these devices (assuming that the report below was obtained with the use of a measuring aperture of 0,250 mm diameter (ref. no. 10) and with a 660 nm light source. The grade should therefore be reported as 3,3/10/660.

**Table G.1 — Example of verification report**

| VERIFICATION REPORT | | | |
|---|---|---|---|
| Date | 23.12.14 | Time | 16:12:36 |
| Aperture: | 0,25 mm | Wavelength: | 660 nm |
| Symbology: | Code 39 | Decoded data: | $M |
| **Overall Symbol Grade:** | 3,3 (B) | Averaged over (no. of scans): | 1 |
| **Scan reflectance profile analysis** | | | |
| **Parameter** | **Value** | **Grade** | |
| Decode | Pass | 4 | |
| $R_{max}$ | 79 % | N/A | |
| $R_{min}$ | 2 % | 4 | |
| Global threshold | 41 % | N/A | |
| Symbol contrast | 77 % | 4,0 | |
| Min. edge contrast | 48 % | 4 | |
| Modulation | 63 % | 3,3[a] | |
| Defects | 16 % | 3,8 | |
| Decodability | 75 % | 4,0 | |
| PCS | 97 % | N/A | |
| Average bar gain | +3,0 % | N/A | |
| [a] Parameter grade(s) determining scan reflectance profile grade. | | | |