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Automatic identification and data capture techniques — Bar code print quality test specification — Evolution of the grading and measurement of linear symbols in ISO/IEC 15416

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

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Automatic identification and data capture techniques — Bar code print quality test specification — Evolution of the grading and measurement of linear symbols in ISO/IEC 15416

1 Scope

This document explains the changes incorporated in ISO/IEC 15416:2016 compared to ISO/IEC 15416:2000 and highlights the impact of these changes for the users' benefit.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 15416:2016, *Automatic identification and data capture techniques — Bar code print quality test specification — Linear symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 15416:2016 apply.

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

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

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

4 Historical background leading to ISO/IEC 15416:2016

ISO/IEC 15416 was first published in 2000 and has been used in many industries throughout the world. Based on a method first developed and published by ANSI in 1990 as X3.182-1990, the methodology for bar code grading has become a foundation of barcode quality in many industries including supply chain management, retail point of sale, warehousing, shipping and logistics, pharmaceutical labelling and many others.

Even with the widespread adoption of ISO/IEC 15416 as the basis of bar code quality measurement, some problems and opportunity for improvement were noticed by many users and members of ISO/IEC JTC1/SC31/WG1 which is responsible for ISO/IEC 15416. Chief among these was the tendency for grades to fluctuate under repeated trials. Accordingly, the revision of ISO/IEC 15416 in 2016 introduced several changes to the grading methodology with the intention of reducing grade variability

Another criticism of ISO/IEC 15416 grading is that scanning/reading technology has improved significantly since its introduction, resulting in a reduction in the correlation between quality grade and real-world scanning performance. Accordingly, the revision of ISO/IEC 15416 in 2016 tends to assign higher grades than before, as is described in this report.

These problems have been largely resolved by the publication of ISO/IEC 15416:2016. This document:

— explains the changes introduced in ISO/IEC 15416:2016;

— explains why these changes were introduced and how they reduce the problems outlined above;

— explains the impact of these changes in existing application standards;

— helps new and existing application standards to consider how to respond to these impacts.

5 Summary of changes introduced in ISO/IEC 15416:2016

5.1 Review of measurements and grades

In the grading method of ISO/IEC 15416, quality parameters are measured and then graded. A measured value for a parameter is obtained on a nominally continuous scale, typically from 0 to 100. In general, grade levels are assigned to ranges of measured values. Prior to the 2016 revision, ISO/IEC 15416 defined only five grade levels, namely 0, 1, 2, 3 or 4, with 4 being the highest or best grade and 0 being the lowest and worst grade. (Historically, these grades correspond to the letter grades used in ANSI X3.182, namely A, B, C, D and F). For example, for the parameter called Symbol Contrast, any measured value in the range of 40 through 55 was assigned a grade level of 2 (corresponding to a "C" in ANSI X3.182).

NOTE The grades 0, 1, 2, 3 and 4 are commonly associated with the ANSI X3.182 grades of F, D, C, B and A and this relationship is noted here for reference only.

5.2 Change to number of grade levels

The assignment of a range of measured values to a single grade, and the fact that there are only five grade levels covering five ranges has two significant consequences. The first is that there is a sharp transition at the boundary of measured value ranges. For example, when symbol contrast is measured as to be 39 it is graded as 1 but when it is measured as 40 or more it is graded as 2. While there is no practical difference in quality between 39 and 40 for symbol quality, there is quite a significant difference in the grades of 1 and 2. Thus the meaning of the grade 1 and 2 is not clear because it is not possible to know (from the grade alone) whether the measured parameter was near the boundary between these grade levels.

The other consequence, as can be anticipated from the previous discussion, is that small variations in the measured values, which are inevitable due to tolerances in any measurement system, can result in large fluctuations in grade (namely a change in grade of 1 full grade level). This effect is exacerbated when the bounded range for a grade is small, as it is for defect (range of only 5) and modulation (range of only 10). The most significant impact from narrow ranges is that measurements are often near boundaries between grade levels, and thus even normal tolerances are more likely to produce changes in grade levels.

NOTE The allowed tolerance for defect and symbol contrast is 8 which is significant compared to the size of the bounded ranges, which in the case of defect is actually smaller than the allowed tolerance which is 8.

To reduce grade variability, the process of assigning grades to the measured parameters was changed in ISO/IEC 15416:2016, by increasing the number of grade levels from 5 to 41, corresponding to grade levels represented by decimal number 4,0 down to 0 in steps of 0,1. This can be referred to as "continuous grading" but in fact is stepwise, albeit with smaller steps than before.

5.3 Change to measurement of defect

Another significant change to ISO/IEC 15416 was to introduce a modification to the measurement of DEFECT, again to reduce a potential source of grade fluctuation. This modification creates a gradual change in the defect measurement value for a gradual change in the size of the size of a "peak" or "valley" in the scan reflectance profile to prevent large grade changes that could occur in the old grading system when a "peak" or "valley" is very small compared to not present at all.

NOTE The grade for DEFECT also utilizes the continuous grading concept described above, but also has another change that is specific to calculating the DEFECT measurement value.

6 Continuous grading

ISO/IEC 15416:2016 introduced “continuous grading” which assigns grades on a gradual basis rather than using only five levels. Figure 1 shows the five grade levels for symbol contrast (SC) defined in ISO/IEC 15416:2000.

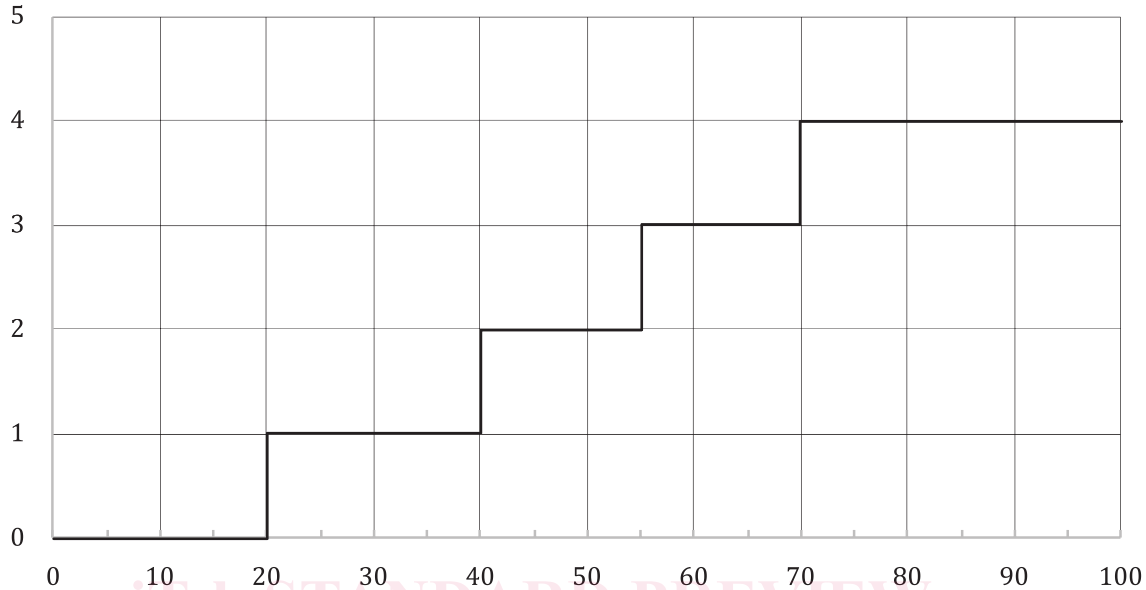


Figure 1 — “Staircase” showing values for SC, assigned to integer grade levels

The continuous grading scale is from 0 to 4 (in keeping with the original grade levels) but assigns values with a step size of 0,1 as shown in Figure 2.

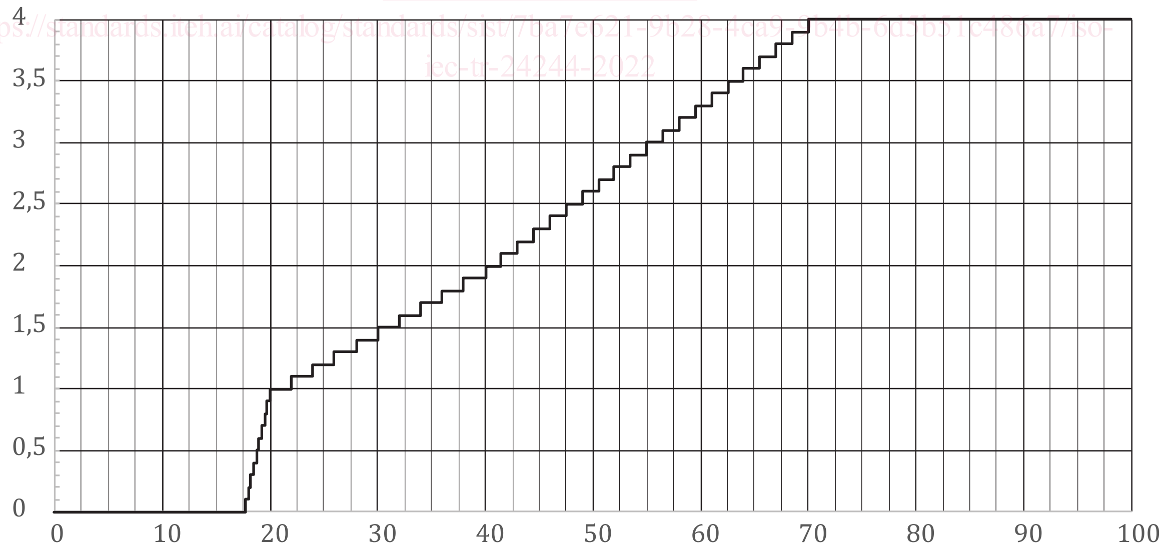


Figure 2 — Continuous grades for symbol contrast, assigned to 41 smaller grade levels

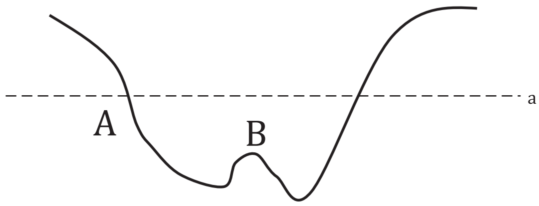
With continuous grading, much smaller ranges of measured values, are assigned to many more grade levels, providing almost continuous grading. The grading is not completely continuous because of the rule that the grade shall be rounded to the nearest tenth, but this is practically inconsequential. The transition from grades 1 to 0 occurs over a small range with a grade of 0 being reached before the measured value reaches zero.

7 Changes to defect measurement

A change to the measurement of defect was also introduced in ISO/IEC 15416:2016. This change is quite independent of the continuous grading change discussed in this document. For completeness, this document also describes the change to the defect measurement.

NOTE Even though the change to defect described in this clause is independent of the continuous grading change, the grade level assignment for defect is also modified to use continuous grading.

A defect is defined as element non-uniformity and is measured by the degree of reflectance variation within an element (bar or space) as a fraction of the symbol contrast. Because elements begin at the boundary where its scan reflectance profile (SRP) transitions across a reflectance threshold, the element non-uniformity is selected only at points represented by a "peak" or a "valley" as illustrated in Figure 3. Note that point "A" does not represent the maximum reflectance for this element, only point "B" does.



Key

a Global threshold.

Figure 3 — Fragment of a scan reflectance profile showing a peak within a bar element

However, the search for "peaks" and "valleys" can lead to unintended consequences when small fluctuations in the SRP, especially near the threshold, can be alternately perceived as a "peak" or "valley" or not seen as one of those. Therefore, ISO/IEC 15416:2016 introduces a formula which assigns a "weight" to the size of the "peak" or "valley" and uses this weight to modify the non-uniformity measured value as a function of this weight. Very slight peaks and valleys will have very small weights and will be highly discounted in their impact on the defect measurement. However, peaks that are at least 7,5 % of symbol contrast will be fully weighted. Notably, defects that are relatively normal and especially those found on calibrated conformance test cards will be fully weighted and therefore unmodified by this change. Small fluctuations near element boundaries, which are sometimes produced by "halos" in flexographic printing, may be reduced by this change. Most notably, the fluctuation that can arise when a small fluctuation in the SRP occurs near an element boundary, and sometimes results in a peak or valley, but sometimes does not, will have reduced impact on any defect measurement produced by this small fluctuation.

8 Impact of continuous grading on final grades and application standards

8.1 General

The final grade assigned to a barcode according to ISO/IEC 15416 is an average of the grades for several (typically 10) individual scan samples of the barcode. Preferably, at least 10 scans are taken at nominally equally spaced cross-sections of the barcode. Each scan is graded and then these grades are averaged to arrive at a final grade. This average is normally expressed to the nearest tenth (as would naturally result with no loss of precision when averaging 10 integers).

Many application standards are written with the intent of accepting a minimum quality corresponding to the historical grade "C" from ANSI X3.182. An average grade (from the several scans taken on a barcode) of 1,5 through 2,4 is considered a "C" grade. Therefore, it has become common for application standards to set an acceptable quality level of 1,5. One important consequence of the continuous grading that is introduced in ISO/IEC 15416:2016 is effectively to change the minimum quality level accepted by application standards that set their minimum grade to 1,5. Subclause 8.2 illustrates and explains why this is the case, in each of several example circumstances, and in general.

8.2 Grading situations

8.2.1 Grades consistently at high end of a grade range

Consider a case in which all 10 scans of a barcode have a measured value of symbol contrast that is just lower than 55 % so that is in at the upper end of the 2 ("C") range, but nearly a grade 3 ("B").

The range for symbol contrast grade of 2 is 40 through 55. In ISO/IEC 15416:2000, the grade given for symbol contrast would be 2,0 for all 10 scans. In ISO/IEC 15416:2016, these would be graded as 2,9 for all 10 scans and the overall grade would be 2,9, nearly the same as a 3,0. If this numerical grade is "rounded" to the nearest letter grade, it would be a 3 ("B") because it is higher than 2,5. Even without rounding, a grade of 2,9 is significantly higher than the 2,0 it would have received in ISO/IEC 15416:2000. It is important to note that the grade that is given to the barcode in this example is significantly different in ISO/IEC 15416:2016 compared with ISO/IEC 15416:2000. (Consider that the measurement that is nearly 55, results in a grade that is nearly 3.0, which it seemingly "deserves").

8.2.2 Grades consistently at low end of a grade range

Consider a case in which all 10 scans of a barcode have a measured value of Symbol Contrast that is just slightly higher than 40 so that it is barely within the 2 range but almost low enough to be a 1.

In the previous revision of ISO/IEC 15416, the grade given for symbol contrast would be 2.0 for all 10 scans. In the new revision, these would be graded as 2 or perhaps 2.1 for all 10 scans and the overall grade would be similar. It is important to note that the grade given to the barcode in this example is similar between the old and new revisions. It is important to also note that 2,1 is much higher than 1,5. which is the minimum in many application standards. The new revision intended to ensure that barcodes would be given grades in the new revision that are not lower than given by the original revision.

8.2.3 Grades consistently at midpoint of a grade range

Consider a case in which all 10 scans are approximately in the middle of the range that was assigned a grade of 2 in ISO/IEC 15416:2000, namely 47,5 for symbol contrast. In ISO/IEC 15416:2000, all these scans would be graded as 2 and the average grade would be 2. In ISO/IEC 15416:2016, these scans would be graded 2,5 and the average grade would be 2,5.

It may be noted at this point that measured values that are in the middle of a bounded range, result in a grade that is in the middle of grade levels such as 2,5, rather than the integer value corresponding to the "bottom" of that grade level.

8.2.4 Grades fluctuating across grade boundary

Consider a case in which the measured parameter value for symbol contrast is approximately 40, which happens to be the boundary between grades 1 and 2. Due to measurement tolerance, some of the scans will be measured below 40, and some will be measured at or above 40. In ISO/IEC 15416:2000, the average grade will depend upon the number of scans in which a grade of 1 and 2 were obtained. Practically any average grade between 1,0 and 2,0 can be produced, although an average close to 1,5 would be expected and most likely. This would happen when half of the scans are graded 1 and half are graded 2. There is no way to distinguish this case from one in which half of the scans are graded 1 at the low end of the range for 1 and half are graded 2 at the high end of the range for 2.

In ISO/IEC 15416:2016, a grade of 2,0 (or perhaps 1,9 or 2,1) is most likely and this is the benefit of continuous grading.

In the revised system introduced by ISO/IEC 15416:2016, a measured value that is approximately at the boundary between grade levels produces a grade that is approximately equal to the corresponding grade level boundary (such as 2,0) and not a grade that is midway between grade levels (such as 1,5) which would be produced previously.

8.3 Impact of continuous grading on existing application standards

8.3.1 Similar Results at different minimum grade level

As illustrated above, the case that can be expected to produce the grade at the boundary of acceptability for application standards in ISO/IEC 15416:2000 results in a volatile grade fluctuating near 1,5 but susceptible to large deviations, but the new system gives a more stable value of 2,0 with much smaller expected deviations. Therefore, it may be appropriate for application standards which seek quality of "C" level to change the minimum acceptable grade level from 1,5 to 2. On the other hand, keeping the minimum acceptable grade of 1,5 will in many cases, permit barcodes with lower quality to pass. Subclause 8.3.2 discusses the issue of minimum acceptance grade in consideration of this effect.

8.3.2 Impact to application standards if acceptable minimum grade level is not changed

Many users of ISO/IEC 15416 have noted that while the standard has been in place for many years, scanner performance has improved over that time. Since one of the goals of ISO/IEC 15416 is to predict scanner performance and readability of barcodes in actual use, it has become less effective at prediction since the grading system has not "kept up" with advances in reading technology. In other words, the old system may be failing more codes than necessary, considering the capability of modern reading technology. Therefore, it may actually be appropriate to leave the acceptable grade level at 1,5 even though the new system allows some lower quality barcodes to be accepted because they would score this grade now and not in the old system.

8.3.2.1 Beneficial impacts of leaving acceptable grade level with no change

8.3.2.1.1 Stability

With the old grading system, a final grade that is near the midpoint between whole numbers is the result of an average of scans that have distinctly different grades (such as 1 and 2). In practice, this often occurs when the measured value of a parameter differs by a small amount on successive scans but happen to be grouped near a boundary between grade levels. This is common because the grade levels themselves are small, relative to the tolerance on these measurements. For example, the range of modulation values that are assigned a grade of 2 is only 10 points (50 to 60) and for defect it is only 5 (20 to 25). Even small variations in the measurement can, and often does, produce a whole number change in the grade for a scan (from 1 to 2 for example). The new grading system removes this instability and actually produces what may have been the original intent of setting the grade at midpoint between grade levels, i.e. to allow some scans to fall below the absolute minimum of a grade level, and still result in an acceptable overall grade.

To explain this further, consider a case in which 9 of 10 scans score a grade of 2, but one scores a grade of 1, due to the parameter falling just below the boundary for the 2-grade level. The overall average grade in this case will be 1,9. If the application standard required a minimum grade of 2,0, it would disallow this case from being an acceptable one, which is probably not the intent. Thus, acceptable grades were typically set by application standards at midpoints between grade levels, even though these values do not correspond to the grade that could be assigned to any scan, or indeed even to any parameter.

With the new grading system, the grades should be more stable because small variations in the measured value can only result in correspondingly small changes in the resulting grade that is assigned.

The new grading system can thereby produce an intended outcome – that of allowing symbols that have grades resulting from some scans in which a parameters value falls on both sides of a grade boundary.

