GS1 US

Bar Code Verification for Linear Symbologies

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1 Introduction

This guideline has been prepared to help answer the more common questions about the role, use, and interpretation of bar code verification and its results. It concentrates on the application of the "Scan Reflectance Profile" assessment methodology (now known as "ISO verification") as defined in international standards and on its use for bar code verification in the GS1 System.

NOTE: The illustrations of bar code symbols in this document will not yield the same results, if verified, as the original symbols.

2 What is Verification?

Verification is:

- A bridge between printing a bar code and successfully scanning and correctly delivering the data that is encoded in the bar code.
- A method to asses a bar code.
- A quality control term to describe the testing of a bar code’s print quality following ISO/IEC 15416 Information technology-Automatic identification and data capture techniques-Bar code print quality test specification-Linear symbols.
- An attempt to predict how reliably a bar code will scan in the field.

2.1 What is Validation?

Validation differs from verification in that it ensures that the elements that are supposed to appear on a printed label do appear. Validation is a critical process used in the production of labels. For example, regulations and laws govern what must be printed on labels for certain controlled substances. Sometimes these laws specify not only what must appear on the label, but where on the label and what the font size must be. A validator “looks” at a label to ensure the designated fields are properly populated.

Often, the manufacturers of this equipment will call them “verifiers”. A purchaser of this type of equipment needs to ensure that they are getting the quality control equipment to perform their necessary tasks.

2.2 How Does a Verifier Differ from a Scanner?

A verifier is a precision measuring instrument designed to provide consistent and repeatable measurements of a symbol. It truly is a scientific instrument. Based on the ISO parameters, it passes judgment on the quality of the bar code. A verifier reports whether a symbol has been printed properly or not.

A bar code scanner is, strictly speaking, only the "front end" of a bar code reading system. It “reads” a bar code and then delivers what is encoded in the bars and spaces to decoding software and collection databases. A scanner does not pass judgment on a bar code and reports nothing about its quality.

A scanner should not be used to “check the readability” of the symbol because no two scanners are the same. Each reading environment is unique. If a particular scanner can read a bar code, you cannot conclude that other scanners will be able to read the bar code as well.

2.3 Who Needs to Use Verification?

Anyone who handles bar code symbols and has an interest in their performance has a potential need for verification. The main classes of user are: the printer of the symbols (this might be a packaging manufacturer or the product manufacturer if he uses an on-demand printing system) for quality assurance and process control purposes; the person on whose product or item the bar code is being applied (the Brand Owner) for assurance that his customers will accept the symbols; the person receiving the bar coded item for assurance that the symbols will work satisfactorily in his operation; persons handling the goods at intermediate stages of the supply chain, who may wish to assure themselves of the symbol quality for similar reasons.

It is the responsibility of the “originator” of the bar code symbol (usually the Brand Owner of the product being bar coded) to ensure that it meets the quality requirements of the entire supply chain.

3 Applicable Standards

The standards listed below are referenced in the guideline. The relevant provisions contained in the referenced specifications constitute provisions of the guideline.

- *GS1 General Specifications* – Available in the Solutions Center through the GS1 US website at www.gs1us.org/solutionscenter
- *ISO/IEC 15416 Information Technology – Automatic identification and data capture techniques – Bar code print quality test* specification – *Linear symbols*
- *ISO/IEC 15426-1 Information Technology – Automatic identification and data capture techniques – Bar code verifier conformance testing – Part 1: Linear symbols*

4 What Verification Does

In simple terms, an "ISO verifier" looks at the symbol in exactly the same way that a scanner sees it. A verifier demands defined environmental conditions to get reproducible results, such as a constant angle, distance, and aperture. The verifier assesses the symbol quality, not as a single "Pass / Fail" decision, but as one of a range of four passing grades. Grades range from 4.0 to 0.0 in order of decreasing quality with 0.0 representing a failing grade. This enables an application to set the most appropriate minimum grade for acceptability. Symbol grades are sometimes referred to as the letter A, B, C, D, or F. The following figure compares the letter grade to the ISO grade range.

ISO Grade Range	Comparable Symbol Grade
3.5 - 4.0	A
2.5 - 3.5	B
1.5 - 2.5	C
0.5 - 1.5	D
0.0 - 0.5	F

Figure 4.1 – ISO grade range compared to equivalent symbol grade

5 When to Verify

Verification of a symbol may be carried out at a number of stages in the life of a symbol, and the purpose for which it is performed may vary each time. As previously stated, it is not necessary to verify every individual symbol. As a general rule, a sampling basis should be used, based on a company's Statistical Process Control (SPC) policies. If symbol grades approach the borderline for acceptability, or there is reason to suspect problems, increase the sampling frequency.

There are several stages during the production process where verification may be appropriate, some examples include:

<u>Film master verification</u> - If you or your printer use an actual film master to produce a printing plate, perform a quality check when you verify the film master. Catch any problems before any more time or effort is expended toward production.

<u>Test print verification</u> - Before production begins, but after a printing plate or digital master has been made, make a test print to check for Bar Width Reduction (BWR), ink spread, and Bar Width Increase (BWI), image shift.

<u>Beginning, middle, and end of a press run</u> - Even if you do not suspect trouble with the print run, check your process at the beginning, middle, and end of a press run.

<u>Finished good</u> - The *GS1 General Specifications* state that a bar code should always be verified in its final configuration if possible. Good manufacturing process dictates that you perform a quality check on a product as your customer will receive it.

The following figure shows a bar code printed on an on demand application (thermal transfer printer). This sample was made before the production run and was printed with a test bar printed above the bar code. The test bar revealed a burned out element on the thermal print head. This problem would have caused "bad bar codes", which would not have been readily diagnosed in the production stage, had the test print not been made.

6 14141 99999 6

Figure 5.1 – UPC-A with test bar showing burned out element

6 The Verification Process

The process of verification includes several subjects:

- Visual inspection - substrate, visual contrast, and color check
- Bar height and Quiet Zone infractions
- Application specification compliance - symbol selection, X-dimension / size
- Data integrity
- On demand printer bar code print density
- Quality specification
- Verifier calibration - calibration patch, *Calibrated Conformance Standard Test Cards*
- Verification aperture selection
- Scan Reflectance Profile (SRP), global threshold
- Scan path, SRP grade
- Overall symbol grade
- Nine ISO Parameters, pass/fail parameters, graded parameters:
  - Edge determination, reflectance minimum, Symbol Contrast, edge contrast, modulation, defects, decode, decodability, and Quiet Zone
- Process troubleshooting
- Verification techniques

6.1 How a Scanner Works

A scanner (and the scanner portion of a verifier) performs two functions; it functions as an illumination device, and as a light collection device. First, the scanner shines a red light onto the bar code. In a laser scanner, the light appears as a line going across the bar code, but it actually is a red "dot" moving quickly across or side-to-side at a set speed that fools the eye into thinking it is a "line". In a Charge Couple Device (CCD), the bar code is "flooded" with red light, and a light pen style scanner requires the operator to move the red "dot" across the bar code.

While the scanner is illuminating the bar code, it is also collecting reflected light. Just as a black automobile absorbs sunlight in the summer and becomes warm, the black bars of a bar code absorb the scanner's red light. The background / spaces of the bar code reflect light back to the scanner. As this reflect / absorb / reflect / absorb process continues, it is noted electronically by the scanner as reflected light (the spaces) "flips the switch" on, no light reflected (or absorbed light - the bars) "flips the switch off". These on / offs are decoded by software into data and sent to and stored in a database.

6.2 Visual Inspection, Colors, and Quiet Zone Infractions

Visual inspection provides the first quality check of a symbol. Inspect the material that will be printed on, called the substrate. If you are using a wet ink process, that is, a process where liquid ink is laid down on the substrate necessitating a dry time, consider the following questions and implications:

- Is the substrate porous? This may cause the ink to spread and flow unevenly.
- Is the substrate dark? This may cause a scanner to have a difficult time distinguishing between the bars and spaces of a bar code.

The best “colors” for a bar code are black bars on a white background. If there is a need or desire to print the bar code in colors, be mindful of how a scanner “sees” a bar code. Remember that many scanners use red light illumination. The best colors for the bars (best to absorb red) are black, dark blue, and dark green; the best colors for the background/spaces (best to reflect red) are white, pink / red, and orange.

It is important to visually inspect the finished product for packaging that may infringe on the symbol or the symbol’s Quiet Zone.

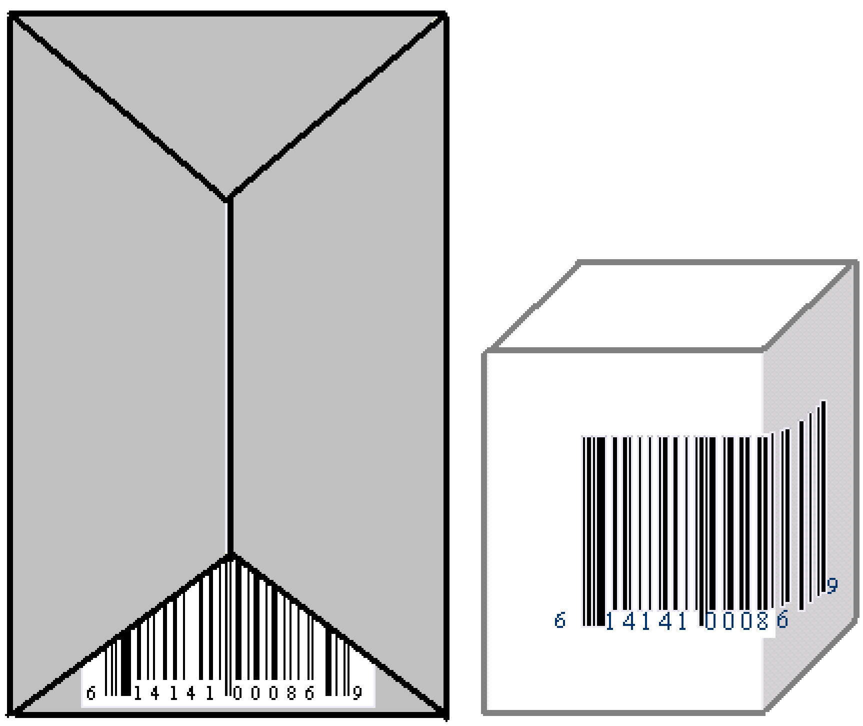


Figure 6.1 – Packaging infringing on the bar code

6.3 Application Specific Compliance

Although this document references the ISO/IEC standard for linear symbol verification, the ISO standard states that guidelines for specific application take precedence over that standard. The *GS1 General Specifications* are just such a document, and areas of the *GS1 General Specifications* differ from the ISO/IEC standard (see the *Verifier Aperture Selection* section). Be aware that in those instances where the *GS1 General Specifications* differ from the ISO/IEC standard, the *GS1 General Specifications* prevail for the supply chain applications they cover.

Symbol Selection - The *GS1 General Specifications* offers the following decision tree in *Section 5.4.2.7.1* for the purpose of selecting the proper symbol for the proper application in the GS1 System. The tables referred to in the decision tree can be found in the next section of this document.

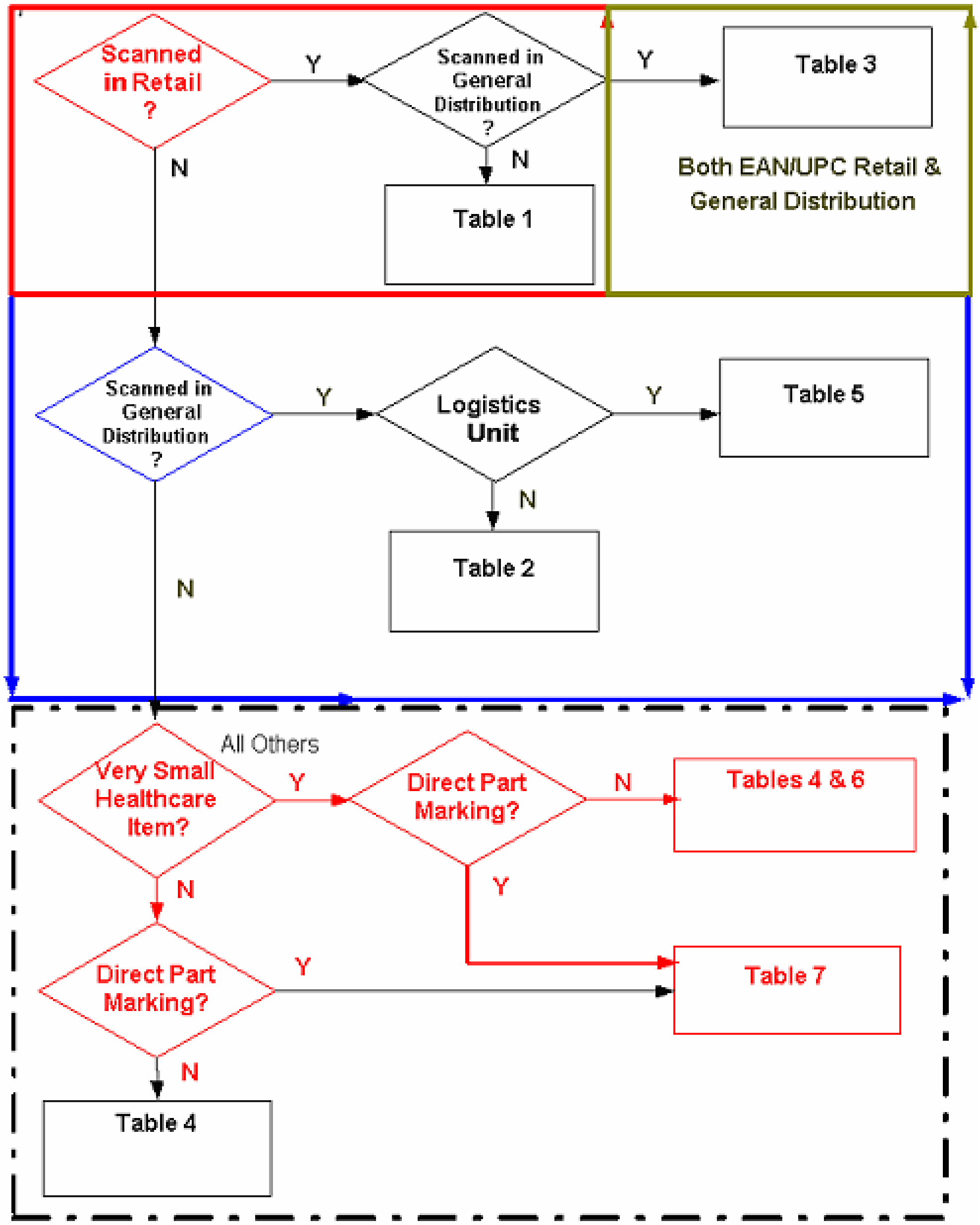


Figure 6.2 – Symbol selection decision tree

6.4 Bar Height and X-dimension

The tables below from the *GS1 General Specifications* specify bar code size (X-dimension), the bar code height, requirements for the Quiet Zone, and the quality specification for given applications within the GS1 System. Verification does not check the application for use, the bar height, or size for application. These tables provide vital information and should be considered part of the verification process for GS1 compliance. These tables consist of:

- *Table 1* describes the bar codes only for retail scanning.
- *Table 2* describes the bar codes scanned in general distribution but not in retail and are not for logistics units.
- *Table 3* describes the bar codes scanned in both retail and general distribution.
- *Table 4* describes the bar codes for special applications, that is, not retail, not general distribution, not very small healthcare items, and not for direct part marking.
- *Table 5* describes logistic unit marking.

* Primary Symbol(s) Specified	X-dimension mm (inches)			*** Minimum Symbol Height for Given X mm (inches)			Quiet Zone			Minimum Quality Specification
	**Minimum	Target	Maximum	For Minimum X-dimension	For Target X dimension	For Maximum X-dimension	Left		Right	
EAN-13	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	11*X*		7*X*	1.5/06/670
EAN-8	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	17.03 (0.67")	21.3 (0.80")	42.58 (1.68")	7*X*		7*X*	1.5/06/670
UPC-A	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*		9*X*	1.5/06/670
UPC-E	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*		7*X*	1.5/06/670
* Primary Symbol(s) Specified Plus Add-on 2 or 5	X-dimension mm (inches)			** Minimum Symbol Height for Given X mm (inches)			Quiet Zone	Minimum Separation Between Symbols	Maximum Separation Between Symbols	Minimum Quality Specification
	**Minimum	Target	Maximum	For Minimum X-dimension	For Target X-dimension	For Maximum X-dimension	Left			
EAN-13 + 2	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	11*X*	7*X*	12*X*	1.5/06/670
EAN-13 + 5	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	11*X*	7*X*	12*X*	1.5/06/670
UPC-A + 2	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*	9*X*	12*X*	1.5/06/670
UPC-A + 5	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*	9*X*	12*X*	1.5/06/670
UPC-E + 2	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*	7*X*	12*X*	1.5/06/670
UPC-E + 5	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*	7*X*	12*X*	1.5/06/670

Figure 6.3 – GS1 System Symbol Specification Table 1

Symbol(s) Specified	*X-dimension mm (inches)			** Minimum Symbol Height for Given X mm (inches)			Quiet Zone		***Minimum Quality Specification
	Minimum	Target	Maximum	For Minimum X-dimension	For Target X dimension	For Maximum X-dimension	Left	Right	
EAN-13	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	38.87 (1.53")	51.82 (2.04")	51.82 (2.04")	11*X*	7*X*	1.5/06/670
EAN-8	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	31.94 (1.26")	42.58 (1.68")	42.58 (1.68")	7*X*	7*X*	1.5/06/670
UPC-A	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	38.87 (1.53")	51.82 (2.04")	51.82 (2.04")	9*X*	9*X*	1.5/06/670
UPC-E	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	38.87 (1.53")	51.82 (2.04")	51.82 (2.04")	9*X*	7*X*	1.5/06/670
ITF-14	0.495 (0.0195")	0.495 (0.0195")	1.016 (0.040")	32.00 (1.25")	32.00 (1.25")	32.00 (1.25")	10*X*	10*X*	1.5/10/670
GS1-128	0.495 (0.0195")	0.495 (0.0195")	1.016 (0.040")	32.00 (1.25")	32.00 (1.25")	32.00 (1.25")	10*X*	10*X*	1.5/10/670

Figure 6.4 – GS1 System Symbol Specification Table 2

Symbol(s) Specified	*X-dimension mm (inches)			** Minimum Symbol Height for Given X mm (inches)			Quiet Zone		Minimum Quality Specification
	Minimum	Target	Maximum	For Minimum X-dimension	For Target X-dimension	For Maximum X-dimension	Left	Right	
EAN-13	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	38.87 (1.53")	51.82 (2.04")	51.82 (2.04")	11*X*	7*X*	1.5/06/670
EAN-8	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	31.94 (1.26")	42.58 (1.68")	42.58 (1.68")	7*X*	7*X*	1.5/06/670
UPC-A	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	38.87 (1.53")	51.82 (2.04")	51.82 (2.04")	9*X*	9*X*	1.5/06/670
UPC-E	0.495 (0.0195")	0.66 (0.026")	0.66 (0.026")	38.87 (1.53")	51.82 (2.04")	51.82 (2.04")	9*X*	7*X*	1.5/06/670

Figure 6.5 – GS1 System Symbol Specification Table 3

Symbol(s) Specified	*X-dimension mm (inches)			** Minimum Symbol Height for Given X mm (inches)			Quiet Zone		Minimum Quality Specification
	Minimum	Target	Maximum	For Minimum X-dimension	For Target X-dimension	For Maximum X-dimension	Left	Right	
EAN-13	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	11*X*	7*X*	1.5/06/670
EAN-8	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	17.03 (0.67")	21.3 (0.80")	42.58 (1.68")	7*X*	7*X*	1.5/06/670
UPC-A	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*	9*X*	1.5/06/670
UPC-E	0.264 (0.0104")	0.33 (0.013")	0.66 (0.026")	20.73 (0.82")	25.4 (1.0")	51.82 (2.04")	9*X*	7*X*	1.5/06/670
ITF-14	0.250 (0.00984")	0.495 (0.0195")	0.495 (0.0195")	12.70 (0.50")	12.70 (0.50")	12.70 (0.50")	10*X*	10*X*	1.5/10/670
GS1- 128	0.250 (0.00984")	0.495 (0.0195")	0.495 (0.0195")	12.70 (0.50")	12.70 (0.50")	12.70 (0.50")	10*X*	10*X*	1.5/10/670

Figure 6.6 – GS1 System Symbol Specification Table 4

Symbol(s) Specified	*X-dimensions mm (inches)			** Minimum Symbol Height for Given X mm (inches)			Quiet Zone		Minimum Quality Specification
	Minimum	Target	Maximum	For Minimum X-dimension	For Target X-dimension	For Maximum X-dimension	Left	Right	
GS1-128	0.495 (0.0195")	0.495 (0.0195")	0.940 (0.037")	32.00 (1.25")	32.00 (1.25")	32.00 (1.25")	10*X*	10*X*	1.5/06/670

Figure 6.7 – GS1 System Symbol Specification Table 5

6.5 Data Integrity

Data integrity is not a subject covered by ISO/IEC 15416; however it is another vital consideration for symbols within the GS1 System. This subject covers the proper structuring and encoding of data such as the Check Digit calculations. *Sections 3* and *4* of the *GS1 General Specifications* discuss the structuring of data as well as Check Digit calculations.

6.6 On Demand Printer Density

The size or footprint of a linear bar code is measured by the width of its narrowest bar. The height of the bars and spaces are along the “y” axis. The width of the bars and spaces are along the “x” axis. Therefore, when referring to the size of a bar code, it is called the “X-dimension”. This X-dimension is measured in thousandths of an inch. The term “mil” is used to refer to one thousandth of an inch. For example, a bar code with a narrow bar width of 0.010 inches is said to be a 10 mil bar code. EAN/UPC symbols do not follow this guideline. They are referred to by percentages of what has been determined to be an optimal size for these symbols. An

EAN/UPC symbol that is said to have 100% magnification has a narrow bar width of 0.013 inches or is a 13 mil bar code.

The *GS1 General Specifications* specify the minimum magnification of EAN/UPC symbols is 80%. However, there is an exception to this rule. Some thermal style and laser style on demand printers cannot achieve an 80% magnification (10.4 mils) because of the print head density. As a result, an allowance for on-demand printing equipment exists. You may print the EAN/UPC symbols at 75% magnification using on demand printing equipment.

Printer Resolution Determines Bar Code Size		
Printer Resolution		
300 DPI	1 dot = 0.003 inches	Equates to 3 mils
300 DPI	2 dots = 0.006 inches	Equates to 6 mils
203 DPI	1 dot = 0.005 inches	Equates to 5 mils

Figure 6.8 – Example of printer density equating to bar code size

6.7 Quality Specification

Symbology	Application	ISO (ANSI) Symbol Grade	Aperture	Wavelength
EAN/UPC	All	1.5 (C)	6 mils	670 nm +/-10
GS1-128	Extended coupon code	1.5 (C)	6 mils	670 nm +/-10
GS1-128	All shipping containers	1.5 (C)	10 mils	670 nm +/-10
ITF-14 < 25 mil X-dim	GTIN®-14	1.5 (C)	10 mils	670 nm +/-10
ITF-14 ≥ 25 mil X-dim	GTIN-14	0.5 (D)	20 mils	670 nm +/-10
GS1 DataBar™ (RSS)	GTIN-14, Other Application Identifiers (AI’s)	1.5 (C)	6 mils	670 nm +/-10

Figure 6.9 – GS1 quality specification

6.8 Verifier Calibration, Test Patch, and *Calibrated Conformance Standard Test Cards*

Before the verification process can begin, the verifier must be calibrated to the manufacturer’s specification. Verifier manufacturers supply test cards and procedures to ensure the verifier is properly calibrated. The test card may be as simple as a test patch (a card with a black field and a white field) or as complex as the GS1 US *Calibrated Conformance Standards Test Cards*.

There is a card for each symbology - EAN/UPC, ITF-14, GS1-128, and GS1 DataBar (RSS). The card contains multiple symbols with engineered defects. Each card is individually verified and a score noted for each of the symbols. When you verify those symbols with your verifier, you compare the scores given by your verifier and the scores derived from the GS1 US National Institute of Standards and Technology (NIST) traceable process.

6.9 Verifier Aperture Selection

The following table represents the ISO recommended verifier apertures categorized by ranges of the bar code's X-dimension.

ISO Recommended Aperture for Verification	
X-dimension Range	**Aperture Size**
0.0040" - 0.0070"	0.0030" (3 mil)
0.0071" - 0.0130"	0.0050" (5 mil)
0.0131" to 0.0250"	0.0100" (10 mil)
0.0251" and wider	0.0200" (20 mil)

Figure 6.10 – ISO verifier aperture

The *GS1 General Specifications* are application specific guidance that takes precedence over the ISO specification. The following table states the verification apertures mandated by the GS1 System, per the bar code and its application. There are differences between the preceding table and the following table. For GS1 purposes, the following table takes precedence.

GS1 Apertures for Verification	
Symbology	**Aperture Size**
EAN/UPC	6 mils
GS1-128 (extended code)	6 mils
GS1-128 (logistics units)	10 mils
ITF-14 < 25 mil X-dim	10 mils
ITF-14 ≥ 25 mil X-dim	20 mils
GS1 DataBar	6 mils

Figure 6.11 – GS1 verifier aperture

If the aperture is ***too small*** (see the following figure), small imperfections and local variations in reflectance have a much greater impact on the scan reflectance profile than they need. It means that the use of a smaller aperture than specified may lower a symbol's defect grade, and / or may improve modulation grades.

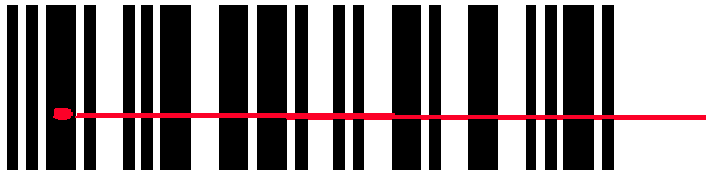


Figure 6.12 – Example of too small aperture size

If the aperture is ***much larger*** (see *Figure 6.13*), it will never be entirely contained within the width of a narrow element. This reduces the apparent contrast of that element with its neighbors. In other words, this kind of adjustment reduces the edge contrast and modulation. It also “blurs” defects and may improve a bar code symbol’s defect grade.

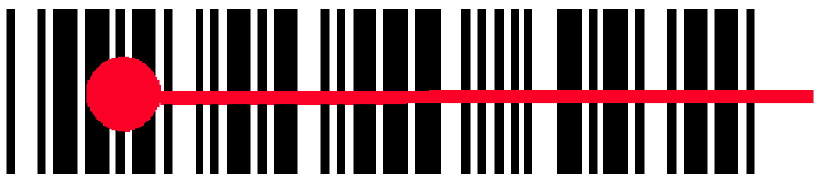


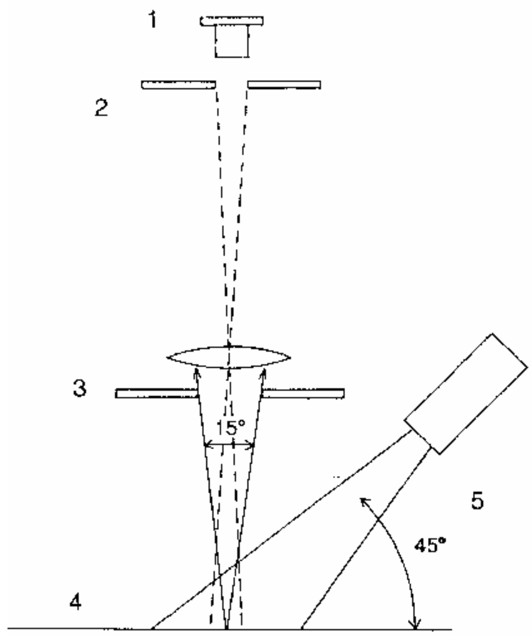
Figure 6.13 – Example of too big aperture size

Either way, the measured symbol grade will be lower than it deserves to be.

Only the use of the correct aperture for the X-dimension of the symbol under test ensures that the grade established from measurement of a symbol is the correct grade according to the method specified in ISO/IEC 15416.

6.10 Light Wavelength

The standards set out a reference optical arrangement (see *Figure 6.14*) consisting of a source of flood incident light at 45 degrees to the surface and a collector (through an aperture) of the diffusely reflected component of this light at right angles to the surface. The vertical plane in which the light source is located is parallel with the height of the bars. This set up is intended to minimize the effect of specular (mirror-like) reflection from glossy surfaces. Not every verifier matches this set up. Some simply reverse the arrangement by having a point light source and narrow beam (such as a laser light) and a larger collecting area. However, the results are likely to be close to those of the standard set up. Others, such as verifiers using a wand, cannot match the 45 degrees / 90 degrees angles. However, if the user avoids holding the wand at an angle where specular reflection might be a problem, the verifier provides adequately accurate results. Many of the latter have a special guide affixed to the wand to help the user to keep to the optimum angle.



1 Light sensor

2 Aperture

3 Optical obstruction

4 Verified sample

5 Light source

Figure 6.14 – Reference optical arrangement (by EN 1635)

The light source and / or collector are chosen so that the peak wavelength of the measured light is the same as what will be used in the scanning application for which the symbols are intended. For most bar code scanning, this light is in the visible red area of the spectrum; most scanners use either visible laser diode or light-emitting diodes (LEDs) with a peak wavelength around 660 – 670 nanometers (nm). The light wavelength is extremely important since the spectral responses of the pigments in printing inks, and of the substrates on which symbols are printed, mean that they absorb and reflect different amounts of light when the light wavelength changes, even by relatively small amounts. This effect is most apparent with colored inks and substrates. With black printing on white paper, the differences are smaller. However, in some thermal label stock, the light absorbency of the dark bars starts to decrease to negligible proportions somewhere around 680 – 700 nm, so their apparent reflectance increases. Variation in the peak wavelength of the verification instrument from that of the scanning system becomes a major source of discrepancies.

Unwanted light falling on the symbol under test is a frequent cause of otherwise apparently inexplicable variances in verification results. If the verifier design is such that the optical head is not adequately shielded from light from external sources, ambient lighting conditions should be controlled as far as practicable. ISO/IEC 15426-1 calls for manufacturers to specify the levels of ambient lighting under which their instrument can operate correctly. Examples of potentially interfering lighting include direct sunlight, indirect sunlight if it causes high light levels at the verification location, high-intensity lighting such as high-pressure sodium or mercury vapor lamps (which may have strong red components in their spectral distribution), and fluorescent lighting (the flicker can be perceived by the verifier as spurious dark and light patterns). High ambient light intensities will cause apparent reflectances to increase, or reduce apparent contrast, or may even completely drown the light reflected from the symbol. Many verifiers include a narrow-pass (notch) filter in the optical train, which allows only light close to the 670 nm wavelength to get through to the light-sensitive element. This may reduce, but will not always completely block, unwanted light from reaching the light-sensitive component.

6.11 Scan Reflectance Profile and Global Threshold

Scan Reflectance Profile (SRP) and global threshold are key concepts in understanding verification.

SRP - When a verifier scans a bar code, it produces a graphic representation of the bar code. The top peaks represent the light spaces of the bar code and the bottom peaks represent the dark bars of the bar code. In the following figure, you see the spaces as the top peaks. The higher the peak goes, the closer the space it represents is to approaching 100% reflectance of the light given off by the verifier during its scan. The lower the peaks that represent the bars get, the closer that bar is to 0% reflectance of the light given off by the verifier during its scan.

Global threshold - The global threshold represents the mid-point of the peaks in the SRP. That means the global threshold is drawn horizontally across the SRP at the mid point between the highest and lowest peak or between the most reflective space and the least reflective bar.

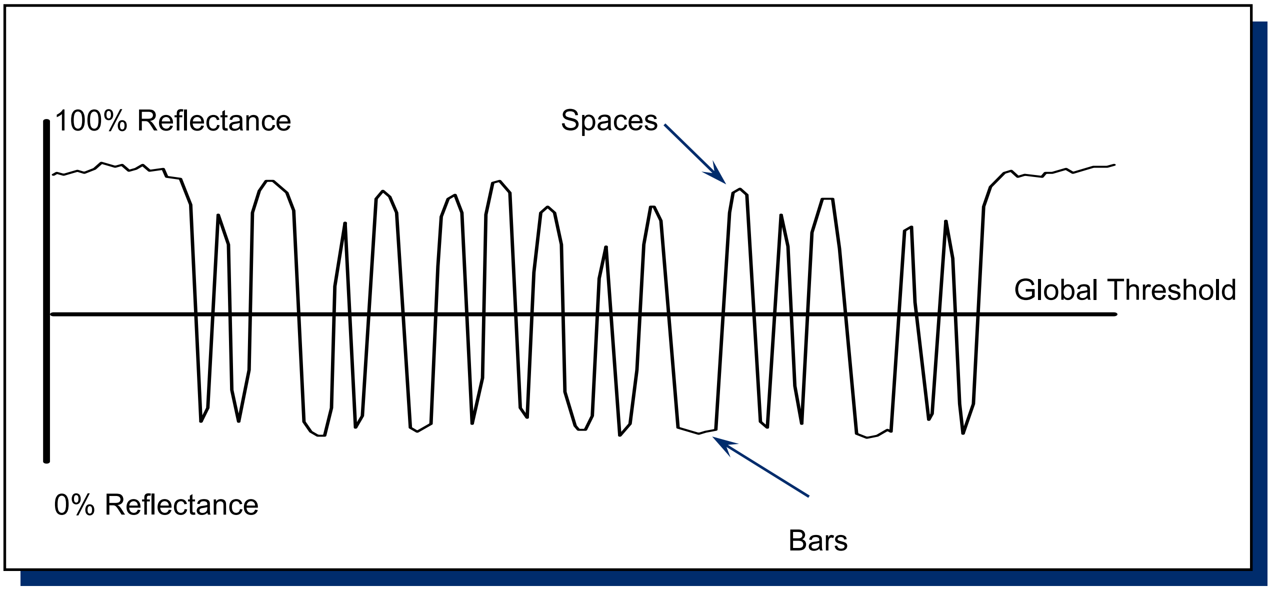


Figure 6.15 – Scan Reflectance Profile and global threshold

6.12 Scan Path and SRP Grade

Scan path - Scan path refers to a single pass of a verifier's reader over a bar code, as represented by the red line in the following figure.

SRP grade - SRP grade refers to the "score" given to the single scan path after the SRP is analyzed by the verifier. The grade is as a result of the analysis of the bar code in the nine ISO parameters described in ISO 15416. Each parameter is graded individually for the scan path. The worst parameter grade given for the scan path is the SRP grade.

Figure 6.16 – Scan Path

6.12.1 Hand-scanned Verifiers

The scan heads containing the optical components can be of different types from device to device, but the operating principle is the same. The scan head must be moved manually across the symbol to generate the scanning action.

With a wand-based verifier, place the tip of the wand on the area somewhat to the left of the symbol with the wand itself inclined at an angle of 15° or so from the vertical, or at the angle specified by the supplier. Many verifiers have a plastic guide fixed to the wand to ensure that the angle of inclination is correct and consistent from one scan to another. Ensure that the symbol is lying on a flat surface. Bumps or irregularities prevent a smooth scan and lead to unpredictable and inaccurate results. Smoothly pass the wand across the symbol at a reasonable speed. Do this up to ten times, traversing a different part of the symbol each time. Learning the best scanning speed is a matter of practice. If you scan too slowly or too fast, the instrument fails to decode the symbol, or it may prompt you to adjust the scanning speed.

Use the same technique with a verifier that uses a mouse as its optical head.

6.12.2 Automatically Scanned Verifiers

This category includes all verifiers where the scanning action is automatically performed and does not rely on the operator to physically move the scan head across the symbol. The category includes Charge Couple Devices (CCD's), linear array or camera-based, and laser-based verifiers employing motorized optical head transports or a controlled rastering operation to sweep the scan beams down the symbol. The most frequent problem with this style of verifier involves symbol positioning. The scanning beam starts outside the Quiet Zone of the symbol and crosses the symbol completely. Some "automatic" verifiers may perform automatic scanning of the horizontal beam across the bar code, but require manual positioning of the scanning head from top to bottom (ten scan paths) of the symbol for individual scans to obtain symbol grades. Some automatic scanning verifiers can determine module width. This feature is useful for confirming adherence to the module size ranges specified for the various symbols and applications in the *GS1 General Specifications*.

Grade	Decode	Symbol Contrast	Minimum Reflectance	Edge Contrast	Modulation	Defects	Decodability
4.0 or A	Passes	≥70%	≤0.5 R_{max}	≥15%	≥0.70	≤0.15	≥0.62
3.0 or B		≥55%			≥0.60	≤0.20	≥0.50
2.0 or C		≥40%			≥0.50	≤0.25	≥0.37
1.0 or D		≥20%			≥0.40	≤0.30	≥0.25
0.0 or F	Fails	<20%	>0.5 R_{max}	<15%	<0.40	>0.30	<0.25

Figure 6.17 – Grade thresholds for scan reflectance parameters

NOTE: Edge determination is a separately graded parameter in the ANSI X3.182 standard on a Pass / Fail basis, carrying grades A or F respectively.

NOTE: Each parameter is separately graded.

6.13 Overall Symbol Grade

Overall symbol grade, as opposed to SRP grade, refers to the evaluation of the entire symbol and not just a single scan. The grading method for the symbol is calculated by performing 10 evenly spaced scan paths for which SRP grades are calculated. The ISO numeric values for the SRP grades are added together and divided by 10. The average of the 10 SRP grades is the overall symbol grade.

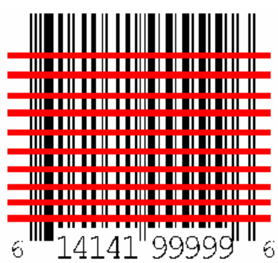


Figure 6.18 – Ten evenly spaced scan paths used to determine overall symbol grade

ANSI Grade	ISO Grade
A	3.5 – 4.0
B	2.5 – 3.5
C	1.5 – 2.5
D	0.5 – 1.5
F	≤0.5

Figure 6.19 – ANSI alphabetic quality grades and the equivalent ISO numeric grade

6.14 Nine ISO Parameters, Pass / Fail, Graded

As previously mentioned, nine parameters are evaluated in the verification of linear bar codes. Five of the parameters are pass/fail parameters. This means a “Pass” is given an “A” grade or 4.0 and a “Fail” is given an “F” grade or 0.0. This is done when there is no middle ground for the parameter. For instance, the Quiet Zone has specifically prescribed attributes. If any of those attributes less than matches the specification, it is not a Quiet Zone. Either the bar code has a Quiet Zone or not. There is not a degree of Quiet Zone.

The pass / fail parameters include:

- Edge determination
- Reflectance minimum
- Edge contrast minimum
- Decode
- Quiet Zone

The graded parameters include:

- Symbol Contrast
- Modulation
- Defects
- Decodability

Each ISO parameter is explained in detail below.

<u>Edge determination</u> - The evaluation of a bar code symbol starts with edge determination. This measures the number of lines in the SRP that cross the global threshold, and makes sure that the number of “crossings” matches a valid symbology (type of bar code).

<u>Reflectance minimum (Rmin)</u> - The lowest value shown on the SRP for at least one bar must be half or less than half the value from the highest reflectance value shown on the SRP for a

space, referred to as $R_{max.}$ This is because, for a given level of Symbol Contrast, many scanners have greater difficulty distinguishing relatively light bars against a high-reflectance background than they do distinguishing darker bars against a relatively low reflectance background. The following figure shows a symbol printed in light brown on a white background, which appears to give good visual contrast. However, the symbol yielded an SRP that failed on this criterion. The R_{max} was 83%, so R_{min} should have been 41.5% or less. However; the actual R_{min} was 43%.

Figure 6.20 – Symbol with failing minimum reflectance

Edge contrast minimum (ECmin) - Each transition from a bar to a space, or space to a bar, is an edge. Edge contrast is defined as the difference between peak values in that bar and space. Each edge in the SRP is measured, and the edge that has the minimum contrast in the transition from space to bar or bar to space is the edge contrast minimum.

Quiet Zones are considered spaces for this purpose. If EC_{min} is less than 15%, it is graded 0.0. Variations in ink weight in different parts of a symbol, or fluctuations in the background reflectance (such as with corrugated brown kraft substrates) are one cause of edge contrast problems. Another cause is that scanners tend to see narrow elements less distinctly than they do wider ones (a narrow space has lower apparent reflectance than a wide one, and a narrow bar appears similarly lighter than a wide one).

Decode - The next step is to apply the reference decode algorithm, the set of rules or steps for decoding a symbol defined in the symbology specification, to the elements "seen" in the SRP. If a valid decode results, the decode parameter passes and is given a grade 4.0 Otherwise, it fails (grade 0.0). If the wrong number of elements is seen, the decode fails.

NOTE: In ANSI standards, this last case is graded separately as an edge determination failure, although the final effect on the profile grade is the same.

A failure to decode may be evidence that the symbol is incorrectly encoded, which may include an incorrect Check Digit. Or it may indicate that the bars and spaces initially identified by the global threshold are too many or too few for a valid symbol, or that one or more edge position is ambiguous.

The ISO standard "decode" failure due to an incorrect number of elements present can be caused by the profile of one or more elements failing to cross the global threshold, or by a gross defect caused by one element being seen as three or more. This ISO decode failure corresponds to the separately graded "edge determination" failure in the ANSI standard. Verifiers following the ANSI methodology may report this error.

The following figure shows a symbol in which the narrow spaces have been partly filled in. This reduces their contrast below the global threshold and causes an edge determination, or decode, failure. This could also be interpreted as an extreme example of modulation.

Figure 6.21 – Symbol with "edge determination" problem

Quiet Zone - This measures whether a sufficient unprinted area exists per the symbology specification. Quiet Zones are a frequent source of scanning problems. Although the ISO standard does not directly require measurement of the Quiet Zones, it requires "any additional requirements specified by the application specification" be graded on a pass / fail basis. The *GS1 General Specifications* detail Quiet Zone requirements for all symbols used in the GS1 System. A Quiet Zone less than the minimum width will cause the profile grade to fail.

Symbol Contrast - Symbol Contrast is governed by the reflectance of the substrate and ink. A symbol printed in black ink on a white paper will almost certainly be a grade 4.0 symbol for Symbol Contrast because white papers typically have reflectance in excess of 75% and black ink will usually be around 3.0 - 8% reflectance. Colored backgrounds or colored inks will affect the result. Highly glossy materials may also appear to have a lower background reflectance than expected. The worst case may be when printing on a corrugated kraft material. This material may have a reflectance in a range between 27% and 40%, so even with a very dense, low reflectance ink, it can never achieve better than grade 1.0 for Symbol Contrast. Grade 1.0 includes Symbol Contrast values from 39% to 20%.

Modulation - Modulation, calculated as the percentage of Symbol Contrast represented by the minimum edge contrast, is reduced for the same reasons as minimum edge contrast is low in the symbol. A scanner tends to see spaces as narrower than bars, and also sees narrow elements as less distinct than wider ones. Consequently, if there is significant bar width loss, modulation is reduced. Measuring with an aperture that is too large for the X-dimension also reduces modulation.

Defects - Defects (called element reflectance non-uniformity or ERN), which show as irregularities in the SRP, may be caused by specks of extraneous ink in Quiet Zones or spaces, or by voids in the bars. In symbols printed on recycled or some other materials, local variations in reflectance of the background also show as defects. The significance of a defect is directly related to the depth of the irregularity it causes in the SRP.

The use of a smaller or larger measuring aperture than specified (see *Section 6.9*) for the symbol in question will produce misleading defect grades. This is perhaps the strongest argument for ensuring that the right aperture size is used. Too small an aperture exaggerates the apparent size of a defect; too large an aperture tends to smooth it out.

Figure 6.22 – Symbol with defect failure from spots and voids

6.15 Process Troubleshooting

6.15.1 Scan Path Problem Minimization

Good scanning practices must involve starting the scan at a point where there is a good likelihood that a constant scanning velocity is achieved as the beam crosses the Quiet Zone and then maintaining a constant velocity as the scanning beam crosses the entire bar code symbol. The scanning instrument must be held (per manufacturer's instructions) at the correct angle while scanning across the bar code symbol. Improper angle orientations are likely to result in incorrect scan grades.

Implement the following scanning techniques:

- Position the symbol and the scan path to ensure that the entire inspection area is covered.
- Keep the scan head and applicable optics clean and free of dust.
- Whenever possible, verify in the final form, but when impossible, verify in the flat.
- Provide adequate operator training.
- Calibrate the instrument for aperture and ambient light. Be sure to use the proper aperture for the symbol.
- Use the Calibrated Conformance Standard Test Cards to train operators.
- Choose an appropriate background when verifying symbols printed on a transparent or semi-transparent substrate.
- Use of a straight edge or similar guide to guide the motion of the scan head.

Care must be taken to avoid the following problems:

- The scan path exits the top or bottom of the symbol (see the following figure), which results in mis-scans, or short reads of some symbols such as ITF-14.

Figure 6.23 – “From top to bottom” scan

- The scan path runs too close to the top or bottom edge of the symbol (see the following figure), which results in poor modulation values due to interference from the light area above or below the symbol.

Figure 6.24 – “Close to the top” scan

- Irregular or curved scanning motion (see the following figure), which results in acceleration or deceleration during the scan and leads to varying decodability values.

Figure 6.25 – “Curved motion” scan

- The scan path starts or finishes too close to the symbol (see the following figure). This frequently leads to failure to decode or Quiet Zone failure. It is almost always accompanied by excessive acceleration or deceleration through the first or last symbol characters resulting in a low decodability grading.

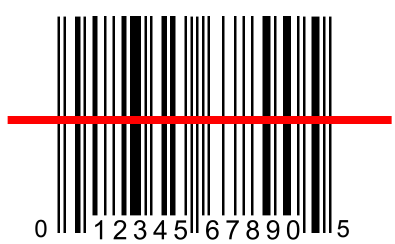


Figure 6.26 – “Too close start or finish” scan

- Scratching of symbol surface due to dust or other contamination of scan head.

6.15.2 *Calibrated Conformance Standard Test Cards*

GS1 US provides a calibrated test card, which is produced and measured to a high degree of accuracy. This card enables users to check the readings obtained on their equipment for consistency and accuracy. It contains both "perfect" symbols and symbols with engineered less-than-perfect characteristics (defects, low decodability, and low Symbol Contrast).

This card can also be used as a training tool for the operator of the verifier.

When using a *Calibrated Conformance Standard Test Card*, make sure you are using the correct aperture. It is listed on the card.

Use of the *Calibrated Conformance Standard Test Card* helps to end disagreements over bar code quality. Two trading partners (supplier and customer) may both verify symbols as a normal part of their process, yet they get different grade results. If only one of them checks the calibration of his verifier by using the test cards, only the one using the test card can be sure of his verifier’s results. When both trading partners are using the *Calibrated Conformance Standard Test Card*, they are both on the same page when it comes to bar code quality.

Figure 6.27 – GS1 US *Calibrated Conformance Standard Test Card*

6.15.3 Decode Failures

Possible causes of decode failure and the possible remedies include:

- The symbol is incorrectly encoded.

  Solutions: Re-originate the symbol; over-label with correctly encoded symbol.

- The Check Digit is incorrectly calculated.

  Solutions: Correct software error in origination system; re-originate symbol; over-label with correctly calculated symbol.

- Gross element width errors due to excessive print gain or loss, or to defects.

Solutions: Apply correct bar width adjustment when originating symbol; adjust press or printer settings.

- Too many elements detected due to defects.

  Solutions: Correct cause of defects; adjust press (relief printing processes) to reduce haloing; replace print head (thermal / ink-jet printing) too few elements detected (failure to cross global threshold).

6.15.4 Quiet Zone Failures

Possible causes of Quiet Zone failure and the possible remedies include:

- Printed box surrounding symbol or other interfering print.

  Solution: Enlarge box; ensure symbol registration to other print allows adequate margins; use light margin indicators if possible.

- Symbol too close to label edge.

  Solution: Adjust label feed; reposition symbol farther from edge; use larger label size or smaller symbol.

6.15.5 Symbol Contrast Failures

Possible causes of low Symbol Contrast and the possible remedies include:

- Background too dark.

  Solution: Use lighter or less glossy material or change background color (if printed) to one with higher reflectance.

- Show through of contents.

  Solutions: Use more opaque material for package, or print opaque white underlay prior to printing symbol.

- Bars too light.

  Solutions: Change bar color for one with lower reflectance, increase ink weight or print head temperature (thermal printing). Note: watch for consequential increase in bar widths.

6.15.6 Modulation Failures

Possible causes of a low value of modulation and the possible remedies include:

- Local variations in background reflectance, e.g. fragments of darker material in a recycled material.

  Solution: Use a more consistent substrate or one with higher reflectance.

- Local variations in inking of the bars.

  Solution: Adjust press settings to ensure even or darker inking.

- Show through of contents.

  Solutions: Use more opaque material for the package, or print opaque white underlay prior to printing the symbol.

- Element(s) adjoining the edge in question appear excessively narrow relative to the measuring aperture used.

  Solutions: Increase the X-dimension; ensure correct measuring aperture is used; apply correct bar width adjustment when originating symbol; print bars marginally narrower than spaces of same modular dimension.

6.15.7 Defect Causes

Possible causes of defects and the possible remedies include:

- Defective print head elements (thermal printing or ink jet printing) which will tend to produce an unprinted line running through the symbol in the direction of printing.

  Solution: Clean or replace print head.

- Satellite ink droplets (ink jet printing).

  Solution: Clean head, change ink formulation.

- Haloing (flexography).

  Solution: Adjust impression pressure and/or ink viscosity.

- Incorrect matching of thermal transfer ribbons and substrate (poor adhesion of ink to surface).

  Solution: Use the correct ribbon for the substrate, use a smoother substrate.

- Measuring aperture too small.

  Solution: Use a verifier with the correct aperture, e.g. 0.15 mm for EAN/UPC symbols.

Appendix A: Printing and Substrates

General Printing Advice

Contrast in General

Verifiers have different parameters for contrast evaluation. According to traditional evaluation, a bar and space reflection can be measured and the print contrast signal (PCS) can be calculated from these reflection values. Sometimes it is possible to select between the worst and best reflection case. The base for the worst case is the reflection values of the minimum edge contrast (ECmin). The base for the best case is the reflection values of the Symbol Contrast.

EAN/UPC symbols have a logarithmic relation between bar and space reflection. This causes variable PCS value limits. If the PCS is out of tolerance, the bar or space reflection is the cause. The bar reflection is the more significant value. Based on the print process or the materials used, it may be necessary to increase the space or/and decrease the bar reflection. A good rule of thumb, for any symbology, is to set PCS to 75%.

The ISO standard defines additional parameters for edge contrast, Symbol Contrast, modulation and R_{min}. Modulation is calculated as ratio of edge contrast and Symbol Contrast. The reason for a low edge contrast can be too low contrast, or an irregular print. Or the bars or spaces may be too wide or far apart. A measuring aperture that is too large will also decrease edge contrast. Additionally, the edge contrast is influenced by material characteristics.

The symbol contrast provides information about the highest contrast of the bar code. If this value is too low, decrease the bar code reflection or increase the reflection of the spaces (background material).

The modulation can be interpreted as regularity of bar or space reflections. If this value is too low, the difference between the edge contrast and Symbol Contrast is too large. To improve modulation, provide a higher density of the background color (or material).

R_{min} should be less than or equal to 0.5 $R_{max.}$ If this is not the case, the bar reflection is too high. This can be caused by unsuitable bar code colors or unsuitable thermal paper.

Measurements in General

Measurement verifies if the bar width, spaces, or a combination of both meet the standards.

The ISO evaluation uses the deviations as a base for the calculation of the parameter decodability. Decodability provides a value for how well a code can be decoded based on metric measurements only. Decodability does not provide the reason for a bad decodability value. For analysis, the traditional evaluation based on symbology standards is required.

Before trying to optimize the printing process, the film master (pre print) should be verified. Film master resolution is very important. A low resolution restricts the size step selection. For all printing systems, using bitmap graphics for transfer to the printer, interpolation may cause problems. Attention should be paid to printer drivers. Often graphics are interpolated without user influence.

Defects in General

Defects are either light areas in bars or dark areas in spaces. Defects can be caused by bad ink transfer or rough print materials. Depending on the printing process, different actions can be taken:

- **Flexography**: Increase pressure (not too high to keep metric sizes).
- **Thermal direct/transfer**: Other labels, higher temperature, other ribbon, higher pressure, lower printing speed.

When grading a bar code, the aperture of the bar code verifier is important with regard to defects. Defects appear larger with too small an aperture and smaller with too large an aperture.

Decode in General

This parameter controls Quiet Zones, Check Digits, and element determination. Sometimes the code length is checked as well. Errors are caused by design in the preprint phase. Attention should be paid to Quiet Zones. Quiet Zone definitions are minimum sizes with no tolerances. This requires preprint to add the print and positioning tolerances to the Quiet Zone minimum size.

Not Decoded Bar Codes in General

If bar codes cannot be decoded, the dimensional and / or contrast deviation are out of specification. Another possibility is an invalid code caused by missing dots or errors in the preprint phase. Check the color combinations (including background influences). Finally, check to determine if there are too many defects.

Thermal Printing Advice

Thermal Direct Contrast

A thermal direct print has, what appear to be, deep black printed bars. To the human eye however, they only appear as deep black. To the scanner, they usually appear gray. To improve this, change the material because the reflection value for the bars depends on the thermal sensitive chemicals in the paper. Always ensure that the thermal paper characteristics fit the printer. A paper with higher or lower thermal sensitivity or end blackness can be used. Some papers with a very high thermal sensitivity have higher bar reflection with too much thermal energy. The thermal sensitive chemicals can have green blue or red as basic color. Paper with green or blue thermal sensitive chemicals are more suitable than paper with red colored thermal sensitive chemicals.

Direct thermal saves money by not requiring the use of an inking ribbon. However, the coated face stock is more expensive than non-thermally coated face stocks and is very sensitive to temperature, light, water, chemicals, and hard use. The life expectancy of direct thermal labels is usually less than one year. Direct thermal labels perform best for short term or indoor uses, such as products with short shelf lives, shipping, or indoor inventory control.

Thermal Transfer Contrast

With thermal transfer printing, it is possible to produce a quality bar code, if the label and ribbons fit together. Contrast problems are usually caused by a mis-adjusted printer or an unsuitable combination of label and ribbon (for example, a paper label and resin ribbon). Contrast is influenced by heating energy, printing speed, and pressure. Other possible influences include changing labels, ribbons, or the printer itself.

A wide variety of thermal transfer ribbons are available and it is important to match your ribbon selection to your application. Three basic formulations of thermal transfer ribbons exist:

- "Wax-based ribbons" are low in cost and suitable for most applications. Label images may be scratched or smear if the temperature is too high.
- "Resin-based ribbons" produce label images that are much more resistant to wear and extreme conditions. Some resin inks used on certain face stocks can withstand temperatures over 1000 degrees. However, resin-based ribbons tend to be expensive.
- "Wax-resin ribbons" produce label images with higher durability than wax-based ribbons but are lower cost than pure resin-based ribbons.

Troubleshooting for Thermal Direct and Thermal Transfer Printing

This type of printer uses a thermal printing head. Each dot is represented by one heating element. The shape of this element is like a square and they are directly neighbored. This prints very clear edges.

Problems are caused by a high setting for heating the print head. The bars get wider because more ink is transferred. Reduce the temperature setting when this defect is detected.

A printout with many defects can be caused by an incorrect combination of label and ribbon, or the printing speed may be too high. If speed reduction does not help, test another label and ribbon combination. The bar code can be printed in picket fence or ladder orientation. The ladder orientation is more difficult to adjust because of smearing (slow cooling increases bar width). Ladder printing, however, has the advantage that the bar code is still useable if one dot is defective. To improve quality in this case, reduce the speed and adjust the temperature setting accurately. The pressure from the print head to the label and ribbon can be adjusted. This can influence defects as well.

Laser Printing Advice

Contrast

Contrast problems may occur with laser printing if the toner levels are low or the optical unit needs to be replaced. Paper quality may cause problems, as well.

Laser Printing Cautions

The black bars are produced by small particles of toner with an irregular size and shape. In bar code printing, this causes blurred edges. If this is a problem, a printer with higher resolution is necessary, or adjust the size of the bar code to match the printer resolution. Some operating systems can have problems with software and printer driver combinations and may not match the physical resolution of the printer. This may cause worse than expected print quality. In these operating systems, bar codes are usually transformed to bitmap graphics. The graphics are resized or interpolated to make the graphics fit. This means dots will print overlapped to get clearer edges.

Ink Jet Printing Advice

Contrast

Ink jet printing contrast problems may occur if the material (paper) absorbency is high. This will happen with recycled pulp content. Proper ink application is very important. Ink jet printers are in wide use for direct printing on corrugate. Corrugated paper quality varies and this may cause contrast problems. Printer adjustment and ink selection may alleviate the problem.

Ink Jet Cautions

High paper absorbency and the irregular shape of the single dots can cause irregularly shaped edges. Change the paper to improve quality or use a higher printer resolution or faster drying ink. Ink jet head distance, also, if not kept within the operating parameters recommended by the manufacturer can create fuzzy edges on the bar. Excessive vibration in the line or inconsistent speed can create wavy bar codes. Glue strands and paper dust can clog some of the ink jet nozzles and further impact the parameters measured.

Impact Printing Advice

General

This printer type is not ideal for bar code printing. It is nearly impossible to print straight edges. Impact printing problems are also caused by the irregular shape of the single dots. Older printers wear out and the needle positioning becomes less accurate.

Flexographic Printing Advice

Contrast

With this printing process, contrast problems are caused by the paper used or the color combination for bars and spaces. Flexography is often used for printing on corrugated paper or films. Corrugated paper has a rough and brown surface. This causes bad reflectance values for the spaces. On flexible packaging films, the background will be printed in white and the bars in black. Because of the restricted amount of ink which can be transferred, the white density is limited. The package contents will have a considerable influence on bar code quality. On flexible packaging film, the background white usually has to be printed two or three times to get the best contrast results.

High Printing Cautions

The main reason for errors is print gain. Print gain must be compensated for by Bar Width Reduction (BWR).

In flexography, flexible, rubber like printing plates may be used. Such plates can allow “squish” (bar distortion) to occur. This effect can be reduced by a frame around the bar code and by plate pressure adjustment.

Offset Printing Advice

Contrast

Offset printing usually offers the possibility to print high quality bar codes. Problems may be caused by insufficient ink transfer or an unsuitable color combination.

Color transfer with high speed offset (used for, say, plastic cups, is usually not optimal). Because of low density color transfer with this process, picket fence (with the web direction) printing is recommended. The amount of color and the density is low, especially with this type of printing process, the bar code shall be printed in print direction.

Offset Printing Cautions

Offset printing is a precise printing. This printing style results in very low bar width gain.

Substrate Advice

Metalized Flexible Packaging Film

If a bar code is printed on such a substrate, the Symbol Contrast is low compared to paper. The metal finish works like a mirror and may darken the white of the bar code background. If the white background has holes, defects will appear. Often, white has to be printed more than once.

Flexible Packaging Film

There are different types of films available. Some types are clear, others are white or otherwise colorized. Clear films require a white field be printed behind the bar code. Depending on the package content, the bar code quality may vary widely. If the package content is white, yellow, orange, or red, these colors will make the white of the bar code background for the scanner “whiter” and improve the Symbol Contrast. In narrow spaces, parts of the light reflected by the package content is reflected to the neighboring bars. This light is lost and the contrast for narrow spaces is significantly reduced. Edge contrast and modulation will be low. To improve this, the white color density can be increased. A larger code or a defined bar width reduction to make bars smaller will help. If the same type of film is used for black, green, or blue package content, the Symbol Contrast is reduced. A white background with increased density is helpful for quality improvement. Often, white has to be printed more than once.

Cans

This material appears to the verifier (and scanner) like a material similar to metallized film or paper labels. If the bar code is printed in picket fence orientation the round shape of the can, it may cause problems. Cans are printed with a white background. Sometimes small metal lines show between the white and the black bars. This leads to defects and should be avoided.

Sometimes only the white is printed and the bars are left blank. The blank bars work as a mirror and appear as black. A can may get dented or scraped and the metal is not mirror like as required, or the scanner angle is not good. This makes the scanning results hard to predict.

Metal Films with Engraving

This material is used, for example, to close yogurt containers. For bar coding, avoid these material types because the engraving changes the angle in bars and spaces for light reflection. This may cause a hard to read or unreadable bar code.

Non-opaque Substrates

Account must be taken of possible “show through” of product behind the substrate. To predict scan performance, take any of the following steps:

- If the color of the contents of the packaging is known, verify the symbol quality with the packaging backed by a material of the same color as the contents.
- Perform verification with the symbol on a dark surface.
- Perform verification with the symbol on a light surface.
- Take the lower of the grades reported as the grade for the symbol.

Glossy Substrates

Glossy substrates and/or inks may cause scanning problems if the angle of the symbol surface relative to the scanner causes specular reflection. If the angle is not controlled by the construction of the scanning device, the manufacturer’s recommended angle of incidence for the light emitted by the scanning device must be used.

Appendix B: Traditional Verification

Print Contrast Signal (PCS) & Tolerances

Traditional measurement has one major advantage for process control purposes. It provides a measure of element widths relative to the ideal, which can be used for correcting for bar width gain or loss. However, bar width deviations, especially systematic ones, do not necessarily correlate well with scanning performance, due partly to the edge to similar edge decoding of the modular symbologies and partly to the tolerant algorithms used in many scanners.

The traditional dimensional "tolerances" were based on arbitrary assumptions and are not directly proportional to the X-dimension of the symbol for EAN/UPC symbols.

Contrast measurements based on print contrast signal (PCS) bear a complex relationship to those based on Symbol Contrast. If the light and dark reflectance values (R_L and R_D respectively) on which the PCS calculation method was based were the same as R_{max} and R_{min}, then a fairly simple mathematical relationship would exist. But since the measurement points for R_L and R_D in a PCS calculation may well differ greatly from one verifier to another, it is risky to place much reliance on extrapolating a Symbol Contrast value from a PCS value.

A further complication is that the minimum PCS for an EAN/UPC symbol varied, depending on the background reflectance value. While for other symbologies, it was a single value (usually 75%).

A few broad conclusions can be drawn, assuming the background reflectance is taken as equivalent to R_{max} and the bar reflectance as equivalent to R_{min}.

No symbol meeting the traditional minimum PCS requirements would receive a grade 0.0 for Symbol Contrast, provided its background reflectance is 30% or better.

For EAN/UPC symbols, the minimum PCS values traditionally specified corresponded to a grade 2.0 Symbol Contrast for background reflectances (R_{max}) of approx. 50% or higher, but to only grade 1.0 Symbol Contrast for materials with a lower R_{max}. In other words, the current minimum quality grade specified of 1.5 (ANSI grade C) excludes a small number of symbols on lower background reflectance materials, which meet the old minimum PCS requirement.

For ITF-14 symbols printed on corrugated, where the minimum grade for acceptability is 0.5 (ANSI grade D), virtually all symbols meeting the traditional PCS 75% minimum also meet this grade requirement.

Supplementing with Traditional Measurements

As previously stated, the primary advantage of the Scan Reflectance Profile (SRP) assessment over the traditional element width / PCS measurement is that it provides a far better indication of how well a symbol is likely to perform when read under typical application conditions, such as at the point of sale, or in back of store and distribution operations. However, it is difficult to deduce from the SRP grading what specific corrective action needs to be taken to improve quality grades, in terms of aspects that the symbol producer can easily control. SRP grading on its own is of little help for process control purposes, one of the two reasons for which symbols are verified.

Appendix C: GS1 Symbology Considerations

EAN/UPC

The main characteristic of this symbology affecting verification is the different treatment of the three sets of symbol characters for the digits 1, 2, 7, and 8 from the remaining digits (0,3,4,5,6, and 9). The reference decode algorithm uses the combined width of both bars in these characters to discriminate between a 1 and a 7, and between a 2 and an 8, which are "ambiguously decodable" since they share the same set of edge to similar edge modular dimensions. The addition to or subtraction from the element widths of 1/13 module is intended to increase the differences between the sums of the bar widths for each pair of ambiguous characters. The decodability parameter for these characters takes account of bar width gain and loss whereas it does not for the remaining symbol characters. The consequence is that a symbol that does not contain any of these four symbol characters may suffer substantial bar width gain or loss without degrading its decodability. A symbol that does contain one or more of them is likely to have a lower decodability grade with the same amount of bar width gain or loss. However, the laws of probability suggest that only 6.9% of symbols would not be affected by this. Therefore, assume that bar width growth or loss is a possible cause of a poor decodability grade for EAN/UPC symbols. It is also wise (for process control purposes) not to assume that the decodability grade correlates with bar width deviation. It is safer, and easier, to rely on the traditional measurement of bar width deviation for adjusting the production process.

The measuring aperture for EAN/UPC symbols, irrespective of magnification, is 0.15 mm, or 6 mil (0.006 inches). This is not one of the four default aperture sizes recommended in the ISO standard, which are 3, 5, 10, and 20 mil, but is usually available from verifier manufacturers. This diameter was based on measurement of symbols with various apertures and much test scanning in order to determine which aperture gave results correlating best with scanning performance.

GS1-128

The important aspects of this symbology to verify are its print quality, which is assessed in the standard way, and its formatting, which may need to be checked visually from the information output by the verifier.

GS-128 is an edge-to-similar edge decodable symbology, but its reference decode algorithm also requires a check of the sum of the widths of the three bars in each character, as part of its parity checking process. Consequently its decodability is affected by bar width gain or loss.

Measuring apertures for GS1-128 symbols vary according to the application and X-dimension. For all applications except the GS1 US extended coupon code, an aperture of 0.25 mm (0.010 inches) is specified, giving a minimum acceptable grade of 1.5/10/670. The GS1 US coupon code requires an aperture of 0.15 mm (0.006 inches) and a minimum grade of 1.5/06/670.

Data contained in GS1-128 symbols must be formatted according to the rules in the *GS1 General Specifications* for the use of Application Identifiers (AI's). Specific features to check include:

- Presence of Function Code 1 (FNC1) as a flag for the GS1-128 symbol, in the first position after the start character.

- Use of FNC1 as a field separator between variable length AI data fields.
- Sequencing of AI's, with fixed length AI's preceding variable length ones.
- Length of data fields with fixed length AI's.
- Correct formatting of data in all AI fields.
- Absence of encoded parentheses around AI's.

The extent to which a verifier can do this automatically varies greatly among devices, even those that have GS1-128 as a specific symbology option.

ITF-14

This symbology is, unlike the others used in the GS1 System, a two-width (narrow / wide) symbology (interleaved 2/5 according ISO/IEC 16390 with some additional restrictions). It cannot be decoded by the edge to similar edge technique. All element widths must be measured. It is, therefore, subject to the problems caused by bar width gain or loss.

The standard ISO verification technique is fully applicable to these symbols. However, in the GS1 application, additional checks must be made to ensure that the magnification factor is within the permitted range and guidelines for automated scanning systems, since many packages carrying the ITF-14 symbol will be read on unattended automatic conveyor systems.

Measuring apertures for the ITF-14 symbol are 10 mil for symbols with an X-dimension up to 25 mil and 20 mil for symbols with an X-dimension larger than 25 mil.

The minimum acceptable grade for symbols printed with the higher range of X-dimension (above 25 mil) is 0.5/20/670. This is because the brown corrugated substrates on which such symbols are often printed typically have a reflectance value below 40%, and sometimes even below 30%, and cannot therefore ever achieve a Symbol Contrast better than 40% (the lower threshold for a grade 2.0 Symbol Contrast) no matter how dense the ink and how well the other attributes of the symbol are graded. As a result, the scan reflectance profile grade will most often be dictated by Symbol Contrast. Therefore, it cannot be higher than 1.0 for symbols on these materials, giving a maximum achievable overall symbol grade of 1.0.

Such symbols may also be affected by the inherent noise in the background reflectance caused by the substrate's composition, which may lead to reduced defect grades and possibly also low edge contrast and modulation values. Ensure that symbols printed on these corrugated materials are of as high a quality as possible in respect of the other parameters.

GS1 DataBar (RSS)

GS1 DataBar is a family of linear symbologies capable of encoding the 14-digit GS1 Global Trade Item Number (GTIN). GS1 DataBar is designed to bring the benefits of full product identification, as well as other supply chain applications, to space-constrained situations where existing linear symbologies can not normally be used. Use the International Standard *ISO/IEC 15416 Automatic identification and data capture techniques – Bar code print quality test specification – Linear symbols* methodology for measuring and grading the GS1 DataBar family of symbols. For more information, see the *GS1 General Specifications*.

Appendix D: Selecting a Verifier

GS1 Member Organizations are often asked for advice on the selection of equipment. Whereas they are expected to be commercially impartial, they ought to be in a position to advise inquirers on what to look for, and it may be helpful for them to encourage the inquirers to consider the following:

1. Will the primary use of the verifier be for monitoring production?

   If it will be used in the press-room by the machine operator, a simpler verifier able to give indications of bar width gain or loss may be sufficient - either by means of light-emitting diodes (LEDs) which show in broad steps how much gain or loss is occurring and in which direction, or by displaying the data in numerical form. A printout of the data may or may not be required. If it is to be used by quality control personnel, a more detailed analysis of both quality grades and traditional bar width gain/loss measurements will be required, and the unit should almost certainly incorporate either a printer or means of downloading data for record-keeping and trend analysis. In the special case of film master verification, both the construction of the device and its measurement accuracy are of equal importance.

2. Will the primary use of the verifier be to check that the finished symbol meets customer requirements?

   This may be in the manufacturer's premises, on the packaging line or in the warehouse; it may be at an intermediate distribution point; or it may be in the customer's receiving operation. In all these, the primary need is for a report of overall symbol grade, to check that it meets the basic grade requirement. In addition reporting of parameter grades is useful. The ability to provide a permanent record of results is highly desirable, both as evidence of compliance and in order to assist subsequent analysis of symbol characteristics.

   Whatever the purpose for which the verifier is required, there is a number of features to check which will help to determine the suitability of manufacturers' products for the particular need. Note that there will almost certainly be a relationship between the features supported and the price of the instrument, so if budgets are restricted, over-specification of the instrument should be avoided - although, equally, under-specification for the user's needs will only lead to frustrations in the future.

3. Does it apply the ISO methodology?

   Some will measure according to American National Standards Institute (ANSI) traditional method and others will measure according to the ISO Scan Reflectance Profile method. The ISO method requires 10 scans to be made and an average grade calculated. The *GS1 General Specifications* require the use of the ISO method for verification.

4. What parameters does it measure and report?

   The ISO method for verification requires testing a bar code on several parameters to ensure an adequate overall testing of the bar code's quality, however, some verifiers may not *report* on all of these parameters. Some verifiers may only indicate whether a bar code passes or fails against these parameters and others will give detailed reports regarding the grade given for each parameter. The reporting method is important depending on how you will be using the information.

5. Has it been tested for conformance with *ISO/IEC 15426-1*?

   ISO/IEC 15426-1 is something of a companion document to the ISO specification on bar code print quality, and describes the use of a verifier to test a bar code against the parameters in ISO/IEC 15416. You will want to make sure that any verifier that you consider complies with these ISO specifications.

6. What is the optical arrangement (wand, mouse, laser, motorized head …)?

   You should first determine the environment in which you will be using a verifier. Do you want your verifier operator to physically move the reader across the bar code or do you wish the verifier to do this automatically? Do you require the verifier to be mobile or stationary? These questions play a roll in selecting the optical arrangement.

7. What wavelength light source does it use?

   The *GS1 General Specifications* require 670 nm ± 10 nm.

8. What measuring aperture(s) is / are available?

   Different apertures from the set (0.15 mm / 6 mil, 0.25 mm / 10 mil, 0.5 mm / 20 mil) are called for depending on the symbologies, X-dimensions, and applications.

9. What form of output is available (e.g. LEDs, display, printout of details and individual scan profiles, PC connection)?

   Verifiers have a variety of outputs: LED's only may simply indicate if a bar code passes or fails, You may get a full display of parameter grade but without print capabilities, The unit may have its own printer or accessory printer that can attach to the verifier, and other verifiers will give greatly expanded capability when connected to a PC utilizing the verifier's software.

10. Is it portable or does it require a fixed location?

    Whether portable or fixed, handling procedures must be established, and lighting and the ambient environment in the area of operation must be considered in conjunction with the manufacturers recommendations.

11. Is this verifier meant to go into, say, a production facility or must it remain in a quality lab?

    Many facilities will have separate verifiers for each environment, one to do spot checks on the production line, the other to troubleshoot quality problems. The same type of unit may not be appropriate for both places.

12. Can you accumulate data in the device and take it back to base to print it out?

    Having the ability to download data all at one time may be key to your operation rather than having to hand write and transcribe the data.

13. Does the verifier you are considering have the ability to store and archive data or bar code quality reports?

Being able to archive data and show a quality path may be important to a production facility, however an independent lab may not require that functionality.

14. Can it perform scan averaging (to meet the 10 scan requirement)?

    Some verifiers only work on the assumption of a single scan path and you must manually average 10 scan paths in order to comply with ISO methodology.

15. Does it provide traditional measurement of bar width gain 0 /loss?

    Some verifiers will report on quality based on both the traditional method and the ISO method.

16. What symbologies is it capable of verifying?

    You should ensure that your verifier supports all of the symbologies you use and at the Narrow bar widths you print them at.

17. Does it support GS1-128 specifically, or merely the generic Code 128?

    GS1-128 is a type of code-128 that uses FNC1 in the first position; your verifier should check for this in order to comply with the *GS1 General Specifications*.

18. Will different verifiers provide substantially different results when measuring the same symbol?

    All of your verifiers should operate consistently, and should be checked for calibration using the GS1 US *Calibrated Conformance Standard Test Cards*.

A precisely defined test program, the Verifier Conformance Testing Project, demonstrated that all instruments checked had the capability of consistent performance. Most instruments are capable of conforming to ISO/IEC 15426-1 requirements. No major difference in accuracy was noted between handheld and automatic scanning, but automatic scanning gave a somewhat narrower spread of results.

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