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PROBLEMS AND CAUSES FOR BARCODES THAT WILL NOT SCAN AT RETAIL LEVEL

presented by

Nucharin Luangsa-Ard

has been accepted towards fulfillment of the requirements for

Master degree in Packaging

Diana Twede

Major professor

Date June 19, 1998

PLACE IN RETURN BOX
to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE

PROBLEMS AND CAUSES FOR BARCODES THAT WILL NOT SCAN AT THE RETAIL LEVEL

By

Nucharin Luangsa-Ard

A THESIS

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ABSTRACT

PROBLEMS AND CAUSES FOR BARCODES THAT WILL NOT SCAN AT THE RETAIL LEVEL

By

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The purposes of this study are to examine package barcode quality and to analyze the problems of nonscanning at the first pass as well as suggest the reasons that cause the failures. The research investigated the current scan-ability of common retail store barcodes. Cashiers were observed and then the packages with barcodes that did not scan on the first pass will be collected and further examined. The details of examination and verification of samples were evaluated by using 2 methods: electronically gauged by using PSC Quickcheck ™ verifier model # 850, and visual check.

Barcodes on labels including pressure sensitive labels and paper adhesive labels have the highest percentage of problems. The causes of the problem barcodes on these materials are not mainly come from the material itself but come from poor printing quality, low quality of paper and the wrong pattern of barcodes. The percentage of problem barcodes from domestic is higher than imported package barcodes. Paper adhesive label barcodes from domestic packages have the highest problem. For imported packages, pressure sensitive label barcodes, has the highest percentage of problem. The problems could be solved by improving the quality of printing by choosing the proper types of label printer, using a better quality of paper label. Frequent use of verifier to check the quality is recommended.

DEDICATION

I would like to dedicate this research to my dearest parents (Pongsak and Sudaporn Luangsa-Ard) for their patience, love, kindness, and support. I will forever grateful. I love you dad and mom.

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Chapter 1

Introduction and Background

For the past 20 years, barcode technology has been widely used in public institutions such as grocery stores, libraries and manufacturing industries. "Barcode technology provides many advantages for the users in many ways, for instance making the check out processes of retail stores faster, easier, less costly and more accurate" (Crouch 1996).

When a symbol on a market item is scanned, the scanner receptor will sense the bar/space configuration and convert it into a numerical language. After the resulting code is translated to a distinctive manufacturer's item, the computer software finds the price and charges the item to the customer. "In many cases, scanning also automatically adjusts inventory records and triggers a re-order" (LaMoreaux 1995).

A barcode symbol consists of a series of parallel bars and spaces with varying widths. Information is represented by the width of the bars and the spaces between the lines (Palmer 1991). The computer translates each barcode using a binary process, which reads either ones (1) or zeroes (0) treating them as light and dark lines, respectively. The scanner projects light onto the barcode symbol. The light passing over a white bar will reflect the light back into the scanner, while at the same time the dark bar absorbs the light. This simultaneous sequence of absorbency and reflectance is performed by the scanner and is relayed into a computer. Using a specific processing program the light and dark bars are converted into a readable language.

Since the barcode has been widely used, the Universal Product Code (UPC) system has been set up by the Uniform Code Council. The UPC is an internationally accepted method of identifying products, serializing shipping containers and clearly communicating other important business transaction data, such as purchase order numbers, expiration dates, and lot numbers in a standard machine readable format.

The aim of the UPC standard is to improve communication between trading partners by setting an exact but flexible method of uniquely identifying products and package in human readable and machine readable formats. Therefore, the UPC system has defined rules for barcode symbols, in order to standardize the "language" (Cardais 1993). These include:

- Rules for assigning stock keeping unit (sku) numbers to individual items called consumer units. A consumer unit is the lowest marketable unit of sale for a specific product and its code consists of all 12 numerical digits.
- Rules for assigning unique serial numbers to cartons and shipping containers of consumer units.
- Rules for assigning sku numbers to intermediate packages and shipping containers of consumer units.
- Rules for communicating secondary information such as purchase order numbers, lot numbers, expiration numbers and other types of data communicated between trading partners.

The quality, or scan-ability, of UPC symbols is essential. Poor printing or insufficient contrast between the light and dark lines can cause scanning failures in such cases, a clerk may need to scan such a symbol multiple times and/or manually key in the code, resulting in inefficiency and possible errors. This research focuses on the scan-ability of barcodes and packages printing factors responsible for barcode quality.

Observations in a real retail site will identify items with barcodes that do not scan on the first pass. The items will be analyzed to identify the sources of the scanning problems.

There are three objectives of this research. The first objective is to examine package barcode quality. The second objective is to analyze the problems of non-scanning at the first pass and suggest the reasons that cause the failure of first time scanning or non scanning barcodes. And the third objective is to compare the quality of package barcodes between domestic and imported packages. Solutions for improving barcode quality will be recommended to decrease the number of poor quality package barcodes.

The second chapter has been written to provide the essential background about barcodes and the verification standard. Chapter 3 deals with the details of the research method used in the experiment and data analyzing. Chapter 4 then lists the results of the study. Finally, chapter 5 presents a summary of the findings as well as the author's recommendations.

Chapter 2

Literature Review

This chapter provides a literature and information review of trade journals, books, seminars, the UPC Symbol specification manual and American National Standards Institute (ANSI) Guidelines for barcode print quality. First, the format of the UPC symbol is presented, showing the purpose of each character. Next, the physical characteristics of the UPC symbol are described, followed by a description of the current methods for verifying the scan-ability of UPC codes. The last two sections of the literature review will explore scan-ability problems and known methods for improving barcode quality.

UPC (Uniform Product Code) Symbol Format

The UPC symbol consists of a machine-readable barcode and a human readable interpretation of each barcode. There are two versions of the barcodes, version A and E, with different uses for each version. Version E is used for small packages.

The Version A symbol is the regular version that has 12 digits. The first digit is the number system character, the next ten digits are additional information characters, and the last digit is the module check character (UCC 1994). The Version A code format is as following:

S XXXXX XXXXX C

Where

S = Number system character

X = additional information characters

C = module check character

The initial number system character designates the type of product as shown in Table 1.

Table 1: Number System Character Designation

Character	Specified Use
0	Regular UPCs (source-marked products)
2	Random-weight items, such as meat and produce
3	National Drug Code
4	For using without code format restrictions and with check digit protection for in-stored marking
5	For using on coupons
6,7	Regular UPCs (source-marked products)
1,8,9	Reserved for uses unidentified at time of this writing

The UPC consumer unit code has 12 different UPC digits, which are divided, into three parts as follows (Cardais 1993):

- The first part consists of 6 digits, which are assigned to each company by the Uniform Code Council (UCC). Each company will have its own Manufacturer's ID number. No two companies are assigned the same numbers.

- The second part consists of 5 digits, which each company assigns to each of its products. In the 5 digits, each company has 100,000 item numbers for each Manufacturer's ID number. If companies need more than 100,000 item numbers, they will need to apply for an additional Manufacturer's ID number from the UCC.

- The third part of the UPC number is a single calculated check digit, which is dependent upon the first eleven digits of the UPC number. The check digit catches transposition errors before they are sent to the computer.

These twelve digit numbers are unique to each of the manufacturers and to their specific item or product.

The check digit, which identifies the encoded number system, is found in the left margin of the symbol.

Version E is the "zero suppressed version", used for symbol marking on small packages. Some of the zeroes that can occur in the UPC are left out. For example, code 012300 00045 would be encoded as 123453. The version E code has format as follows;

XXXXXX

UPC Symbol Characteristics and Structures

The UPC Symbol has been very precisely specified. Two dark bars and two light spaces represent each character or digit of a code. Each module consists of seven data elements in each character. A module can be dark or light. The symbol size can be varied within a specified range, which depends on the acceptable quality range of the printing process. Generally a larger symbol is better. The symbol has to be able to be read by a simple hand held scanner. The symbol should also have the code in a human readable form for key entry when the symbol is not able to be scanned (UCC 1994).

The Version A code has some specific characteristics. The number system character is located in the left margin of the symbol and then followed by the ten additional information characters. As well as, the modulo check character which is located in the rightmost position of the symbol. The nominal width of each dark bar and light space is 0.013 inch. The nominal size area is 1.4984 square inches.

There are 113 modules in Version A, including nine in the left margin and nine in the right margin designating quiet zones. The symbol itself begins at the left with the guard bars followed by a number system character. Five UPC characters are on the left side and five on the right, with a center pattern separating them. The right side information characters are followed by the module check character and the guard bar. Dark modules are represented by 1's and light modules are represented by 0's. The first two (guard) bars at the left and the last two bars at the right are encoded with 101; the center bars are encoded with 01010. The encodation of the left and right halves of the Version A symbol is shown in Table 2.

Table 2: Encodation of Right and Left Characters

Decimal Value	Left Characters (odd parity)	Right Characters (even parity)
0	0001101	1110010
1	0011001	1100110
2	0010011	1101100
3	0111101	1000010
4	0100011	1011100
5	0110001	1001110
6	0101111	1010000
7	0111011	1000100
8	0110111	1001000
9	0001011	1110100

(Note. The left hand characters use an odd number of modules to make up dark bars while the right hand character use an even number.

Check Character Calculation Chart

Position	12 (number system character)	11	10	9	8	7	6	5	4	3	2	1 (check digit)
	0	1	2	3	4	5	0	1	1	2	3	8

The check digit is the result of a calculation. It can be derived by following these steps:

1. Start from position 2 of the number from the Check Character Calculation Chart, and then add up the values in only the even number positions. For example

   3+1+0+4+5+0 = 10

2. Multiply the result of 1 by 3

   10 x 3 = 30

3. Start from position 3 of the number, and then add up values of the digits in odd number positions.

   2+1+5+3+1 = 12

4. Add up the results of 2 and 3

   30+12 = 42

5. The number that added to the result received through step 4 gives a number that is a multiple of 10 is the check digit.

   42 + x = 50 (multiple of 10)

   x = 8 (8 is the number that added to 42 results in a multiple of 10. Thus, the check digit is 8.)

The human readable check digit character is shown in the right hand margin of the symbol as shown in Figure 2-1

The Version E symbol has only six encoded information characters. It has one module check character, which corresponds to the parity patterns of the information characters. These characters are coded in odd parity and there are in even. The quiet zone is the same as Version A.

Figure 2-1: UPC Standard Symbol

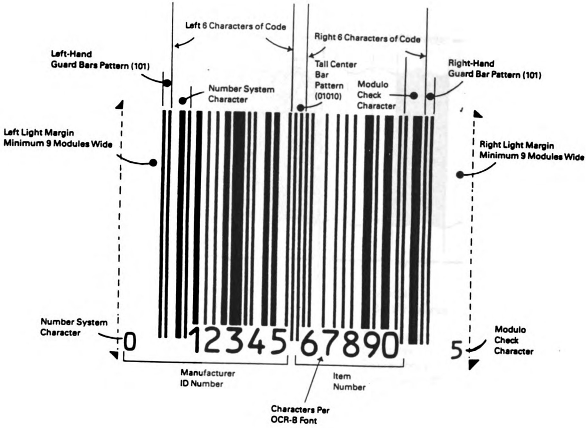
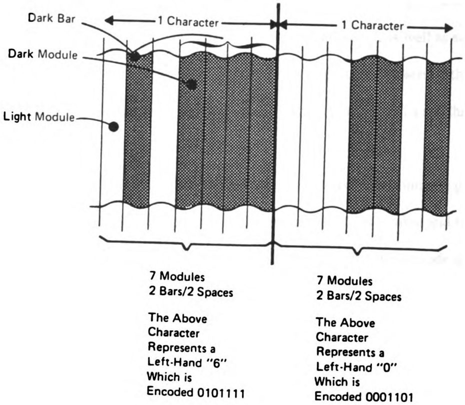


Figure 2-2: Character Structure of UPC Standard Symbol



Verification of UPC Symbols

Verification is a process of barcode quality checking in order to confirm conformance to specification. The verifier is a quality control gauge, which is used for checking the symbol quality. Mostly, the barcodes that can be read by verifiers will be able to read by all scanners (LaMoreaux 1995).

Verification is essential for the producers of barcode as an expected quality control process to assure that the barcodes meet the specification as well as satisfy customers' requirements. In addition, verification is important for users of the barcode for a specified job to check if the barcode has a function, a need, and a use that meets all required parameters.

There are two basic methods for barcode verification: electronically gauged verification of the printed elements and visual inspection of the symbol and related items. The two methods, used together, form the basis for comprehensive barcode quality measurement.

Visual inspection incorporates the use of a ruler and magnifying glass. A ruler which is made of transparent red plastic, is a good tool for measuring bar dimensions. Besides, the red enables one to view the surface as scanner does and facilitates checking the color of bars and background. A small magnifying glass can be used for roughly checking bars and spaces in a barcode. The visual check is used to examine bar height (truncated), human readable characters, symbol location, symbol size and color (LaMoreaux, 1995).

When a barcode is put in a small space, the symbol can be shorter in height than the ANSI specification. But the barcode still has to be in the standard length. This is called a " truncated" barcode. Truncation may have an impact on a symbol's scan-ability, especially in fixed scanners since the fixed scanners require an oversquare symbol to allow one beam to cut it for a sufficient read.

In most UPC codes, the human readable characters will show the encoded numbers as well as the initial system characters and the check digit. The human readable characters have to be printed in such a way as to provide optimum visible correlation with the UPC symbol.

The location of the barcode should be checked to see if it meets a specified standard. The symbol should not be located in an area that might cause scan-ability problems. Normally, the preferred location for the UCC/EAN barcodes is on the horizontal plane. On a flat or curved surface packages the symbol should be at least 5 mm. away from any of the packages' folds or seams, and on the small cylindrical products the symbol should be printed vertically to the curve to decrease any possible problems (Article Number Association 1997).

The size of the bars need to be checked to see if they are in the minimum% and maximum % range of UPC specification. A normal size is 100%, while a minimum is 80% and a maximum is 200% of the normal size. Generally, a large bar is better for the scanning process.

The inspector should be concerned about if the color of the bars and background, have negative scan-ability effects. Since scanners use red light, the choice of colors for the barcode is restricted to a solid color. Black, blue or green content is best for the bars, and white, red or yellow for the background (Article Number Association 1997).

Electronically gauged verification of the printed elements incorporates the use of a specialized instrument to measure the parameters of the symbol. A verifier is an instrument which is used to measure some defined attributes of the printed UPC symbol, decode the barcode symbol as defined by the specification and visually inspect the symbol with the corresponding proper barcode layout.

The ANSI (American National Standards Institute) methods are widely accepted for verifying the barcode symbol (Uniform Code Council 1994). To measure the quality of a nominal UPC symbol or a barcode based on the ANSI/UCC5-1995 Quality Specification for the UPC Print Symbol, a verifier must have 6 mil. aperture and 670 +/- 10 nm. wavelength (Uniform Code Council 1996).

In the ANSI Standard, verifiers classify Scan Reflectance Profile (SRP) into nine parameters. Four parameters are subject to pass/fail criteria and five are graded on a 5-point scale.

(A) Superior

(B) Good

(C) Satisfactory

(D) Unsatisfactory

(F) Poor

The nine parameters of Scan Reflectance Profiles (SRP) are described in the following paragraphs (American National Standards Institute 1988).

Edge determination or *global threshold* is the total amount of light space and corresponding dark bars that are presented in a barcode. When the verifier cannot find the same number of spaces as the standard specification, it will report edge determination. For instance, the version A barcode has 59 total spaces, 30 dark bars and 29 light spaces. If the dark bar width is printed without adequate adjacent light space, this barcode may fail edge determination. This attribute is graded on a pass/fail score. A global threshold is a line, which is drawn halfway between the highest and lowest reflectance points in the profile and parallel to the direction of the scan; the profile of barcode will fail if any bars or spaces are missed by the line (LaMoreaux 1995).

Minimum Reflectance (Rmin) is a measurement that determines whether the reflectance of the darkest bar is less than half of the lighter background. Failure will indicate that the barcode printing is not dark enough relative to its lighter background. R(min) is a pass/fail score.

Symbol Contrast (SC) is a measurement of the contrast between the lightest background (Rmax = the highest reflectance value in a scan) and the darkest bars (Rmin = the lowest reflectance value in a scan). If the contrast is not adequate, a scanner will not be able to determine the difference between a bar and a space. SC has a scale of A-F.

Minimum Edge Contrast (ECmin) is the smallest difference between bar and space at each edge. ECmin is graded on a scale A-F. This attribute is related to symbol contrast and modulation. The low symbol contrast and modulation scores always occur, if the minimum edge contrast fails.

Modulation (MOD) is comparing the measurement of the intensity of narrow spaces to wider space. Narrow spaces are observed by the measuring hardware as less intense because of the smaller amount of space which is occupied. If the smaller amount of space is occupied, the intensity is low. Modulation is scored from A-F. A low score might indicate ink spread in the symbol.

Defects are categorized into two types: voids and spots. Voids are light areas in the bar(dark area). Spots are dark areas in the spaces. Both kinds of defects can confuse the scanners and cause them to read the defects as an additional bar or space within the symbol. A low score on defects may be due to insufficient ink (void) or unwanted deposits(spots). Defects are scored from A-F.

Quiet zone(QZ) is the area of light area surrounding a symbol on the left and right edges. The scanners will not be able to determine the location of the beginning and the ending of the barcode, if other printing is too close to the barcode. The quiet zone is measured on a pass/fail score. The quiet zone can be calculated from the average of narrow bar or space (Z) multiplied by 10 (ANSI 1988).

Decode is determined by pass/fail score. When the verifiers can decode a symbol, it indicates that the bars and spaces were successfully decoded into correct series of digits and guard bars for the barcode specification.

Decodability is scored from A-F. It is a measurement of how nearly and wells of barcode printing relative to its scan reflectance profile. Symbols which are printed with well-defined and exact edges exhibit high decodability. A low score on decodability will refer to low barcode resolution and poor quality.

Table 3: Scan Reflectance Profile Parameter Criteria Scoring

Parameter	Score/Grade	Criteria
1. Edge Determination	Pass Fail	Conforming Version A – 59 elements (30 bars, 29 spaces) Version E – 33 elements (17 bars, 16 spaces) Non-conforming
2. Minimum Reflectance	Pass Fail	≤ 0.5 x R(min) > 0.5 x R(max)
3. Symbol Contrast	A B C D F	≥ 70% ≥ 55% ≥ 40% ≥ 20% < 20%
4. Minimum Edge Contrast	A F	≥ 15% < 15%
5. Modulation	A B C D F	≥ 70% ≥ 60% ≥ 50% ≥ 40% < 40%
6. Defects	A B C D	≤ 15% ≤ 20% ≤ 25% ≤ 30%
7. Quiet zone	A F	Meets minimum requirement For quiet zone widths Fails minimum requirement For quiet zone widths
8. Decode	Pass Fail	Valid character and symbol decode Invalid character and symbol decode
9. Decodability	A B C D F	≥ 62% ≥ 50% ≥ 37% ≥ 25% < 25%

Scan-ability Problems

Barcodes are now considered a primary technology that is being used throughout the world for commercial and industrial automatic identification. Barcode technology can save a large amount time and thus cost of manpower, although sometimes the technology can cause problems for the users.

The main problem is the scan-ability of the barcode, which depends on the barcode itself as well as scanners. The barcode (symbol) print quality is a significant factor, which affects the scan-ability of every scanner. In order to solve this problem, the UCC has asked companies such as Kmart Corporation, and Bar Code System Inc. to study the causes and effects of symbol quality.

According to the 1990 finding of Bar Code Inc., only 80% of the package barcodes were successfully read. The first scan failure rate of package barcode were due to the poor print quality of the symbol. One retail chain estimates that if re-scans were eliminated, productivity in its 128 scanning stores would be improved by more than 7.5% and result in a $2 million saving annually (Shuman 1995).

Poor quality symbols cause four problems. They decrease productivity, increase cost, decrease data integrity, and they cause consumers and employees doubt and frustration because of scanning errors.

The K-mart study found that one sku with an unscannable package can result in over $ 1,000 extra cost per month. In this 1991 study, 2,232 bags of Halloween candy with poorly printed barcodes were sent to Kmart stores. These codes had to be hand-keyed, 2,206 times in 50 stores between 10/20 and 11/16, because of the poor printing of the barcodes. Normally checkout operators at these stores are trained to hand-key the number after they have tried to scan the symbol 3 times. A hand-key transaction takes about 10 seconds, which would result in an extra 273 hours in the case described. That means in one month at the checkout trying to scan this item, at the minimum wage of $4.25 per hour, K-mart would have paid an extra wage of $1,160 (Brandes 1996).

In December 1995 Ed Madigan & Julie Huffman from AT&T Human Factors Services published a study entitled "An Examination of UPC Quality". It was found that from 84 problem packages, 44% of them failed at least one level of barcode quality evaluation. The failures were due to edge determination (27%) decode (29.7%) and decodability (29.7%) problems, each respectively. These failures might be caused from "ink spread" and "ragged or uneven bar" attributes (Madigan & Huffman 1995).

In addition, it was found that the major types of problem packages were medium sizes plastic bags and tubs. The edge determination and decode/decodability failures, which could indicate problems with space and bar and overall barcode resolution were the main factors for this failures. Furthermore, the rectangular and barcoded produce items accounted for 10.8% for each of the problem packages type. The effects of this failures were due to edge determination, symbol contrast, decodability and quiet zone attributes. The other problem package such as cellophane bags, small bags, bottles, blister packs, cans, flats, in-store barcoded and small items combined represented 43.2% of all attribute failures (Madigan&Huffman 1995).

Due to the problems that have been mentioned, people who work with barcodes including manufacturers, retailers, researchers and UCC are trying to improve the quality of barcodes. The following section describes some programs and methods which provide barcode users and manufacturers useful information for producing good quality barcodes.

How to Improve Barcode Quality

The verification section showed that the symbol quality of barcodes can be measured in two ways. One is the technical process called verification, the process of comparing a printed barcode against an accepted set of specifications. The second is a visual inspection. A third way to evaluate symbol quality is a practical scanning test. A robust program of quality control combines all three evaluative methods.

An example of the combination approach is Kmart's internal quality control program (Brandes 1996). The company constructed a series of checks, including visual inspection, scanning and technical inspection procedures. K-mart's visual inspection procedure checks the human readable numbers for proper placement and the symbol size for truncation and magnification. Other visual checks include quiet zone, symbol defects such as ink/dirt etc., and proper location. The scanning test involves scanning the symbol 10 times in the same way in a store's scanning environment. If the symbol scans easily, the symbol is accepted. If the symbol does not scan easily, a verifier is used to perform a technical evaluation and validate that the symbol has been printed to specifications.

Barcode Quality Goals

In order to have a successful barcode system, Sprague Ackley (1990) from Intermec Corporation recommends three quality goals: a good read rate, a dependable printing process and a low cost. Each goal is discussed below.

There are three basic requirements to insure a good read rate: adequate contrasts correct element count and element accuracy. The first and most fundamental parameter is contrast, which is the difference in reflectance between the dark areas and the light areas. The contrast needs to be in acceptable range when the barcode is read and used especially in a harsh environment. An example of a harsh environment is the manufacturing process of Titanium Di-Oxide, which is a finely ground white powder. The symbol was lighter and hard to read due to the effect from the color of Titanium Di-oxide.

Figure 2-3 shows the differences in scan reflectance profile between a good contrast symbol and a lower contrast symbol (Ackley 1990)

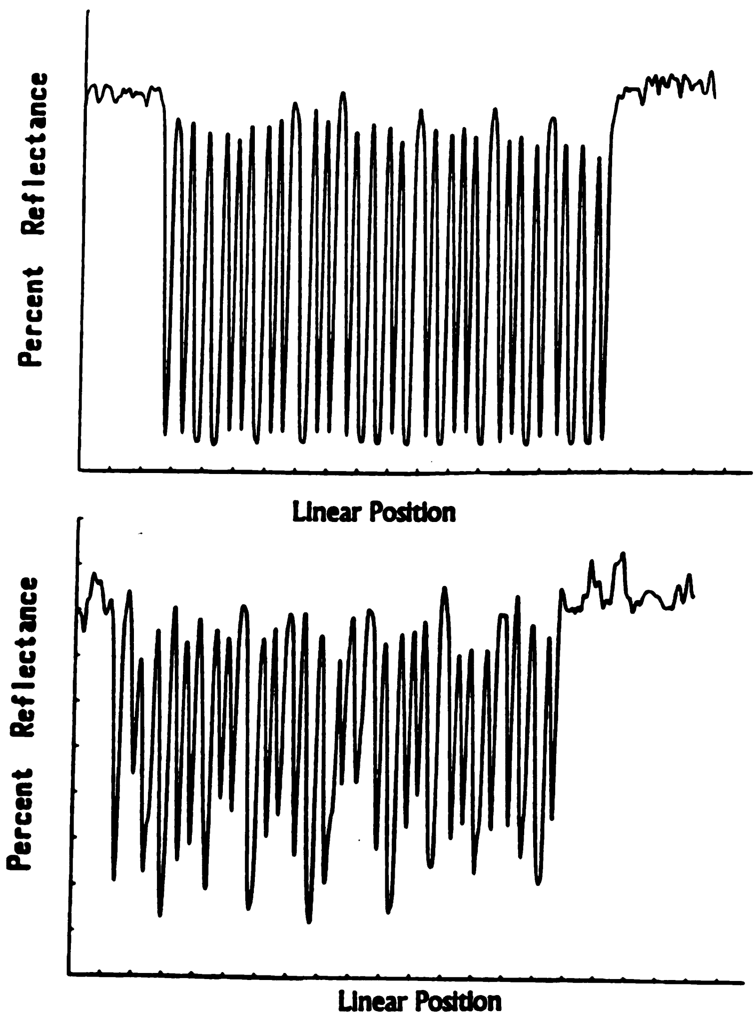
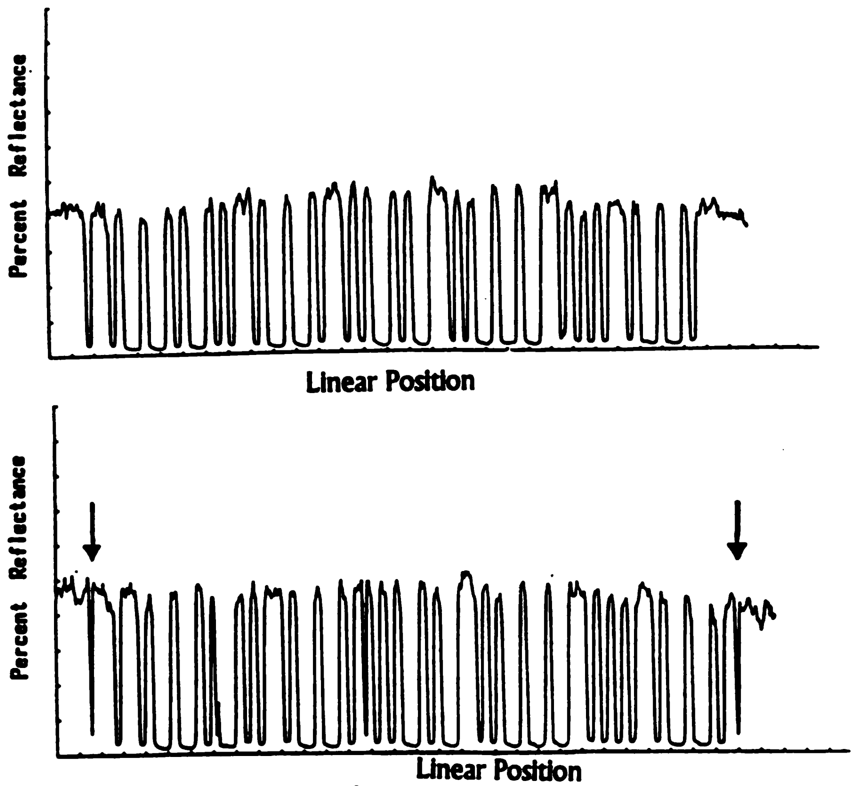


Figure 2-3, the first profile shows the profile of good contrast symbol because there is a large difference between light and dark. The second profile is a symbol from a harsh environment where white industrial powder is presented. This environment can make the symbol dirty and light that will be more difficult for a verifier to find the elements and correctly extract the element sizes.

Element count errors can occur because the scanner picks up an element which is not supposed to be in the symbol or the scanner misses an element which should have been presented. In the first case, it usually occurs because of a printing defect such as a spot or void. In the second case, it might be caused by printing which is uniformly too dark or too light, or by severe environmental damage such as a scrape. In some cases, the error might be from incorrect encodation.

Figure 2-4: Profiles of Symbols which were printed by a stencil technique (Ackley 1990)



The first profile in Figure 2-4 shows the desired effect of printing with an unusual technique such as a stencil. A stencil technique which used to paint black bars onto a light background, such as concrete. The symbol in Figure 2-4 is white paint on a black tile. The first profile is white paint on a black tile where all the elements are present and no extra element can be found. The second profile will occur when an error in the printing coincides with a particular scan path. In this sample the error is caused from chips in the white paint on the dark background symbol. Then the symbol does not have the correct element count and will not decode.

The other important factor for a good read rate is the sizes of the individual bars and spaces. In all cases, if the widths vary too much, the scanner may think the individual element is big when it is supposed to be small or a different size than it was intended to be. That might force the scan to be rejected, and result in an unnecessarily poor read rate.

The second quality goal of Ackley (1990) is to develop a dependable printing process. All printing processes have an elemental set of print variables. It is necessary to study and follow the recommendations of printer manufacturers. The environmental parameters such as ambient humidity and temperature as well as printing tensions and pressure should be highly controlled. Variables for several specific print processes will be described later in this literature review.

After the printing variables have been considered, it is necessary to consider the limiting factor of the parameter set for the particular printing method. For instance, direct thermal printing is limited by the ability to make a dark bar. The background is quite bright but bars may not dark enough for the scanner to read. The important property, which governs the perception of the bar darkness is the color of the scanning light. Since direct thermal printing is quite sensitive to light color, then it cannot be used with Infrared wavelengths if special printing stock is not utilized.

It is also essential that the printing technology should be in an acceptable range for the use. The broader the range of operation, the easier to implement an application of a printing technology. Usually, though the printing process has been carefully set up, the printing will deviate from normal range. Then, the important step to make the process in complete loop is to install a spot checking procedure when major changes occur in each process, for example when the media in a thermal system is replaced or after a high speed toner system has been used for a long time. Figure 2-5 profile represents a symbol produced with a high-speed toner printing process; when toner is not replaced soon enough a poor read occurs.

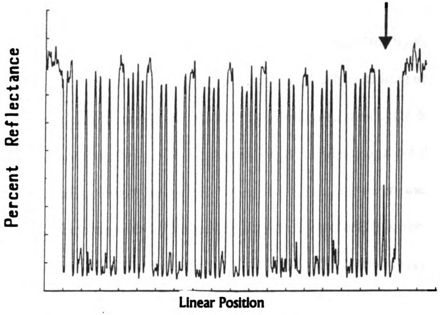


Figure2-5; show a profile of the high-speed toner printing process symbol(Ackley1990)

The last important factor to be considered for a quality control program is the symbol cost. Usually, the barcode producers will try to lower symbol cost without affecting their symbol quality by trying new product developments in media. One inexpensive method of printing symbols is the wet ink process. The wet ink process uses an accurate film master and then makes the same symbol over and over again on a printing press.

Besides those quality goals, Sprague Ackley also recommends some specific methods for controlling barcode print quality and methods for improving the quality of barcode labels. These are described below.

Single pass printers which use ribbons or thermally sensitive labels have better print quality than multi-pass printers. The single pass printers have better quality because a measured and known amount of ink is transferred to the printed surface. The examples of this type of printing technology are thermal transfer, impacted formed font and direct thermal printers, while the impact dot matrix printer is included in multi-pass printing technology. Though the impact dot matrix printers have lower print quality than other types of printers, many computer companies are still using it due to its long utilized.

Impact dot matrix printers create the symbols by overlapping the dots to form the bars. When a ribbon is new, the bars will generally be dark and uniform but the spaces will be rather small due to the spreading ink. When the ribbon is used up, the bars will become lighter and narrower and will have visible voids. Therefore, it is important to use a good quality ribbon and monitor the amount of ink left on the ribbon in order to get good quality barcode symbols when using an impact dot matrix printer (Ackley 1990).

Ackley (1989) suggests a quick and easy method to compare the size of narrow bars to the narrow spaces of the symbol printed by dot matrix printers. This method is called "the snip trick" which is done by snipping the label in half and shifting the lower half sideways until a narrow bar on the lower half matches with a narrow space on the upper half. The resulting comparison of narrow elements becomes clear, even without magnification, and provides an easy way to make sure the narrow spaces are equal to or bigger than the narrow bars.

Nicholas and Sevcik (1996) recommended that the producers of barcodes use a proper material and printer combination; including the correct printing supplies such as ribbon, ink and toner. One needs to have properly trained operators, a barcode verification system, and printer maintenance.

In the printer point of view, the authors pointed that there are many types of printers with defined application, some of them designed for specific materials. Do not use a printer for an application for which it was not designed. If not the symbols might have poor performance and might increase cost if the printer breaks down frequently.

In the supplies area, one should be sure that the supplies match the specification. The second consideration is to be sure that the application and service are in the proper range temperature range in order to select the proper label and adhesive. The supplies should be stored in a dry, controlled environment and should be kept away from sunlight. The labels should not be stored too long since adhesives could dry out.

Proper training can ensure that the printers run efficiency with maximum output and quality. The operators should clearly understand preventive maintenance techniques and select the proper supplies as well as proper technical configurations.

Printer maintenance is essential: a clean print mechanism is extremely vital to the performance of the printers. Moreover, it is important to check that the label path is free of obstructions, one should check the printing environment such as dusty, humidity as well as heat or cold since all of these element can effect the print quality of the labels.

After a quality barcode is printed, the other important factor is how to maintain the barcode label quality. Miner (1992) provides considerations for choosing the suitable label construction for in different environments. Before attaching label to products, the manufacturers should consider if the products inside would have any effect on the label. For example acid fumes, solvents, cleaning solution and alkaline liquids can corrode label components, the oily dirty or rough surfaces may affect the label adhesives, and discontinuous surfaces can obstruct barcode scanning. Moreover, the fluctuation of temperature can be another factor of lowering barcode scan-ability.

Miner (1992) also made some recommendations to optimize label longevity. First, the surface preparation is key to label durability. To wipe the surface with a dry cloth or a wet cloth with solvent is a way good to prepare the surface for label application. For pressure-sensitive labels, applying pressure during application can enhance the intimate contact. Second, select more than one label construction to meet the varied demands of a project, which will increase cost a little but will add greatly to barcode durability. Finally, "the key to success is the optimum balance of printing technique, label layout, symbology, code density, and label construction for the particular application". Willingness to over-engineer the label construction, use multiple label constructions and code densities, where indicated, will pay dividends. The label is the first link in the chain of automatic data collection. A strong first link assures ease and accuracy of data input" (1992,p.23)

Reducing Printing Variation

Ackley (1994) recommends that "the key to scanning success is to understand the variation inherent in each printing technology and to control that variation for the least cost". The variations are separated into printing variation and local and global variations.

Most ordinary printing variation is uniform, meaning that all the bars and spaces suffer the same size change. The uniform variation can cause the bars to all get bigger by the same amount or all the bars to get smaller uniformly. The problem will have an effect with the scanner since the scanner can find all the elements resulting in sluggish scanner performance. The printing technologies that need the attention to control the uniform variation are thermal, impact dot matrix, laser toner(xerographic), ink jet, laser etching and wet ink.

Local variation is caused by "spots" or lack of printing in the bars "voids". It can effect the scanner since the scanner will find too many elements causing the decode to be rejected. Normally, dot matrix and ink jet printing technology will have the local variation problem.

Global variations are the limitations that can affect the entire symbol. Usually, the effect of global variations is too little contrast between bars and the background. It can cause scanner problems by making it difficult for the scanner to find any bars and spaces at all. Printing methods affected by global variations are direct thermal, ink jet and laser etching.

To provide more knowledge and understanding about those variations above Ackley (1994) describes problems and some solutions for each type of printing technologies. These descriptions are summarized in Table 5.

Thermal Transfer: Uniform variation is usually found in thermal transfer printing. Since thermal transfer involves laying down an optically opaque ink on a paper or plastic substrate, the scanner might see the bars bigger than they might look to the naked eye. In order to be optimally read by the scanner, the bars have to be printed a little narrower, around 10% of the actual size.

Direct Thermal: Uniform and global variation may occur in thermal printing. Direct thermal is different from thermal transfer because direct thermal does not utilize an opaque ink but turns a chemical coating on the paper dark with the application of heat. Consequently, the bars will not be as dark as they are with thermal transfer and will not show the substrate distortions found with the opaque inks. Therefore, direct thermal labels should be darker than nominal and the bars should be slightly larger than the spaces to compensate for the lack of optical density.

Impact Dot Matrix: Uniform and local variations are involved with barcodes printed by impact dot printers. When a new ribbon is used on the printer, usually the bar growth is excessively large but the symbol is still useful though it may show less depth-of-field in scanning. Since impact dot matrix printers typically use opaque inks, in order to get optimum printing quality the bars should be a little narrower than the spaces when analyzed visually.

Furthermore, old ribbons can be a major cause for poor scanning performance with dot matrix printing. When the ribbons are used up the bars will be narrower and lighter and the voids will occur. The voids will cause the scanner to think there are too many elements and the read rates will become low. When the ribbon is extremely depleted, the symbols will be nonscanable.

Laser Toner: Uniform variation is the most important problem with laser toner printers. The problem sometimes comes from the software used to run the laser toner printers. Since the software is made to graphically fit a symbol into a given area, the narrow element dimension may not come out as an integer multiple of the dot size. Though, the resulting symbol looks perfect for the eyes, the quantization errors induced by the graphical interface will cause problems with the widths of the bars and will cause scanning sluggishness. Because laser toner printers cannot adjust, the only way to improve print quality is to make all bars and spaces larger. On the other hand, the narrow element size or "X dimension," should be at least .013 inches or larger.

Ink Jet: Uniform, local and global variation can be found in ink jet printing. Inkjet printers can print symbols directly onto packaging materials, which will reduce the cost of labels. Though this process is hard to control, it is still widely used due to the cost advantages. The uniform variations come from ink spread which occurred because the substrate is too absorbent or the ink is too runny. The local variation appears when inadequate coverage of a bar results in voids, and ink splatter causes spotting. Global variation happens when ink jet printing of barcodes on corrugated cardboard containers that have inherently low reflectance characteristics.

Laser Etching: Uniform and global variation are the important problems that have to be considered when using laser etching. The symbol in this process is made by burning off the black material exposing lighter material underneath or by burning lighter material with the laser to create darker areas for the bars. Typically, the global variations are caused by low contrast and the uniform variations are caused by the software that is driving the laser spot location. Carefully programming of the laser system and frequently testing for the bar growth with a verifier will be able to decrease those problems.

Wet Ink: The major problem with the ink jet process is uniform variation. A verifier is an ideally suitable instrument to measure and control wet ink processes. Sometimes visual measurement might be a reliable method to check the symbol quality since the wet inks are not opaque. In addition, the barcode printed with wet ink on a plastic bottle will show many narrow elements hardly coming up to the centerline of the reflectance profile. This symbol can be improved by adjusting the film master used in the fabrication of the printing plate by making all the bars smaller and the spaces larger by about 10-15%.

Table 4: Variation associated with Printing Processes

Variation	Printer Correction		
	Uniform	Local	Global
Thermal Transfer	Bar smaller than spaces	Not applicable	Not applicable
Direct Thermal	Bars larger than spaces	Not applicable	Not applicable
Impact Dot Matrix	Bars smaller than spaces	Change ribbon when light	Not applicable
Laser Toner	All elements larger	Change to pixel-based program	Not applicable
Ink Jet	Increase ink viscosity	Decrease ink viscosity	Print with white ink
Laser Etching	Bars smaller than spaces	Increase laser spot overlap	Spaces more diffuse
Wet Ink	Decrease film master bars	Use film master or pixel-based program	Not applicable

Examples of Recommended Locations of Barcodes on Various Types of Packages

One of the important factors that affect with scan-ability of barcode is the location of barcode. The location of barcode should be suitable for different types of scanner: horizontally mounted fixed laser scanners and vertically mounted fixed laser scanners. Though, there is no location that suits all scanners completely, the recommended position mostly suits most types of scanners and dose not have problems for any particular type. There are some recommended locations of barcode which divided by their packages types. The locations are as following: (Article Numbering and Symbol Marking 1995)

-The location of barcode on bottles and jars: in a wrap-round label of the bottles or jars, the symbol should be located on the back near the base of the label.

-The location of barcode on boxes, cartons, and cubic tubs: the symbol on these types of package should be located on the left side of the package when looked from the front. It should be located towards the base with the light margin far from edge at least 5 mm.

- The location of barcode on metal boxes: this category includes non-cylindrical metal containers such as cans for processed meat, sardines and motor oil. The symbol should be taken to avoid seams and should be located on the back, near the base.

- The location of barcode on beaded cans: the symbol should be located to avoid any bead and oriented with bars perpendicular to the beads.

- The location of barcode on printed wrappers: this category includes paper, plastic, film, or foil wrapper around rectangular or cylindrical products. If the package has the design in the front, the symbol should be located on the reverse on the right hand side. If the package does not have a design front, the symbol should be located on the overlap end of the wrapper, on the right hand side. The symbol on margarine wrapped butter should be not closer than 5 mm. of the crease, fold or corners.

Chapter 3

Research Method

This research empirically investigates the current scan-ability of common retail store barcodes. The researcher will observe the behavior of typical cashiers and identify packages with barcodes that do not scan on the first pass. These packages will be analyzed to find the reason for the scan failure. This chapter discusses the research method including selecting of the store, data collecting details, and the details of the examination and verification of samples using two methods: electronically gauged verification and visual check.

The retail store where this research took place is one of the big "hypermarket" retail stores in Michigan. It is included in a chain of retail stores that are widely used for research. The chain is one of the nation's hundred leading retailers, and carries approximately 102,000 items per store including food, hardware and soft goods, etc. The stores have various kinds of products that provide the greatest chance of getting various types of packages' barcodes.

The researcher observed the cashiers scanning the barcodes. In this retail site NCR Class II scanners were used at every check out counter. The problem packages were taken from the customers and then new packages were given in stead. Packages with barcodes which did not scan the first time were recorded and collected for further investigation. Observation was made about 4 hours per day for 7 days. Four different cashiers were observed over each one-day period. The number of problem packages that were collected during the observation period is 65 items.

The second step of the procedure was further investigation of the packages that did not scan the first time. Imported packages and packages made in the US were separated from each other in order to compare the extent and nature of the barcode problem in the packages. Moreover, the problem packages were categorized by package material types such as plastic bag, paperboard, film overwrap, tags and paper wrap. Then each barcode was inspected for various aspects such as the quality of printing, color of the barcode, and the color of the package, in order to examine if the contrast of barcode and package is in the acceptable range or not. The inspection was done by both visual inspection and electronically gauged verification.

For electronically gauged verification, the PSC Quickcheck ™ verifier model #850 (produced by PSC Inc. in New York) with a pen wand (660 nm. wavelength 06 mil.) was used to analyze and identify the characteristics of each barcode. The Quickcheck ™ 850 has a laser verifier which performs pass/fail testing of dimensions and formats quality barcode such as average bar deviation, encodation, ANSI decodability test and quiet zone tests. The Quickcheck ™ requires data using the Scan Profile Methodology specified in ANSI's "Bar Code Print Quality Guideline" (ANSX3.182-1990). The Quickcheck ™ will evaluate the data and provide a scan grade. The barcode quality was measured according to the ten attributes outlined in the UCC Quality Specification for the UPC Printed Symbol guideline(1994) as described in the literature review section.

To print the data, the verifier was connected with PSC Quick-check Super Speed Printer (QCSSP.PSC,Inc.,NY). After the barcode was scanned , all the result would automatically print. The Quickcheck ™ 850 would give the scan reflectance profile, decodability, symbol contrast, R(min)/R(max), modulation, edge contrast, defects, symbol grade, traditional test, format tests and pattern error. The samples of print results are provided in the appendix section.

Chapter 4

Results and Discussion

This chapter will discuss the results, which are divided into 3 sections: (1) evaluation of problem packages by their material types, (2) evaluation of problem packages which are able to be scanned by the verifier (3) Visual inspection of problem barcodes which were not able to be scanned by the verifier.

Evaluation of Problem Packages by Their Material Types

The problem packages which did not scan the first time (65 items), were first divided into domestic and imported packages. After that all packages were categorized by their material types, and the data are shown in Table 5.

Fifty-two percentage of all problems were with labels. Pressure-sensitive label had more (34%) problems than paper adhesive with liquid adhesive (18%). It was found that the percentage of problem barcodes from domestic packages is higher than the percentage of problem barcode from imported packages. In addition, 6 % of problem packages were not identified by where they were made.

For domestic packages, paper adhesive label barcodes, have the most problems (15%) see Table 5. This possibly because the solvent in the adhesive can corrode or dissolve label components (Miner 1992). In addition, the rough surface of package material can also reduce scan-ability of the scanners.

Six percent of the domestic problem barcodes were on plastic bags. This problem may come from the reflectance of material which can reduce the scan-ability of the scanners. Problem barcodes which were printed on paperboard (9%) were mostly caused by poor quality printing such as void, spot, burr and ink spread. In film-overwrap (6%) the problem was caused from inappropriate location of barcode, while in paper tags (6%) the problem resulted from wrong barcode patterns (bad left, right or center guard). The last problem, barcodes on metal can (2%), had insufficient contrast between the color of the bars (metallic ink) and the background (can).

In imported packages, it was found that barcodes on pressure sensitive labels are the highest problem (20%). The causes of the problem mostly came from poor printing quality and low quality of paper. Barcodes on paperboard in blister pack and paper tag have the same percentage (5%). The results of barcodes on paperboard in blister packs possibly came from the reflection, which can impact the scan-ability of the barcode inside. Problem barcodes in paperboard, film over-wrap, paper adhesive label and plastic bags resulted from the reasons mentioned above. The barcode problem with the plastic can was the poor absorption between material and ink. Barcode on this material does not have good contrast between bar and background and printing quality, making it difficult for the scanner to read the barcode.

One reason why so many pressure sensitive label problems were found in imported packages is that there are more imported packages with pressure sensitive labels, as part of a common strategy to market the " same" package in several different language by simply changing a label.

Table 5. Percentage of Problem Barcodes Divided by their Packaging Material and their Original Source

	Problem Barcode (%)			Total (%) for each type of package
Material type	Identified place of manufacturing		Unidentified place of manufacturing	
	Domestic	Imported		
Plastic bag	6	2	-	8
Paperboard	9	3	-	12
Film-overwrap	6	3	-	9
Tag(paper)	6	5	-	11
Paper adhesive label	15	3	-	18
Pressure adhesive label (paper)	8	20	6	34
Paperboard in blister pack	-	5	-	5
Plastic can	-	2	-	2
Tin can	2	-	-	2

<u>The Evaluation of Problem Packages which are able to be Scanned by the Verifier</u>

After separating the problem barcode by previous criteria, the evaluation of barcode quality attributes was further done with the PSC 850 verifier. From 65 items, there were 41 items that the verifier could scan, 24 items could not be scanned by the verifier due to their poor quality and wrong pattern. However, all 24 items were evaluated by visual inspection and their data is shown in the next section.

Table 6 shows the percentage, by grade of nonscanable barcode packages, which could be scanned by the verifier. According to the ANSI Standard, the Scan Reflectance Profile has been graded on 5-point scale. Each grade has its meaning as follow; A= Superior, B= Good, C= Satisfactory, D= Unsatisfactory, F= Poor. From the Table it was found that both domestic and imported barcoded packages have the same percentage of grade F symbols (32%). The percentage of grade D symbol on domestic packages (7%) is higher than the percentage of imported package barcode (2%). The percentages of grade C and B symbol of domestic package barcode are 10% and 2% respectively. The percentage of grade C symbols on imported packages is 5%.

Generally, most scanners should be able to scan all grade C symbols and above. They might have difficulty reading the grade D symbol and below. In this research, there are grade C and B symbols that were not able to be scanned the first time. The factors of their failures may due to the environment of the scanners at that time as well as the cashiers' behavior when they were scanning the packages. For example, the glass of the scanner might be not clear which might obstruct the way of laser to read the symbol. Meanwhile, the position and length between laser's source and packages can affect scan-ability.

Table 6. Percentage of Problem Barcode Grades on the Scan Reflectance Profile Scale

Grade	ANSI parameter grade (%)		
	Domestic	Imported	Unidentified
A	-	-	-
B	2	-	-
C	10	5	5
D	7	2	-
F	32	32	5
Total	51	39	10
	100		

Table 7 shows the percentage of the grade of problem barcodes which were categorized by their material types. The data shows that barcodes on pressure sensitive label has the highest total percentage of problem barcodes (34%) and the highest percentage of grade F barcodes (29%). Likewise, the barcodes on paper adhesive label have 22% of total problem barcodes and 15% of grade F barcodes. From the result, it was found that the quality of barcode on pressure sensitive label and paper adhesive label have high percentage of poor quality barcodes. The causes of their poor quality were coming from poor printing quality, poor quality of the material (paper) as well as the wrong pattern of barcode such as bad left, right, and center guard. Some of problem barcodes on paper adhesive label have grade C which mean their quality are in the acceptable range but the causes of non-scanning at the first time might come from the environmental factors of the scanners and cashiers' behavior. In addition some of barcodes are truncated which could obstruct the scan-ability of barcode.

The next material type that has significantly high total percentage of problem barcodes is paperboard. The barcodes on paperboard have 15% of total percentage of problem barcodes and 10% of grade F barcode. The causes of poor quality of these barcodes are mostly caused by the wrong pattern of barcode (bad left, right, and center guard) and poor printing quality. There are some problem barcodes on this material that have grade C and B which should be able to scan at the first time, but they were not able to be scanned. The causes of their failure might be the same as the grade C barcode on paper adhesive label:

The problem barcodes on tag (paper) have the total percentage of 12% and the percentage of grade F barcode of 10%. Most of barcodes on this type of material have failed on scan profile because they have bad left, right, and center guard, bad quiet zone, and truncated as well. These factors can have directly effect with the scan-ability of barcodes.

The problem barcodes on plastic bags have 7% of total percentage and grade F barcodes. The main reason for these poor quality barcodes on this material is bad left, right, and center guard of barcodes.

The last 2 material types that have the same total percentage (5%) of problem barcodes are film-overwrap and paperboard in blister pack. Barcodes on film-overwrap have failed the scan profile because of their bad right guard and their wrong location. Some barcodes were printed in the seam area which is restricted for barcode's location since the structure of the barcode might change and might lead to the failure of scanning.

Meanwhile, the failure of first time scanning of barcodes on paperboard in blister pack is come from bad right, left, and center guard of the barcodes.

From all reasons of nonscanable barcodes that are mentioned, the finding indicates that the material itself is not the major factor that leads to the failure of first time scanning barcode. Thus, the main factors are the poor printing quality of the barcodes and the wrong pattern of barcodes. In the next section and Table 8 will compare domestic and imported packages by examining each failure parameter in SRP (Scan Reflection Profile).

Table 7. Percentage of Problem Barcode Grade on Scan Reflectance Profile Scale Which Categorized by their Material Types

Material type	Barcode grade base on ANSI standard					Total
	A	B	C	D	F	
Plastic bag	-	-	-	-	7	7
Paperboard	-	2	2	-	10	14
Film-overwrap	-	-	-	-	5	5
Tag (paper)	-	-	2	-	10	12
Paper adhesive label	-	-	7	-	15	22
Pressure sensitive label	-	-	-	5	29	34
Paperboard in blister pack	-	-	2	-	2	4
Total	-	2	13	5	78	98

After separating the problem barcodes by grade, all items were categorized by the parameters in the scan reflectance profile (SRP). The data in table 8 presents the percentage of barcodes that have fail criteria in pass/fail criteria and have grade F in the 5-point scale. These problem barcodes have failed the ANSI/UCC standard requirement and they were categorized by each parameter.

The first parameter is edge determination or global threshold. The percentage of imported package barcode (34%) is higher than of domestic package barcodes (29%).

According to ANSI/UCC standard, the symbols that failed edge determination are these which were printed with inadequate light spaces and dark bars. From this, it is concluded that the imported package symbols may have higher problems of inadequate printing space between light and dark bars than domestic package symbol. No package barcodes had a grade F in the symbol contrast parameter.

The third parameter is modulation. The percentage of grade F domestic packages (17%) is higher than the percentage of imported packages (10%). Modulation is the comparing measurement of the intensity of narrow spaces to wide spaces. Referring to the definition of modulation in literature review chapter, these data can indicate that the domestic package barcodes might have higher problems with ink spread in the symbol than the imported package barcode.

The next parameter is edge contrast. The percentage of grade F symbols on imported packages is higher than the percentage of grade F symbol of domestic package. This might be concluded that the domestic package symbols may have lower problem with insufficient different contrast between bars and spaces at each edge.

The next parameter is defects. Defects can be divided into 2 types: voids and spots. Voids are light area in the dark area are and spots are dark areas in the spaces. From the Table8, the data shows that the percentage of grade F from defect of domestic packages is lower than the percentage of grade F from this defect on imported package.

A low grade on this defect might be due to insufficient ink (void) or unwanted deposits (spots). The imported packages had been shipped from oversea countries over for a long time and long distance. During transportation, the symbols can be damaged by the reaction between symbol and product itself or environmental factors such as humidity, and product handling. These damages may have effects with the symbol and may decrease the scan-ability of the symbol.

The last parameter is the quiet zone. The quiet zone is the area of light area surrounding a symbol on the left and right edges. If the symbol was printed too close to other printing area on the package, the scanner will not be able to scan since it does not know where the beginning and ending of the symbol. Both domestic and imported packages have the same percentage of symbols that fail the quiet zone criteria (2%).

Table 8. Percentage of Problem Barcode which Categorized by each Parameter in Scan Reflectance Profile

Parameters	Place of manufacturing.	
	Domestic packages (%)	Imported packages (%)
Edge determination or global threshold	29	34
Symbol contrast	0	0
Modulation	17	10
Edge contrast	5	7
Defect	22	24
Quiet zone	2	2

All problem barcodes are categorized by where their material types and SRP parameter Table 9. In the edge determination or global threshold parameter the percentages of grade F barcodes on paperboard, film-overwrap, tag (paper) and paper adhesive label are the same (5%). While the percentage of barcodes on plastic bag that have grade F in this parameter is also low, 7%. From all types of material in this research, problem barcodes on pressure sensitive label (paper) have the highest percentage of barcodes that have failed on edge determination (22%). This can indicate that barcodes on pressure sensitive label were printed with inadequate light spaces and dark bars which might be come from the printers as well as the poor quality of paper itself.

The percentages of barcodes that failed in modulation parameter are as follow: barcodes on plastic bag 2.44%, barcodes on tag (paper) and paper adhesive label 4.88%, barcodes on film-overwrap 4.88%, and barcodes on pressure sensitive label 14.63%. According to the definition of modulation as mention before, it could be concluded that the barcodes on pressure sensitive label have the highest problems with ink spread in the symbol area. The poor quality of paper and improper of choosing the printing process could be the factors that cause the failure. Normally, each type of printer such as thermal, impact dot matrix, ink jet has its own problem and solution. Therefore, the manufacturers should know the technique before printing their barcode. For the barcodes on plastic bag since plastic is not a good absorbent material then ink spread could be easily occurred when the barcodes were printed.

For the barcode that have failed in edge contrast parameter, barcode on film-overwrap and pressure sensitive label have the same percentage which is 5%. And barcodes on paper adhesive label as well as paperboard in blister pack have 2% of barcodes that have failed this parameter. This might be explained that the barcodes that were printed on paper adhesive label and film-overwrap have more problem of insufficient different contrast between bars and spaces at each edge than paper adhesive label and paperboard in blister pack. However, this problem was not found in the other types of material in this experiment.

The next parameter is defect. The percentages of problems that have failed in this parameter are shown as following: paperboard in blister pack 2%, film-overwrap and tag (paper) 5%, plastic bag 7%, barcodes on paperboard and paper adhesive label 10%, and pressure sensitive label 12%. According to the definition of defect in the explanation of Table 6, it could be concluded that barcodes on paper (in both pressure sensitive label and paper adhesive label) have significantly high problem of voids and spots. Besides the poor quality of the printer and low quality of the label paper, sometimes the symbols could be stained the environmental and human factors during the handling and distribution process which could decrease the quality of the barcodes.

There are 2 material types which failed in quiet zone parameter. The first one is tag which has 5% and the second one is paper adhesive label which has 2%. For this parameter, the types of materials are not the reason of the scanning failure of barcode scanning. The failure might be caused by the errors from manufacturers and printing companies who were in charged of printing those barcodes. In addition, the wrong pattern of barcode such as bad right, left and center guard is also the problem that is not depended on the types of material. The data shows that barcode on pressure sensitive label has the highest percentage of wrong pattern barcode (15%). The second high percentage in this parameter is barcodes on paperboard. Besides, barcodes on plastic bag, tag (paper), paper adhesive label, and paperboard in blister pack have the same percentage (5%) of wrong pattern barcode. The last material is film-overwrap which has 2% of wrong pattern barcode. Though, the problem of wrong pattern barcode has nothing to deal with the types of material but it is the major problem that has been found in this experiment. Therefore, this problem should be highly concerned before printing or barcoding the symbol.

Table 9. Percentage of Barcode (Categorized by Their Material Types) that have Failed in Each SRP Parameter

Problem barcodes which categorized by material types and SRP parameter (%)							
Material type	Edge determi-nation	Symbol contrast	Modula-tion	Edge contrast	Defect	Quiet zone	Wrong pattern
Plastic bag	7	-	2	5	7	-	7
Paperboard	5	-	-	-	10	-	7
Film-overwrap	5	-	5	5	5	-	-
Tag (paper)	5	-	5	-	5	5	5
Paper adhesive label	5	-	5	2	10	-	5
Pressure sensitive label (paper)	22	-	15	5	12	-	15
Paperboard in blister pack	-	-	-	-	2	-	5

Visual Inspection of Problem Barcodes Which were not able to be Scanned by the Verifier

From the 65 problem packages, 24 items could not be verified by the verifier due to their very poor quality. After examining all of the items by visual inspection, they were categorized by different errors and problems as shown in table 10 and 11.

Table 10 shows the errors and problems of domestic package barcodes. After inspecting each barcode, it was found that each had more than one error and problems. For instance, from the Table, item No. 2 has the error and problems of wrong pattern and poor printing quality. Item No.5 has problems of wrong color of bar and background and truncated barcode. From the data in table 10, it can summarize that there are five items which have problem and error of the location of barcode. There are 2 items that have bad quiet zone pattern and there are 3 items that have poor printing quality. Errors and problems of color of bar and background have the highest amount of problem symbols which is six. For the errors and problems of wrong pattern, truncated and material itself, there is only one item that was found in each type of error.

Table 10. Errors and Problems of Barcode which cannot Scan by the Verifier in Domestic Package

Item No.	Location of barcode	Bad quiet zone	Wrong pattern	Color of bar and Background	Truncated	Material	Printing Quality
1		X					
2			X				X
3				X			
4	X						X
5				X	X		
6	X			X			
7							X
8	X			X			
9						X	
10				X			
11	X						
12	X	X					
13				X			
Total	5	2	1	6	1	1	3

Table 11. Errors and Problems of Barcode which cannot Scan by the Verifier in Imported Package

Item No.	Location of barcode	Bad quiet zone	Wrong pattern	Color of bar and background	Truncated	Material	Printing quality
1	X						
2			X				
3							X
4							X
5						X	
6					X		X
7		X					
8	X						
9	X	X			X		
10					X		X
Total	3	2	1	0	3	1	4

The data of errors and problems of barcode which cannot verify in imported packages was shown in Table 11. There are 4 package barcodes that have problems of poor printing quality. The amount of errors and problems of location of barcode and truncated is the same (3 items). While the number of problem barcodes with bad quiet zone is 2. There is only one item, with the problems of wrong pattern barcode and material. Likewise, there is no imported package which has problem and error of wrong color of bar and background.

Table 10&11 show the comparison of each problem and errors of barcode which could not verify between domestic and imported package. The amount of the problems and errors of improper location of barcode in domestic package (5 items) is higher than the amount of problems and errors in imported package (3 items). In domestic packages, most of the problem package barcodes are on single cheese packages. The cause of this scanning failure maybe because the barcode is printed in the seam area of the package. Part of the barcode in the seam area could be changed from the original barcode that might lead the failure of scanning. The rest of problem barcodes in this criterion might be caused the wrong direction of barcode. The problem barcode were not printed vertically to the package surface which could affect with the scan-ability of barcode. In imported packages, the problem of improper location is caused by the shape of products. Since the products are small ceramic dolls and glasses in heart shape, it is difficult to find the proper location to attach the barcode label. Thus, the barcode have to be labeled on the products' surface that leads to the failure of barcode scanning.

The second error is bad quiet zones. There are the same amount of problem barcodes (2 items) in both domestic and imported package. Most of them have no quiet zone; the scanners and verifiers cannot find the beginning and the ending of the barcode. For wrong pattern barcodes, there is only one item found in both domestic and imported package. The problem barcodes do not have left, center, and right guards, which are needed in every UPC barcode. It is a critical error that definitely affects the scan-ability of barcode.

There are 6 items that have problems and errors of color of bar and background. All of them are domestic packages. Some of the problem symbols were caused by the color of printing ink (metallic ink) which may decrease contrast between bars and background and decrease scan-ability of barcode. The other problems come from the wrong choice of the colors between bars and the background. Some problem symbols were printed in restricted color such as red bar on yellow background and red-brown bar on brown background. These colors will have negative scan-ability effect.

There is only one domestic package that has the problem of truncated barcode, while there are three imported packages that have truncated problem barcodes. This problem might be resulted from the product's size. Since the size of products is small, then the manufacturers have to shorten the height of barcode in order to fit in the given area. Most of imported barcodes in this criterion, are pressure sensitive label barcodes on the products such as flower and ceramic doll. As well as the problem barcode from domestic package is a candy bar which the barcode had to be shorten to fit in the small size of bar. These truncated barcodes have directly impact on the barcode scan-ability.

The amount of error and problem symbols from material of package is only 2. One of them is a domestic package and another is an imported package. In both types of package, the problem might relate to the reflectance of the material. Because the material is too shiny, then the laser might have reflectance problem with the material that will obstruct the scan-ability of barcode.

The last problem and error is printing quality. There are 3 problem packages from domestic and 4 problem packages from overseas that have printing quality problems. In both domestic and imported packages, the printing quality is very poor. There are a lot of spots, voids, ink spread and burr in the barcode area which is impossible for scanners and verifier to read those barcode.

Chapter 5

Conclusions and Recommendations

From the evaluation of problem packages by their material type, barcodes on paper adhesive labels of domestic packages have the highest problem percentage (15%). Likewise, the highest percentage of problem barcodes on imported packages is 20%, barcodes on pressure sensitive label. The possible causes of the problem of paper adhesive barcode may come from the corroding or dissolving of solvent in adhesive that had an effect on the barcode quality. Meanwhile, the causes of the problem in pressure sensitive label barcodes mainly comes from poor printing quality, and low quality of paper.

After verifying all problem barcodes, it can be concluded that from 65 items, there are 41 items that can scan, and there are24 that cannot scan by the PSC850 verifier. From 41 items that can be verified, the data show that the percentages of grade F barcodes in domestic package and imported package are equal (32%).

The other data received from the verifier are the data of each parameter in the scan reflectance profile. The barcodes that failed in edge determination in imported packages have higher percentage (34%) than the failed in edge determination barcode from domestic packages. It can be summarized that the major cause of problem barcodes is coming from inadequate printing between light spaces and dark bars in the symbol.

The other significant problem is defects. In both domestic and imported packages, the percentages of barcode that failed in defect parameter are quite high. Many problem barcodes failed at the first scanning because of voids and spots in the symbol.

From the barcodes which could not be scanned by the verifier, domestic package barcodes have major problem in wrong color of bar and background. Since the manufacturers have used the restricted colors between bar and background, then these restricted colors can have negative scan-ability effect of barcode scanning. The other essential problem is the problem of improper location of barcode. This failure is caused by not printing the symbol in recommended locations suggested by UPC standard, and instead of printing the symbols in the seam area of the package. In the imported package barcode, the most problem barcodes found was the problem of poor printing quality of barcode. The other important problems are the problem of wrong location of barcode and truncated barcode.

According to the results in this research, the total percentage of problem barcodes from domestic is higher than the total percentage of imported barcodes. This could be summarized that the quality of domestic barcode is poorer than the quality of imported barcode. However, the conclusion might not be a good reference since the total number of the samples is quite small as well as the types of product are not various enough to represent all package barcodes. Furthermore, there may have been more domestic packages in the store.

In the material point of view, it was found that the problem barcodes on paper label including paper adhesive label and pressure sensitive label have the highest percentage of grade D and below barcodes (base on ANSI standard). Their percentages are 22% and 34% respectively and their total percentage is 56%. The main causes of the failure in these materials are poor printing quality, low quality of paper and the wrong pattern of the symbols.

To enhance the conclusion about the material in the previous paragraph, the problem barcodes had been further examined their scan reflection profile. Barcodes on pressure sensitive label have the highest percentage of barcode that have failed in each SRP parameter. The percentages in each parameter of pressure sensitive label are as following: Edge determination 22%, Modulation 15%, Edge contrast 5%, Defect 12% and wrong pattern 15%. All parameters that barcodes on pressure sensitive label have failed depend on the printing of the barcode. Then it could be concluded that the major causes of the failure on this material are due to the poor quality of printing such as voids, spots, ink spread, and insufficient contrast between bars and spaces. Besides, the types of printer that had been used might not be appropriate for the types of materials.

The other interesting cause of scanning failure that was found from this research is coming from attaching the pressure sensitive label on small size products. The manufacturers may decrease this failure by printing barcodes on tags instead of labels.

The problem of wrong color and background might be corrected by using the recommended color from UPC /ANSI standard that is mentioned in Chapter 2. This solution increases the production cost since the manufacturers might have to redesign their packages. However, this could protect the company from the penalty charged by retailers for their poor quality barcode. In the worst case, some retailers will not accept the products that always have high number of problem barcode that will have huge effect with the company.

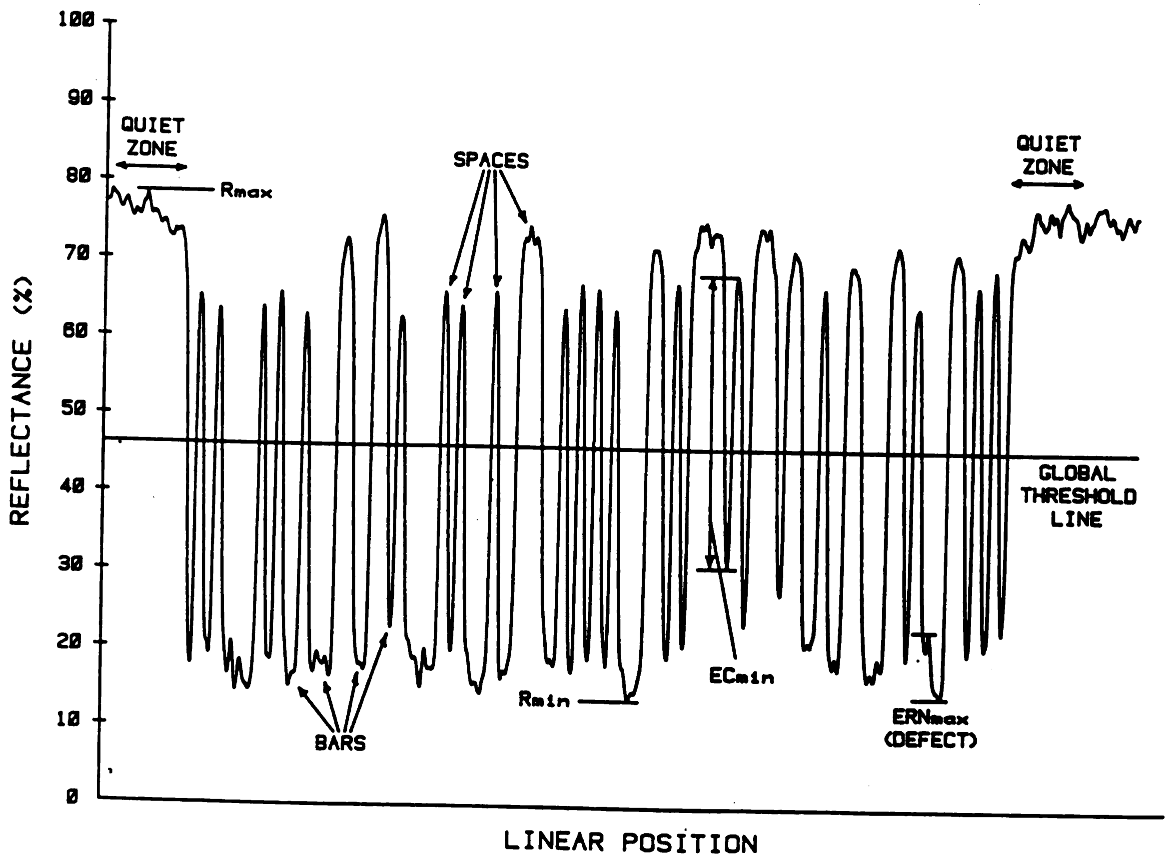
Recommendations

To minimize the failure of first time scanning, there are several recommendations for manufacturers and retailers as following:

- To decrease the problem of poor printing quality, low quality of paper and wrong pattern, the manufacturers should be more selective about how to choose the types of printing process and types of printers for their labels.
- Try to print barcodes on tags in stead of labels on the small size products in order to avoid the difficulty of scanning due to the surface and figure of products themselves.
- Use the recommended color from UPC/ANSI standard for the barcodes and their background.
- The manufacturers and retailers should keep examining their barcodes' quality. When the problems occur, they should not hesitate to contact each other and try to solve the problem.
- Setting the seminars between the manufacturers and the retailers is highly recommended in order to provide recent knowledge to each other.
- Finally, to do more research of scanning problem could be one of the methods that can decrease the problems.

APPENDIX A

Scan Reflectance Profile with Features Detailed



*** Quick-Check 850 ***

660 nm, 06 mil Scanner

UPC-A: 100% Mag. Factor

0-2410012138-0

AvgBar = -.02 X OK!
Decodablty= 70% <A>   Symbol Totals 095 X

PCS = 98% OK!   R(L)=76% OK!   R(D)=00% OK!
SymbolContr=76% <A>   R(mn)/R(mx)=00% <A>
Modulation= 68% <B>   EdgeCtr(mn)=52% <A>
"Defects" = 22% <C>

Msg Length = 11 OK!   ModCheck Passes OK!

Bar Growth: IN TOL
"P C S" : OK
Traditional Tests -PASS-
Format Tests -PASS-

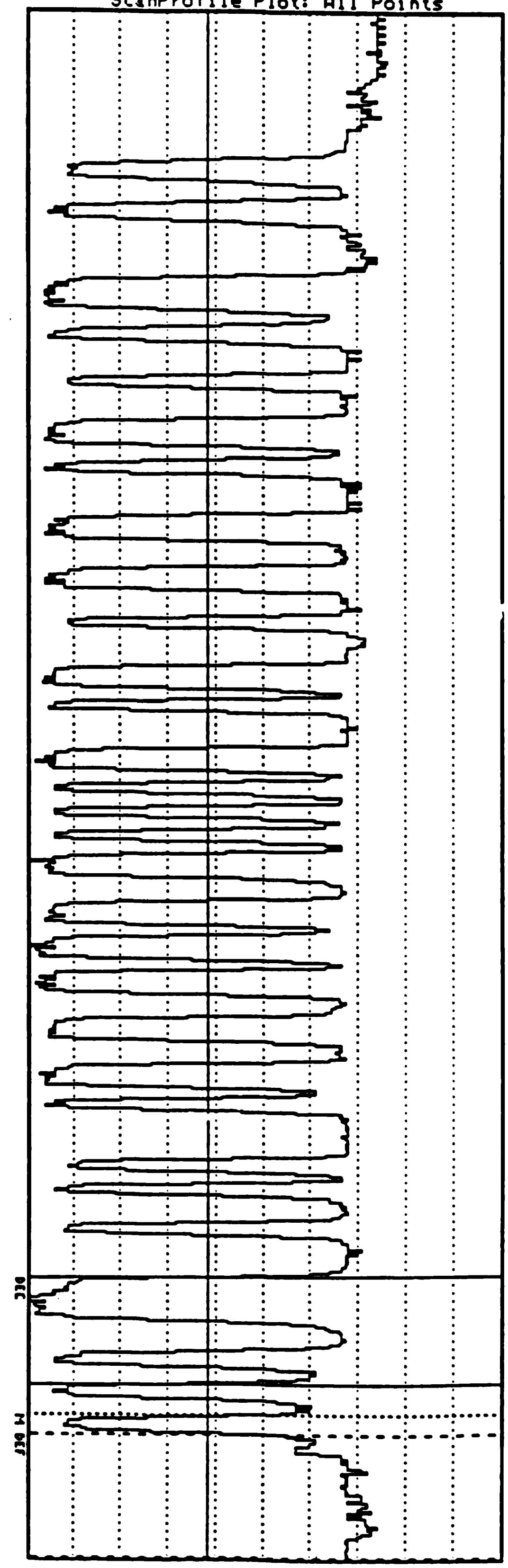
ANSI Parameters: <C>
Add'l P/F Checks: <P>
Format Checks: <P>
Profile Quality Grade is <C>

Passing = ANSI <C> ==> ScanProfile PASSES

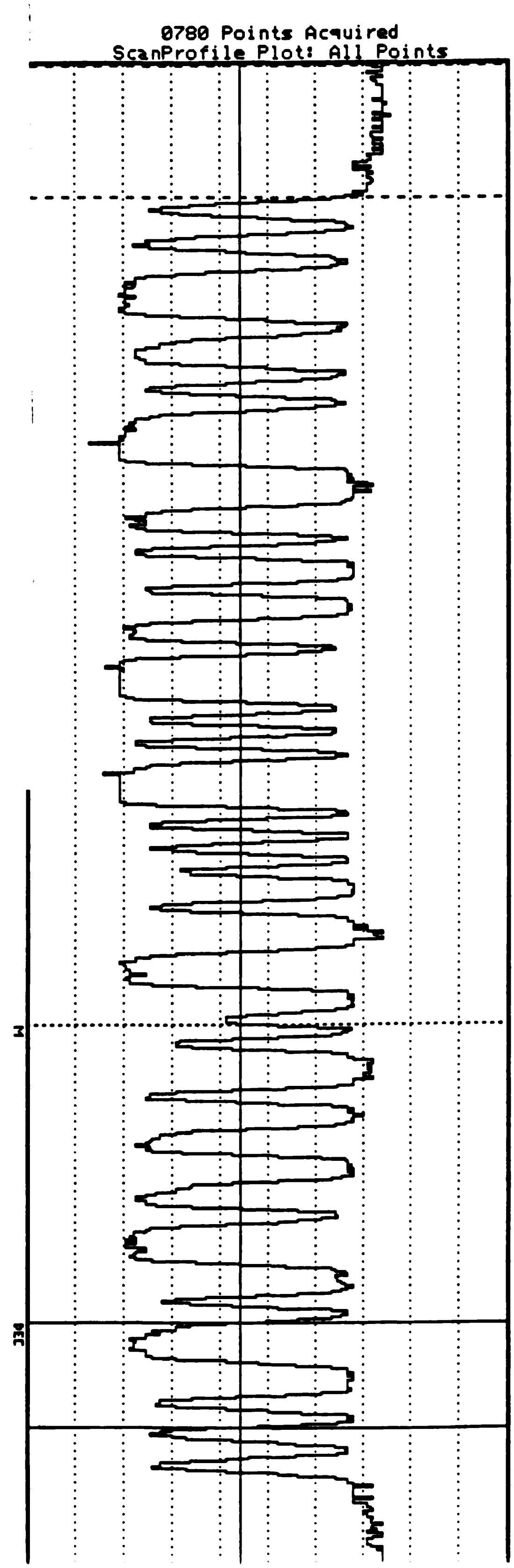
****
* Symbol Grade: Avg. 3.0 => B/06/660*
*   After 003 of 010 Scans*
****

Name: ______________ Date: __________

0783 Points Acquired
ScanProfile Plot: All Points



```
* Quick-Check 850 *
660 nm, 06 mil Scanner
UPC-A: 100% Mag. Factor
7-6023680710-0

AvgBar = -.10 X OK!
Decodablty= 54% <B>     Symbol Totals 095 X

PCS = 82% OK!   R(L)=76% OK!  R(D)=12% OK!
SymbolContr=64% <B>     R(mn)/R(mx)=17% <A>
Modulation= 41% <D>     EdgeCtr(mn)=26% <A>
            "Defects" = 11% <A>

Msg Length = 11 OK!     ModCheck Passes OK!

          Bar Growth: IN TOL
           "P C S" : OK
       Traditional Tests -PASS-
          Format Tests -PASS-

         ANSI Parameters: <D>
        Add'l P/F Checks: <P>
           Format Checks: <P>
      Profile Quality Grade is <D>

Passing = ANSI <C>  ==> ScanProfile FAILS

******************************************
*   Symbol Grade:    Avg. 1.0 => D/06/660*
*                  After 001 of 010 Scans*
******************************************

Name: _________________ Date: __________
```



*** Quick-Check 850 ***

660 nm, 06 mil Scanner

UPC-A: 100% Mag. Factor

0-4431941830-9

AvgBar = +.47 X HI!
GlobThrs Fails <F>   Symbol Totals 095 X
Pattern Error: BAD Left Guard Pattern
Pattern Error: BAD Center Guard Patrn
Pattern Error: BAD Right Guard Pattrn

PCS = 94% OK!   R(L)=78% OK!   R(D)=03% OK!
SymbolContr=75% <A>   R(mn)/R(mx)=05% <A>
Modulation= 46% <D>   EdgeCtr(mn)=34% <A>
"Defects" = 48% <F>

Msg Length = 11 OK!   ModCheck Passes OK!

Bar Growth: OUT (+)
"P C S" : OK
Traditional Tests -FAIL-
Format Tests -PASS-

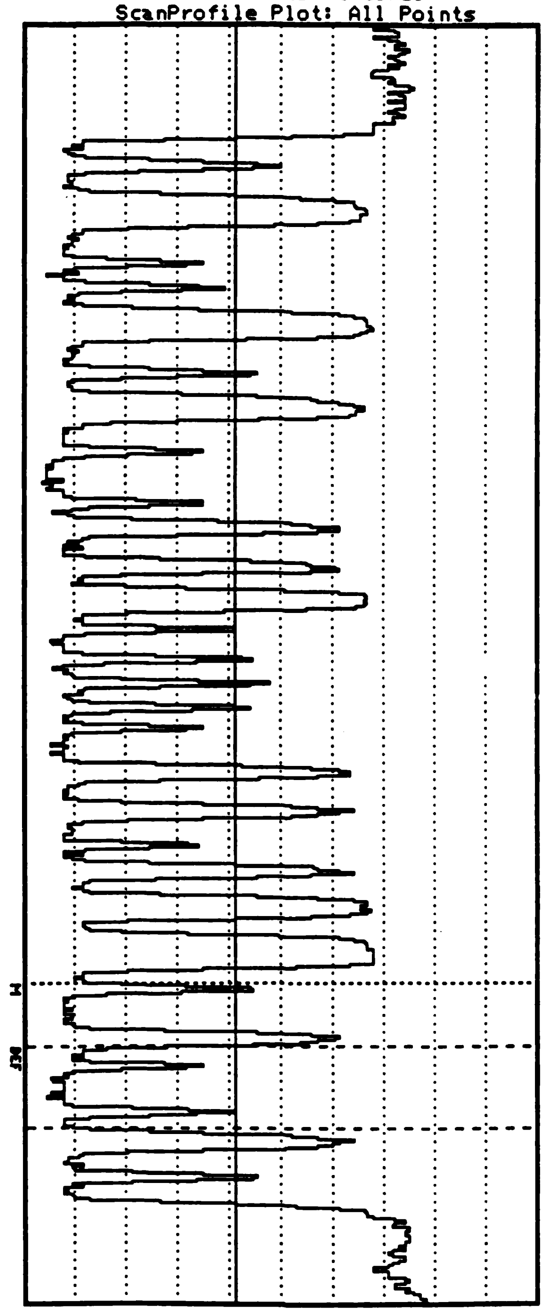
ANSI Parameters: <F>
Add'l P/F Checks: <F>
Format Checks: <P>
Profile Quality Grade is <F>

Passing = ANSI <C>   ==> ScanProfile FAILS

****
* Symbol Grade: Avg. 0.0 => F/06/660*
*   After 001 of 010 Scans*
****

Name: ________________ Date: __________

0605 Points Acquired
ScanProfile Plot: All Points



* Quick—Check 850 *

660 nm, 06 mil Scanner

UPC-A: 100% Mag. Factor

0-2000002103-2

AvgBar = -.19 X OK-
GlobThrs Fails <F>   Symbol Totals 095 X

PCS = 98% OK!   R(L)=84% OK!   R(D)=00% OK!
SymbolContr=84% <A>   R(mn)/R(mx)=00% <A>
Modulation= 01% <F>   EdgeCtr(mn)=01% <F>
"Defects" = 48% <F>

Msg Length = 11 OK!   ModCheck Fails BAD
Format Error: BAD Symbol Check Chr

Bar Growth: IN TOL(-)
"P C S" : OK
Traditional Tests -PASS-
Format Tests -FAIL-

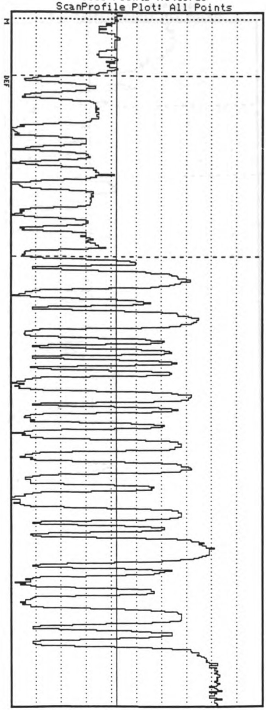
ANSI Parameters: <F>
Add'l P/F Checks: <P>
Format Checks: <F>
Profile Quality Grade is <F>

Passing = ANSI <C> ==> ScanProfile FAILS

****
*   Symbol Grade: Avg. 0.0 => F/06/660*
*   After 001 of 010 Scans*
****

Name: ________________ Date: __________

0665 Points Acquired
ScanProfile Plot: All Points



* Quick—Check 850 *

660 nm, 06 mil Scanner

UPC-A: 100% Mag. Factor

7-6023602709-6

AvgBar = +.12 X OK!
GlobThrs Fails <F>   Symbol Totals 095 X
Pattern Error: BAD Left Guard Pattern
Pattern Error: BAD Center Guard Patrn
Pattern Error: BAD Right Guard Pattrn

PCS = 99% OK!   R(L)=68% OK!   R(D)=00% OK!
SymbolContr=68% <B>   R(mn)/R(mx)=00% <A>
Modulation= 40% <D>   EdgeCtr(mn)=27% <A>
"Defects" = 50% <F>

Msg Length = 11 OK!   ModCheck Passes OK!

Bar Growth: IN TOL
"P C S" : OK
Traditional Tests -FAIL-
Format Tests -PASS-

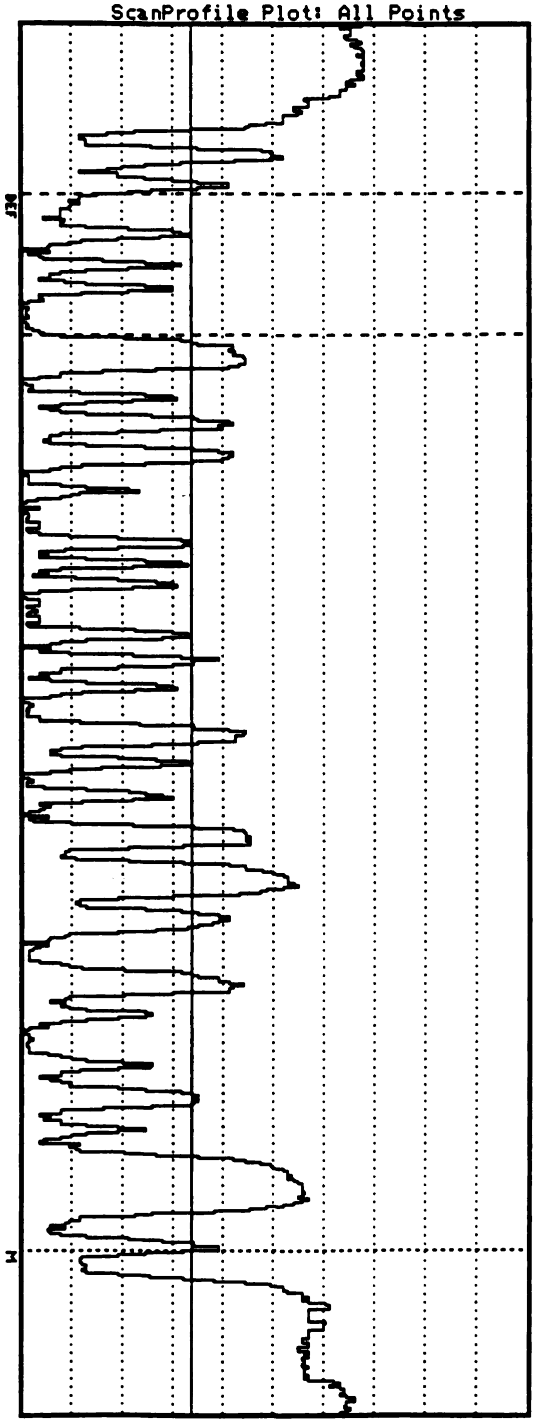
ANSI Parameters: <F>
Add'l P/F Checks: <F>
Format Checks: <P>
Profile Quality Grade is <F>

Passing = ANSI <C> ==> ScanProfile FAILS

****
*   Symbol Grade: Avg. 0.0 => F/06/660*
*   After 001 of 010 Scans*
****

Name: _________________ Date: __________

0662 Points Acquired
ScanProfile Plot: All Points



* Quick-Check 850 *

660 nm, 06 mil Scanner

UPC-E: 100% Mag. Factor

0-755955-6 (0-7559500005-6)

AvgBar = -.02 X OK!
Decodablty= 41% <C>   Symbol Total= 051 X

PCS = 98% OK!   R(L)=79% OK!   R(D)=00% OK!
SymbolContr=79% <A>   R(mn)/R(mx)=00% <A>
Modulation= 57% <C>   EdgeCtr(mn)=45% <A>
"Defects" = 12% <A>

Msg Length = 06 OK!   ModCheck Passes OK!

Bar Growth: IN TOL
"P C S" : OK
Traditional Tests -PASS-
Format Tests -PASS-

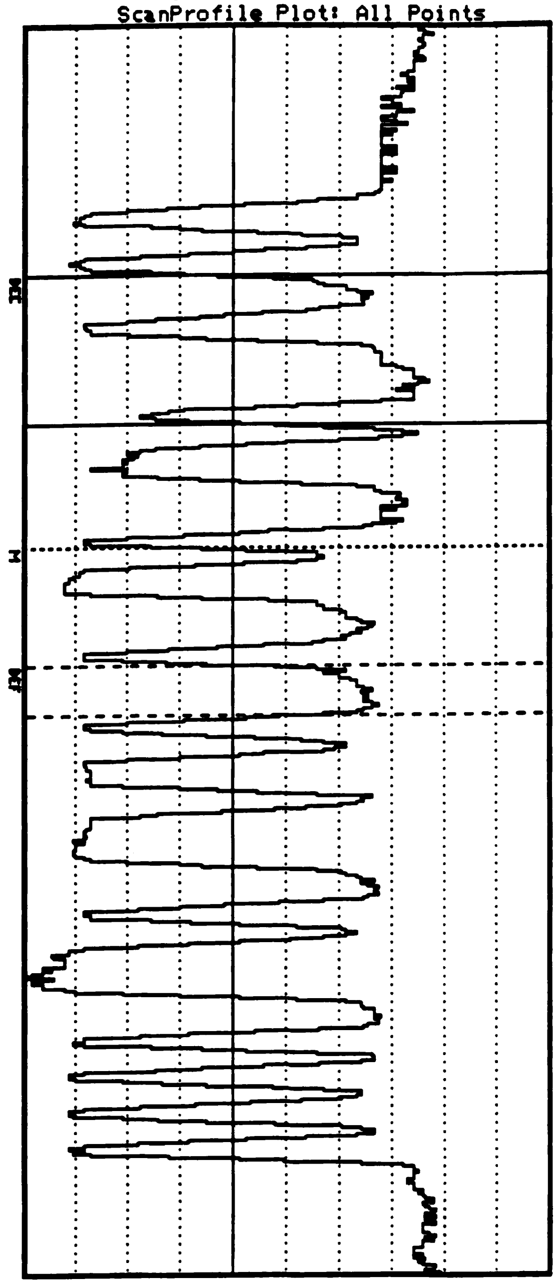
ANSI Parameters: <C>
Add'l P/F Checks: <P>
Format Checks: <P>
Profile Quality Grade is <C>

Passing = ANSI <C> ==> ScanProfile PASSES

****
*   Symbol Grade: Avg. 2.0 => C/06/660*
*   After 001 of 010 Scans*
****

Name: ________________ Date: __________

0579 Points Acquired
ScanProfile Plot: All Points



*** Quick-Check 850 ***

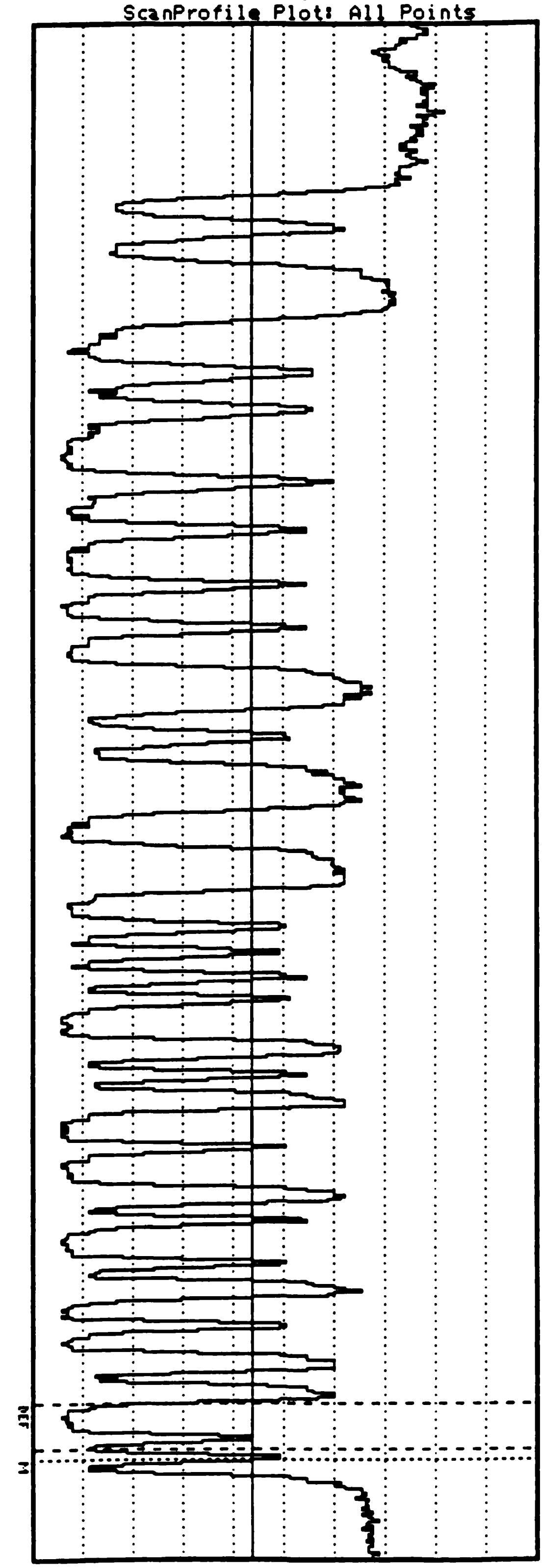
660 nm, 06 mil Scanner

UPC-A: 100% Mag. Factor

0-7754005092-5

```
AvgBar = +.09 X OK!
GlobThrs Fails  <F>    Symbol Totals 095 X

PCS = 92% OK!   R(L)=82% OK!  R(D)=05% OK!
SymbolContr=77% <A>    R(mn)/R(mx)=07% <A>
Modulation= 50% <C>    EdgeCtr(mn)=37% <A>
           "Defects" = 50% <F>

Msg Length = 11 OK!    ModCheck Passes OK!

            Bar Growth: IN TOL
              "P C S" : OK
         Traditional Tests -PASS-
            Format Tests -PASS-

           ANSI Parameters: <F>
          Add'l P/F Checks: <P>
             Format Checks: <P>
       Profile Quality Grade is <F>

Passing = ANSI <C>  ==> ScanProfile FAILS

*******************************************
*   Symbol Grade:    Avg. 0.0 => F/06/660*
*                  After 002 of 010 Scans*
*******************************************

Name: _________________ Date: __________
```

0744 Points Acquired
ScanProfile Plot: All Points



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