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Automatic Ammunition Identification Technology Test Report for the Datamatrix and Code 49 Symbologies

B. S. Weil

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AUTOMATIC AMMUNITION IDENTIFICATION TECHNOLOGY TEST REPORT FOR THE DATAMATRIX AND CODE 49 SYMBOLOGIES

B. S. Weil
Robotics & Process Systems Division

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ABSTRACT

A series of tests was conducted to evaluate the two-dimensional bar codes called Datamatrix and Code 49. Two-dimensional bar codes are being considered for use in ammunition logistics systems and automated reloading equipment. For this reason, the purpose of these evaluations was to determine the capabilities and limitations of the existing symbology and decoding hardware as they pertain to the diverse and harsh field environments in which they may be used for ammunition identification. The tests conducted and their results are presented in this report.

1. INTRODUCTION

The Automatic Ammunition Identification Technology (AAIT) Project is an activity of the Robotics & Process Systems Division at the Oak Ridge National Laboratory (ORNL) for the U.S. Army's Project Manager–Ammunition Logistics at the Armament Research Development Engineering Center at the Picatinny Arsenal in New Jersey. The project objective is to evaluate new two-dimensional bar code symbologies for potential use in ammunition logistics systems and automated reloading equipment.

The benefits of bar coding technology have been widely demonstrated in the manufacturing and distribution industries. Symbols can be applied directly to items or material to permit automatic handling. Since bar codes can be quickly scanned and interpreted with fixed or portable equipment, bar codes can be used anywhere, perhaps even on the battlefield. Two-dimensional symbologies have recently been developed by the automatic identification industry. These new symbologies have higher character capacities and are more space efficient than older linear bar codes. They are a durable and inexpensive way to encode considerable amounts of information in a relatively small area. Their maximum data capacities range from 49 to over 2000 characters per symbol, and they can encode alphabetic, numeric, mixed alphanumeric, or ASCII characters.

These new symbologies are being considered for their improved reliability and information capacity. These compressed data symbologies are expected to significantly improve logistics and inventory management tasks and to permit automated feeding and handling of ammunition to weapon systems. The results will be (1) increased throughput capability, (2) improved inventory control, (3) fewer human errors, (4) lower operation and support costs, and (5) a quicker resupply of various weapon systems.

Two-dimensional symbologies can be divided into three classes of compressed data symbols: stacked bar codes, matrix codes, and portable data files. A symbology from each class of two-dimensional bar codes was selected for evaluation testing. The selection was based upon printer and decoder support currently available for each symbology. Datamatrix was selected to represent matrix codes, and Code 49 was selected to represent stacked bar codes. The only portable data file symbology available in the public domain is PDF417. This report describes the testing and results obtained for Datamatrix and Code 49.

2. DATAMATRIX EVALUATION TESTS

2.1 SYMBOLOGY DESCRIPTION

Datamatrix is a two-dimensional symbology developed by International Data Matrix, Inc. (ID Matrix), in Clearwater, Florida. It was first introduced in 1987 as a proprietary symbology, but in 1992 it was submitted for use in the public domain. A Datamatrix symbol can contain from 1 to 2000 alphabetic, numeric, mixed alphanumeric, or ASCII characters. Symbol size is directly dependent on the marking method, the type and quantity of characters encoded, and the level of overhead required for any optional error correction. Symbols have been produced that range in size from 0.001 to 14 in. square. The optional error correction feature of the symbol allows a scanner to recover information from degraded or damaged symbols. Data within a symbol can also be encrypted for information security.

Datamatrix is described in a patent as a machine-readable binary code that is dynamically variable in size, format, and density of information.[1] The binary code is formed as a matrix having a perimeter border and data contained therein. The border is provided with indices for indicating the density of the data contained within the matrix. The border also provides bars for indicating the size of the matrix. By using the size bars and density indices, a scanning device can calculate the size and density of the binary code. Figure 2.1 shows examples of the Datamatrix symbols used for testing.

2.2 EVALUATION OF EQUIPMENT AND SOFTWARE

Omni-directional symbols, like Datamatrix, can be scanned and decoded in any orientation. The only scanner currently supported by ID Matrix for capturing Datamatrix symbols is an RS-170-compatible charged coupled device (CCD) television camera. ID Matrix is developing a hand-held CCD scanner but has not yet announced a release date. The decoder tested at ORNL was a Model 102S-2F single-camera unit, but models are available that support up to three cameras. A 9600-baud serial communication port is provided on the decoder to interface with an appropriate controller. A general purpose input/output port is also provided to interface with external trigger sources. The controller used for all evaluation tests was an 80286-based computer with an 8-MHz clock speed. The operating system used was MS-DOS. Data were automatically acquired using the ASYST data acquisition language from Keithley Instruments, Inc., in Taunton, Massachusetts.

The scanning system for Datamatrix is very versatile due to the programmable features of the decoder and available status report commands. The system can automatically decode any valid Datamatrix symbol which is properly focused, positioned, and magnified. Special tuning commands are provided to compensate for symbol contrast, inverse images, and surrounding image clutter. In addition, hint commands for the character set, the error correction level, the total character count, and the matrix density for a symbol, can be given to the decoder. These hints decrease the decode time since the decoder does not derive these hinted values directly from the

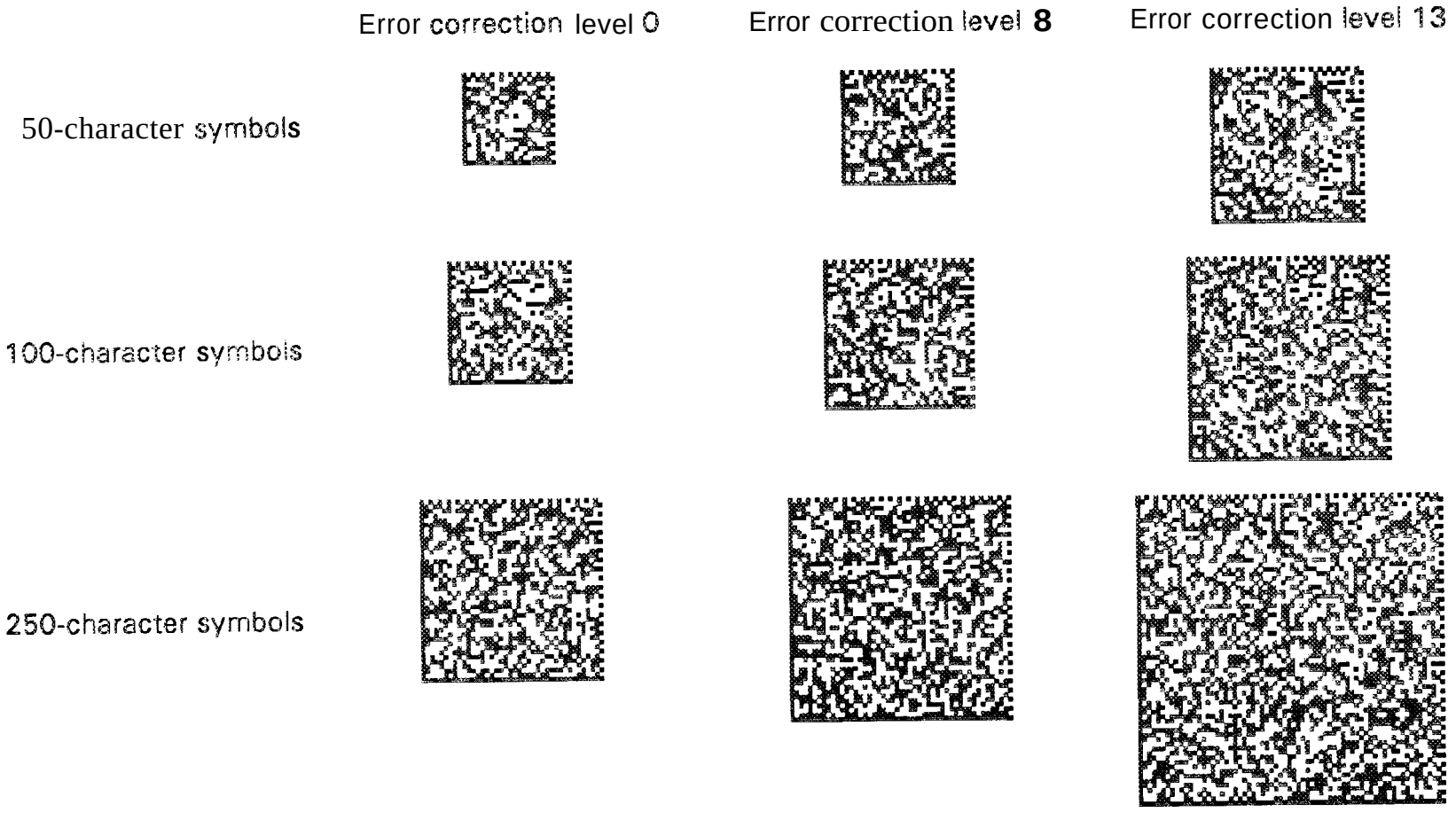

Fig. 2.1. Examples of Datamatrix test symbols.

symbol. In addition, the status conditions of the last symbol processed can be requested from the decoder. This feature was used by the data acquisition controller during the evaluation tests.

The standard equipment setup for all tests in this evaluation is described in Table 2.1. Unless specified otherwise in the description of the test, this standard setup remained constant for each test. The scanning sensor, a Pulnix TM-7CN camera, was operated in its highest resolution mode. A Tamron 25-mm 1:1.6 lens with a 1.5-mm extension tube was attached to the camera and provided a field of view approximately 76 mm (3 in.) wide by 50 mm (2 in.) high. An aperture setting of f11 was used to provide a good field depth. All test symbols were printed on white pearlescent polyester self-adhesive lables using a 300-dots/in. Zebra Model Z91 thermal transfer printer. The uppercase mixed alphanumeric character set (format 3) with five punctuation characters was used for all symbols.

Table 2.1. Standard Datamatrix evaluation test conditions

Scanning sensor	Pulnix 7CN CCD camera, high-resolution mode 768 (h) by 480 (v)
Shutter speed	1/60 s, automatic gain active
Scanner tilt angle	0° from the surface normal
Optical system	Tamron 25-mm 1:1.6 lens with 1.5-mm extension tube, f11 aperture, field of view 76 mm wide by 50 mm high, camera distance ~34 cm
Lighting	Standard office levels (~1000 lx) measure by light meter
Decoder setup	Black-to-white cutoff at 500
Printing technology	Zebra Model Z91 thermal transfer printer (300 dots/in.)
Label material	Zebra Z-Ultimate 5A white pearlescent polyester
Character set	Uppercase mixed alphanumerics with five punctuation characters (space, comma, slash, period, and minus)

2.3 EXPERIMENTAL APPROACH

A two-phase test plan was developed to determine the capabilities and limitations of the Datamatrix system. The first phase evaluated, using high-quality symbols, system variables such as symbol size, scanner tilt angle, substrate curvature, symbol motion, and symbol contrast. The second phase evaluated the effects of symbol degradation. Degradation was created by photocopy and facsimile duplication, smoke obstruction, blowing sand abrasion, and random corruption.

Scanning and decoding a symbology is essentially a "go or no-go" process. During a test event, the system will either render valid information and signal the user or it will reject the symbol. A single test event is defined as a single triggered request and the resulting pass or fail response. The tendency to successfully read is called the pass rate, and it is usually reported as a percentage. Statistically, if 100 successful events are observed out of 100 attempts, then the true pass rate response at the 95% confidence level is greater than 97%. For all evaluation tests in this report, the recorded values are the number of successfully decoded events out of 100 attempts. These tests were not intended to estimate the absolute pass rate response for each set of conditions but to indicate only the general effect of a changed condition.

Appendix A provides a description of each test symbol in the evaluation. Three error correction levels (levels 0, 8, and 13) were tested. Four cell sizes (0.0200, 0.0233, 0.0266, and 0.030 in.) were used for each error correction level, and four message lengths (50, 100, 250, and 500 characters) were selected for each cell size. In total, there were 48 Datamatrix symbol specimens printed for testing.

2.4 GENERAL EXPERIMENTAL SETUP

A professional photographic copy stand with four flood lamps was used to maintain constant camera and lighting conditions during each evaluation test. The CCD camera scanner was attached to the copy stand camera support. Light level was measured by a Minolta hand-held light meter, and flood lamp power was controlled by a Variac transformer. Figure 2.2 shows the general test setup.

Before the cell size and scanner tilt evaluation tests, test symbols were attached to plastic plates and stacked near a computer controlled turntable. During a test each plate, in turn, was removed from the top of the stack and placed onto the turntable by a programmable robot. For each symbol, 100 test events were performed. Between each test event, the turntable was rotated 3.6°. After a symbol plate completed the evaluation, the programmable robot removed the old plate and positioned a new plate on the turntable. This automated testing equipment was very cost efficient and allowed repeat testing without adverse effect on the total program schedule.

During a symbol test, the data acquisition computer downloaded read status information from the Datamatrix decoder after each test event. The computer formatted a data file record from the known test symbol characteristics and read status data. All data records were archived to a permanent text file and then converted to a Lotus 1-2-3 data spreadsheet. All charts and results in this report were prepared from these data spreadsheets.

2.5 DIGITIZED CELL SIZE TEST

The main purpose of this test was to determine what effect digitized cell size has on the tendency to successfully read a symbol. Additional objectives for this test were to determine what effects error correction level and message length have on the pass rate response. The digitized cell size is defined as the minimum side dimension of a single (black or white) cell in a digitized image of a Datamatrix symbol. For a fixed optical system, we expected that the pass rate could be improved by increasing the cell size of printed symbols. However, the critical requirement for any optical system is the actual digital cell size of the scanned image (i.e., when a symbol is scanned by a camera, how many pixels must a single matrix cell trigger, either black or white, to optimize the pass rate response). ID Matrix recommends either optics or symbols be used to create a 5- by 5-pixel image in the camera for each Datamatrix cell in the printed symbol. For conditions described in Table 2.1, Fig. 2.3 shows that test symbols printed with 0.026- and 0.030-in. matrix cells meet or exceed the manufacturer's 5- by 5-pixel array recommendation, while the other test symbols fall below the minimum requirement. The cosine shape of the curves in Fig. 2.3 is a result of the rectangular pixels in the Pulnix CCD camera. Figure 2.4 illustrates the pixel array for a single binary cell in the CCD camera for each printed cell size.

Two test series, with and without hints given to the decoder, were performed to evaluate cell size. The black/white cut-off control in the Datamatrix decoder was set at 500 for both tests. The black/white cutoff represents a contrast discrimination level which the decoder uses to distinguish black and white binary colors from shades of gray in the CCD camera. Only symbols smaller than 2 in. were used for these tests since larger symbols could not totally remain within camera view during rotation. The results of the first test series, without symbol hints provided, are presented in Table 2.2.

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Fig. 2.2. General test setup.

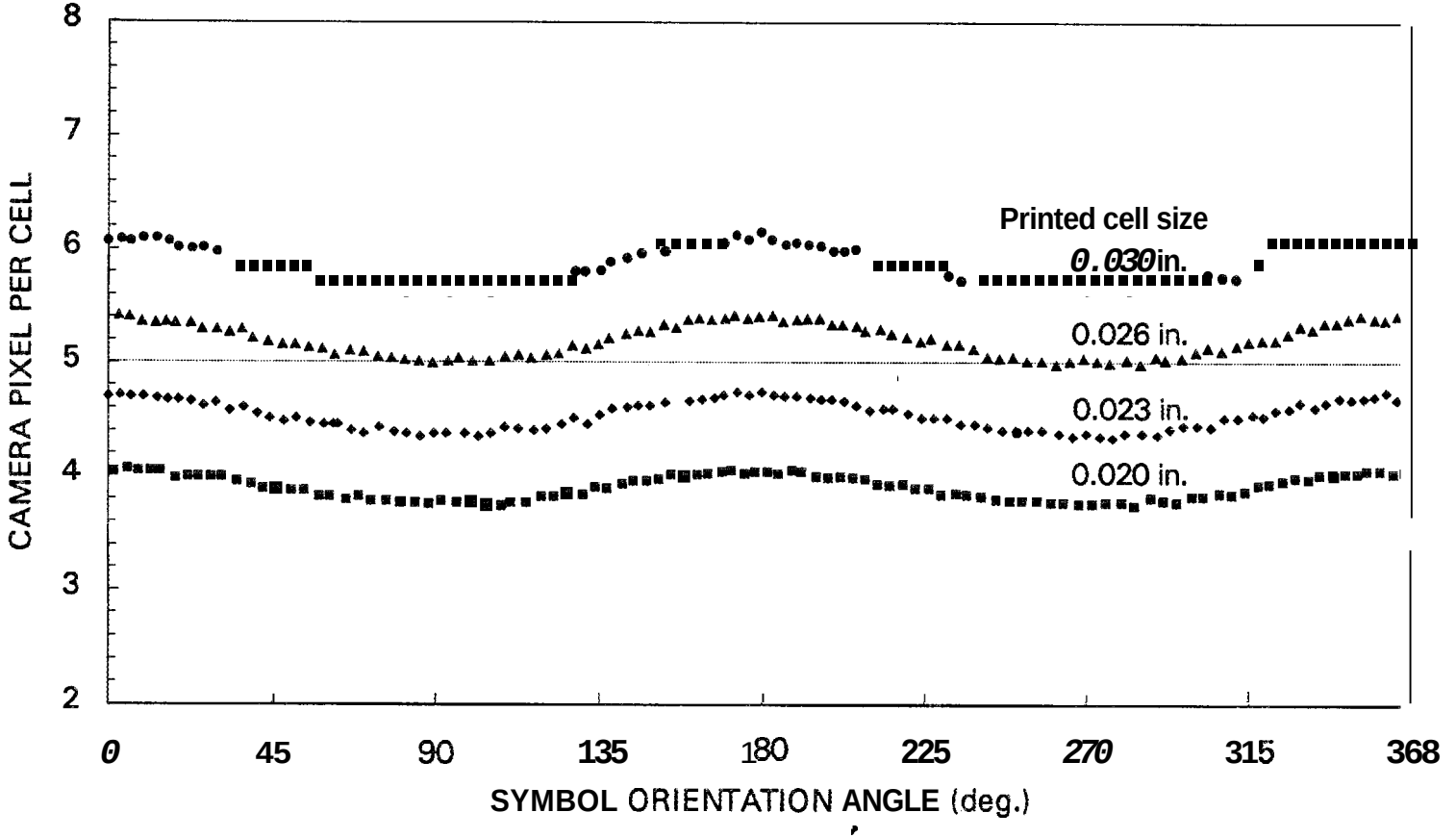


Fig. 23. Cell dimensions in pixels for digitized Datamatrix symbols with different printed cell sizes.

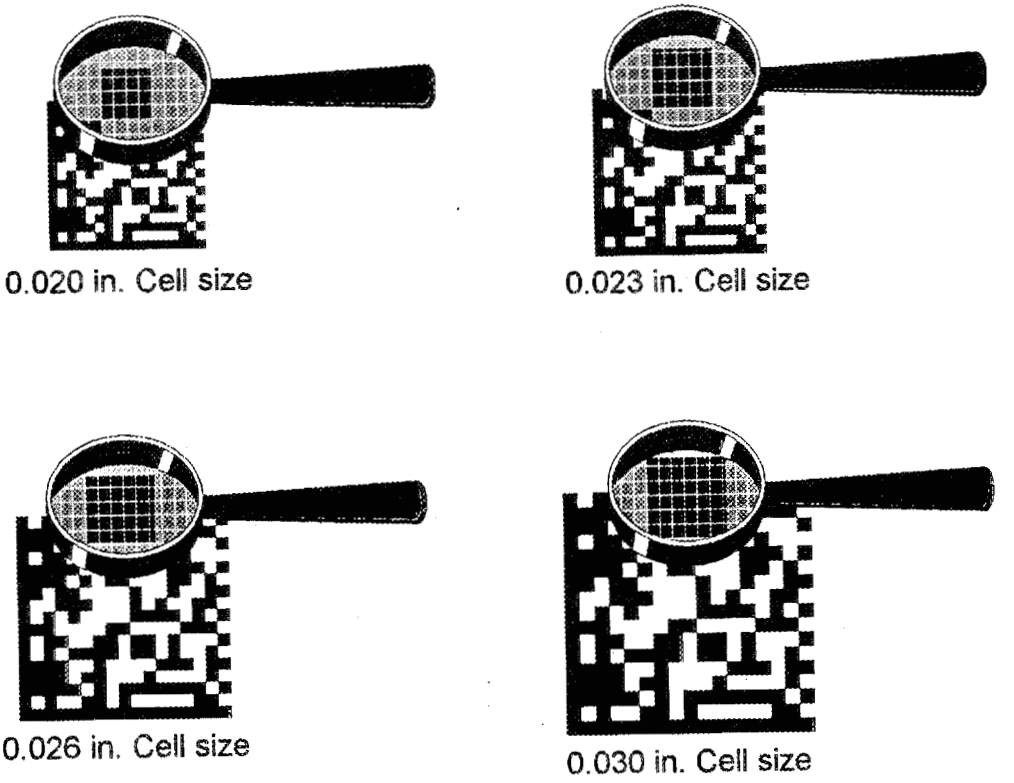


Fig. 2.4. Pixel array images for the Datamatrix test symbols.

The results from the first test series indicate that without error correction, the pass rate improves (as expected) for increasing image cell size. The same results also show that the pass rate decreases as the message length increases for a symbol without error correction (see Fig. 2.5).

When error correction is introduced, symbols with digitized cell sizes just below the manufacturer's specification have improved pass rates (see Figs. 2.6 and 2.7). However, the highest error correction tested (level 13) did not provide the best pass rate response. One explanation for this observation could be that the additional overhead required for higher error correction has a diminishing return as error correction increases.

The low pass rates in Figs. 2.6 and 2.7 were unexpected for messages of 250 characters using error correction level 8. After investigation, ID Matrix discovered that the decoder software could not reliably determine symbol densities automatically above a 25- by 25-matrix cell. The software has been revised to correct this problem, but the revision was not available in time to repeat tests for this report. Therefore, a second series of tests were executed which provided hints for symbol density, error correction, the character set used, and message length. In a closed system, such as in AAIT applications, use of these hints would not be considered limitations.

The results of the second test series, with symbol hints provided, are presented in Table 2.3. The results from the second test series reconfirms that the pass rate improves for increasing image cell size (see Fig. 2.8).

A comparison of Figs. 2.5 and 2.8 also indicates that providing decoder hints improves the pass rate. The second test series results also reconfirm that the pass rate decreases as the message length increases for a symbol without error correction.

Table 2.2. Pass rate results during the Datamatrix cell size test without system hints provided

Characters	ECC level	Cell size (in.) 0.020	0.023	0.026	0.030
50	0	82	94	100	100
	8	99	99	99	100
	13	91	98	99	99
100	0	71	96	99	100
	8	93	97	100	99
	13	87	85	98	100
250	0	51	92	97	100
	8	10	48	64	82
	13	51	83		
500	0	30	74	88	92
	8	74	96		
	13				

When both error correction and decoder hints were introduced during the second test series, symbols with digitized cell sizes below the manufacturer's specification had better pass rates than the first test series (see Figs. 2.9 and 2.10).

Several determinations were made by the cell size tests just described. Test results verified a manufacturer's recommendation that either optics or printed symbol size must create a video image large enough to cover a minimum area of 5 by 5 camera pixels for each printed symbol cell, either black or white. Test results also verified that error correction can improve the Datamatrix scanner's tendency to read. Without error correction, the pass rate declines as the message length increases. This is probably due to the increasing chances of a binary color error occurring as the matrix dimensions (density) of the symbol increase. Additionally, the tests showed that providing decoder hints for the data length, character set, error correction level, and symbol density improves the decode success rate. The tests also verified that the Datamatrix decoding system has omni-directional reading capability.

2.6 SCANNER SKEW ANGLE TEST

Since the ID Matrix decoding system has omni-directional reading capability, we expected that the pass rate might be affected by the scanner skew angle. Therefore, a test was designed to determine the sensitivity of the pass rate response to changes of the skew angle. The skew angle is defined as the angle between a line normal to the surface of the symbol and the line of sight to the scanner. To compare pass rates with the cell size test, angles of 30 and 45° were tested while providing decode hints to the system. The twelve 100-character symbols from the previous test were selected for this test. Except for skew angle changes, the procedure for this test was identical to the cell size test. The test results are shown in Table 2.4.

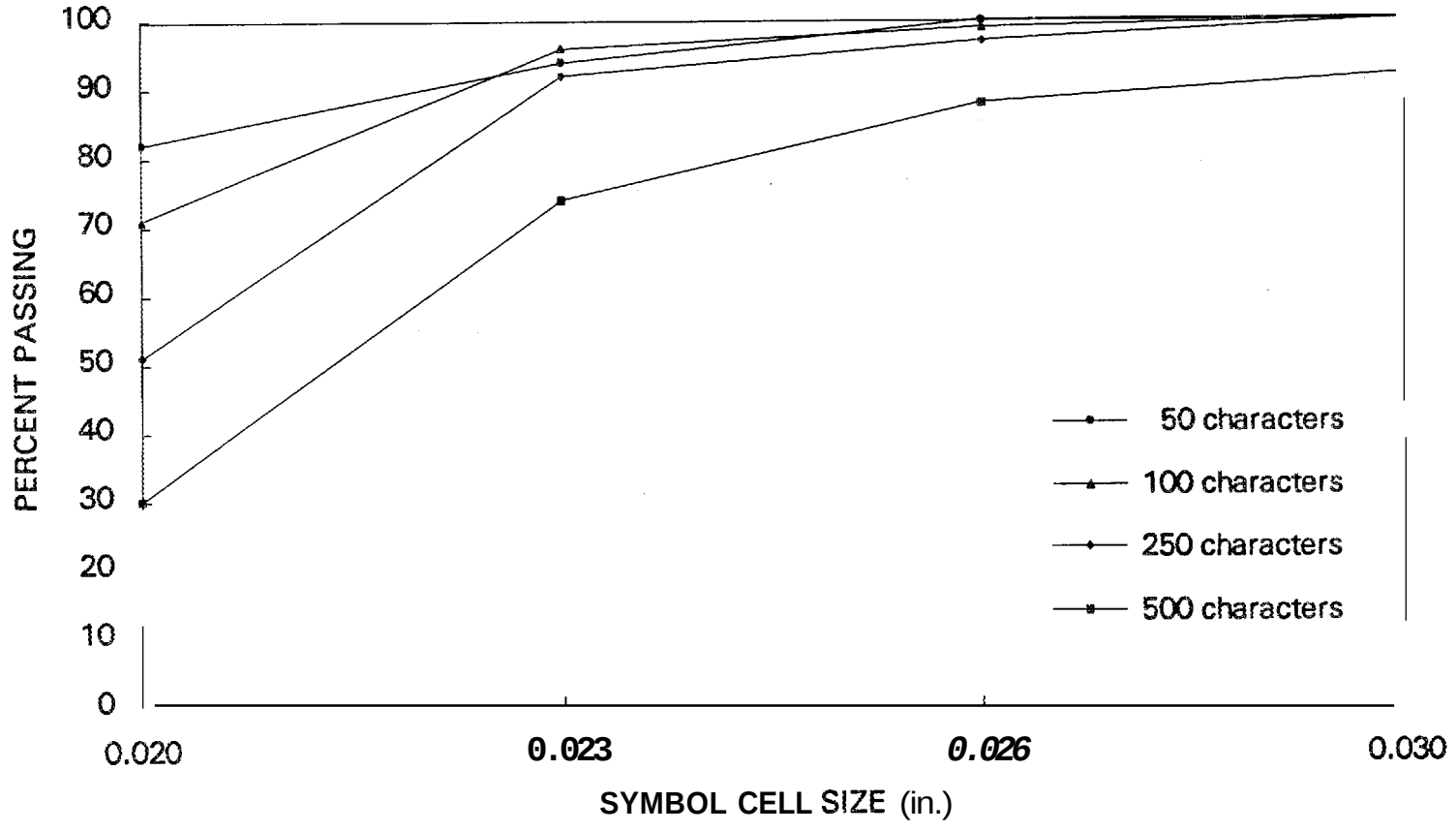


Fig. 2.5. Pass rate results for Datamatrix symbols without error correction or decoder hints provided.

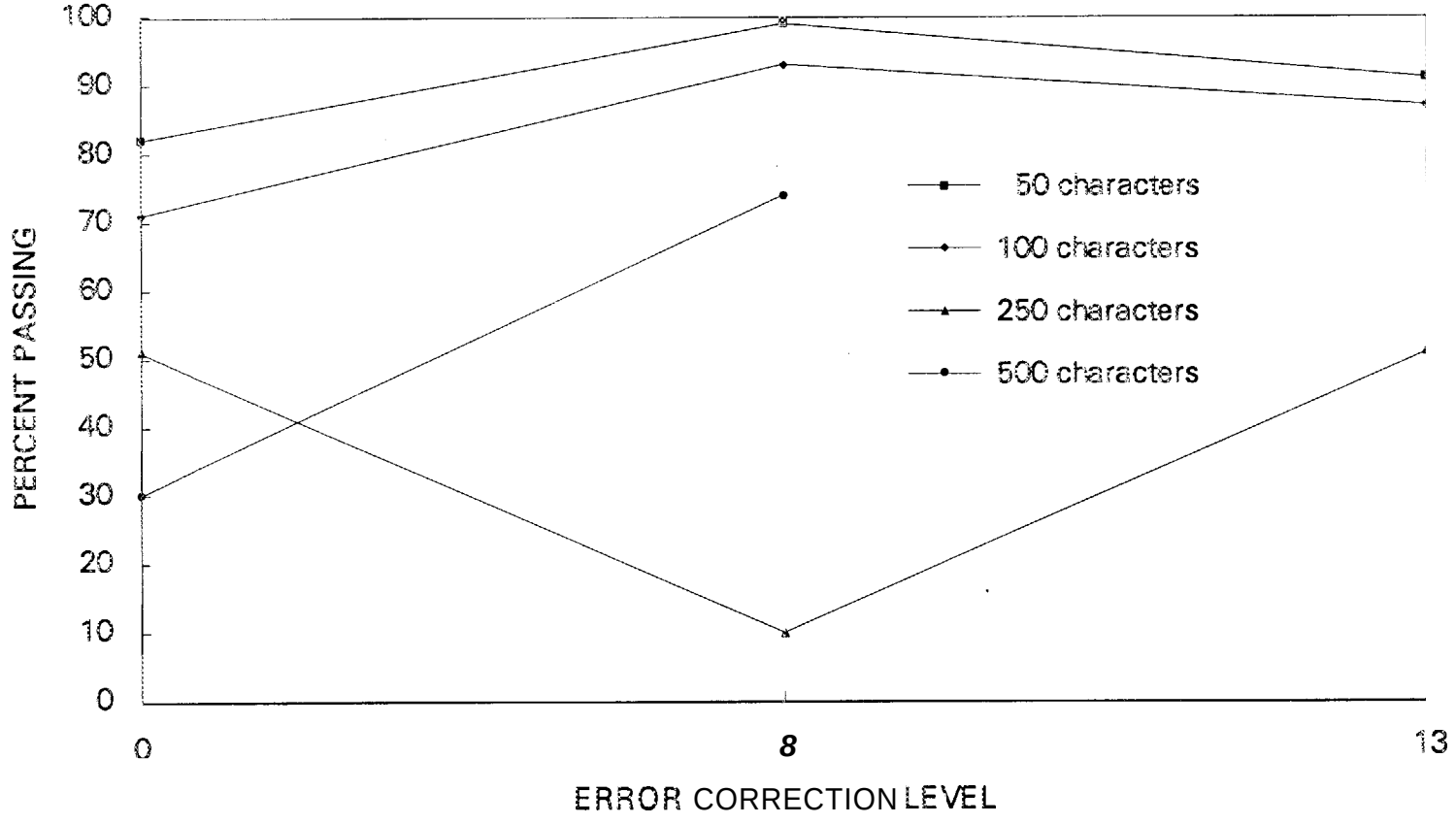


Fig. 2.6. Pass rate results for Datamatrix symbols with a cell size of 0.0200 in.

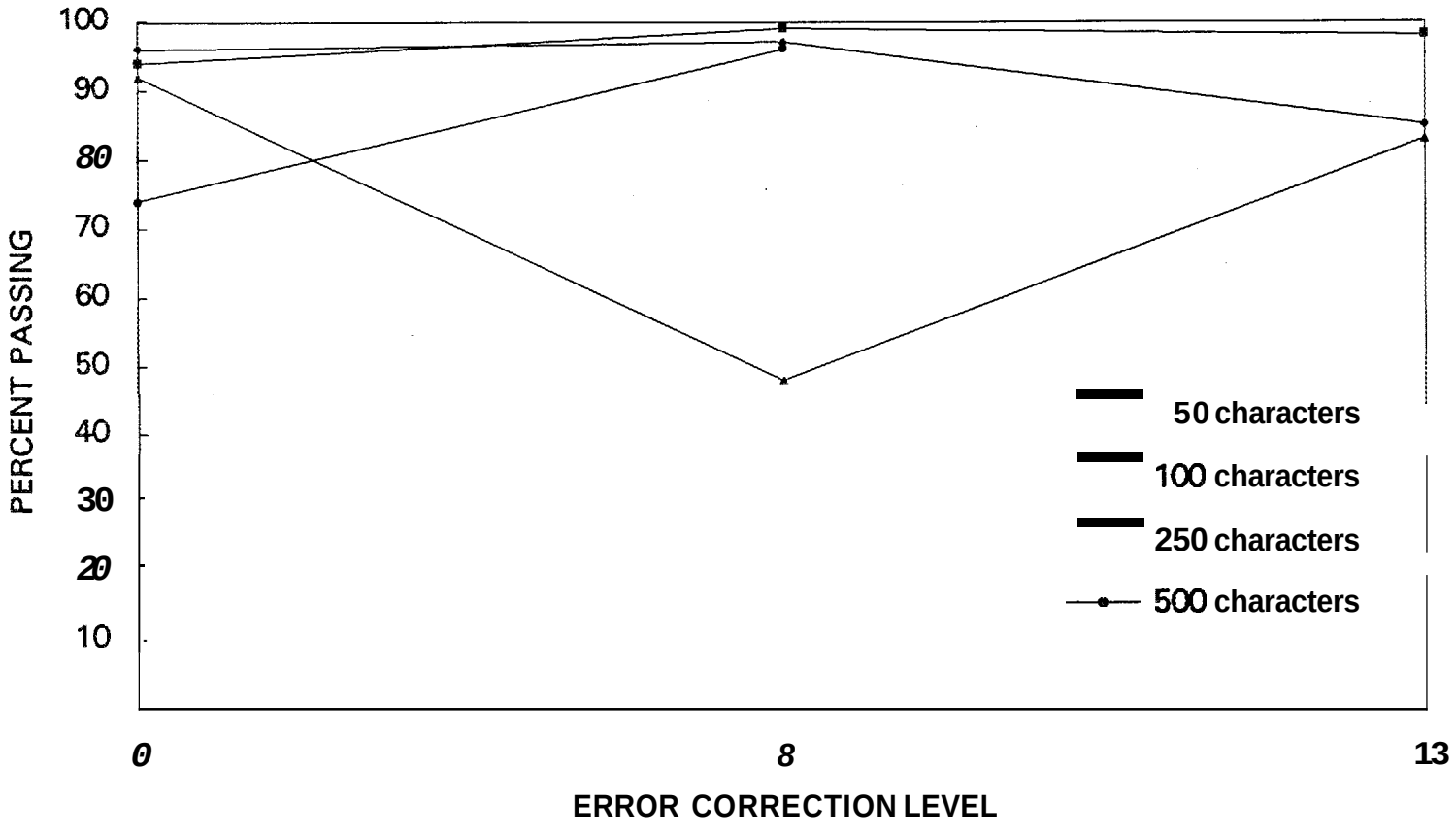


Fig. 2.7. Pass rate results for Datamatrix symbols with a cell size of 0.0233 in.

Table 2.3. Pass rate results for the Datamatrix cell size test with system hints provided

Characters	ECC level	Cell size (in.) 0.020	0.023	0.026	0.030
50	0	90	98	100	100
	8	100	100	100	100
	13	100	100	100	100
100	0	71	93	100	99
	8	100	100	100	100
	13	100	100	100	100
250	0	56	91	98	100
	8	100	100	100	100
	13	100	100		
500	0	49	89	99	99
	8	100	100		
	13				

The results indicate that as the skew angle increases, the tendency for the scanner to read successfully decreases. This effect occurred at each error correction level tested. The 45° skew angle data indicate that a limited depth of field begins to have a possible effect on large high-density symbols. For AAIT applications, the skew angle should be kept below 30°.

2.7 SUBSTRATE CURVATURE TEST

Since the skew angle has a detrimental effect on read success, symbols could be difficult to read from curved surfaces; therefore, a substrate curvature test was designed to determine the sensitivity of the pass rate response to surface curvature. Four sets of the twelve 100-character symbols from the test data base were printed on 3-in.-square polyester labels. Each label set was attached to plastic carriers having one of four surface shapes. Three surface shapes were made from 6-, 4- and 2-in. schedule 40 plastic pipe. The fourth shape matched the conical surface at the fuze interface of a 155-mm projectile. The worst test case for skew angle was the largest symbol (46) on the smallest radius (1.25 in.), as shown in Fig. 2.11.

The only deviation from previous test procedures was the elimination of symbol rotation between each reading test event. The test results are shown in Table 2.5. The data in Table 2.5 indicate that curved surfaces can degrade the reading of symbols when error correction is not used and cell size is too small. When the cell size exceeded the manufacturer's recommendation, no sensitivity was detected for surface radii down to 1.25 in. When curved surfaces are involved, high levels of error correction might be counter productive and symbol users should trade decreasing symbol error correction for increasing symbol cell size.

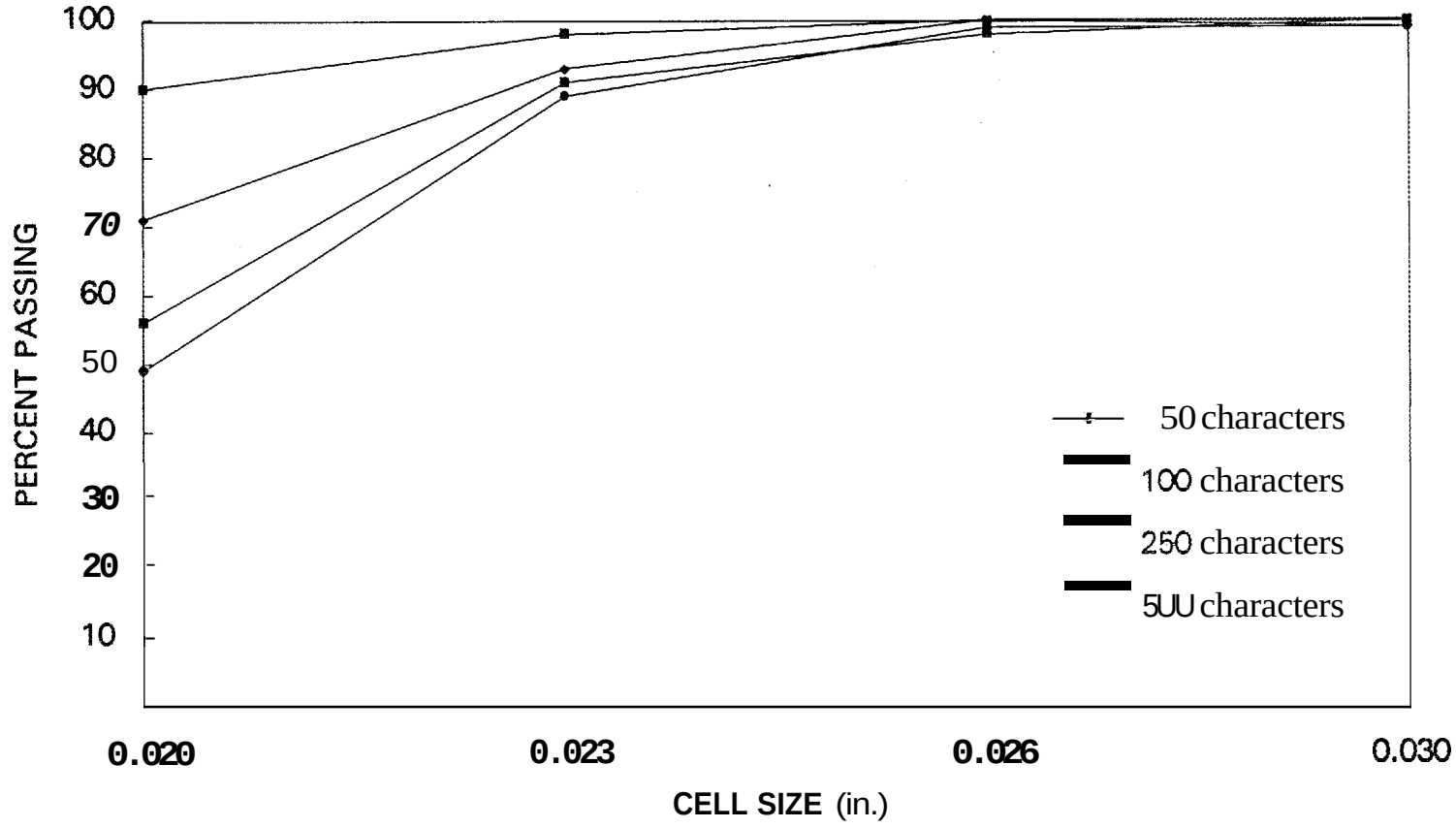


Fig. 2.8. Pass rate results for Datamatrix symbols without error correction but with decoder hints provided.

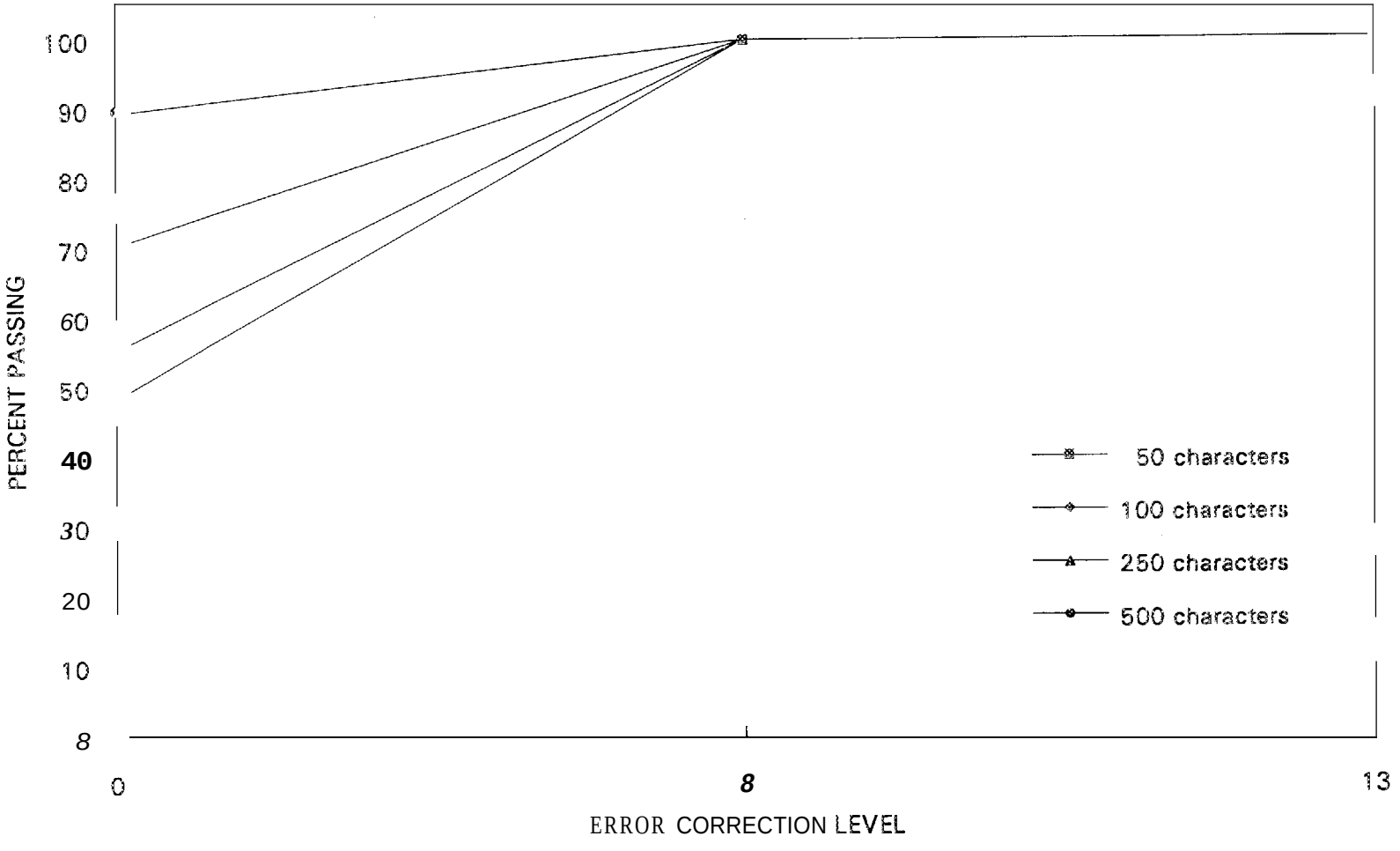


Fig. 2.9. Pass rate results for Datamatrix symbols with a cell size of 0.0200 in. and decoder hints provided.

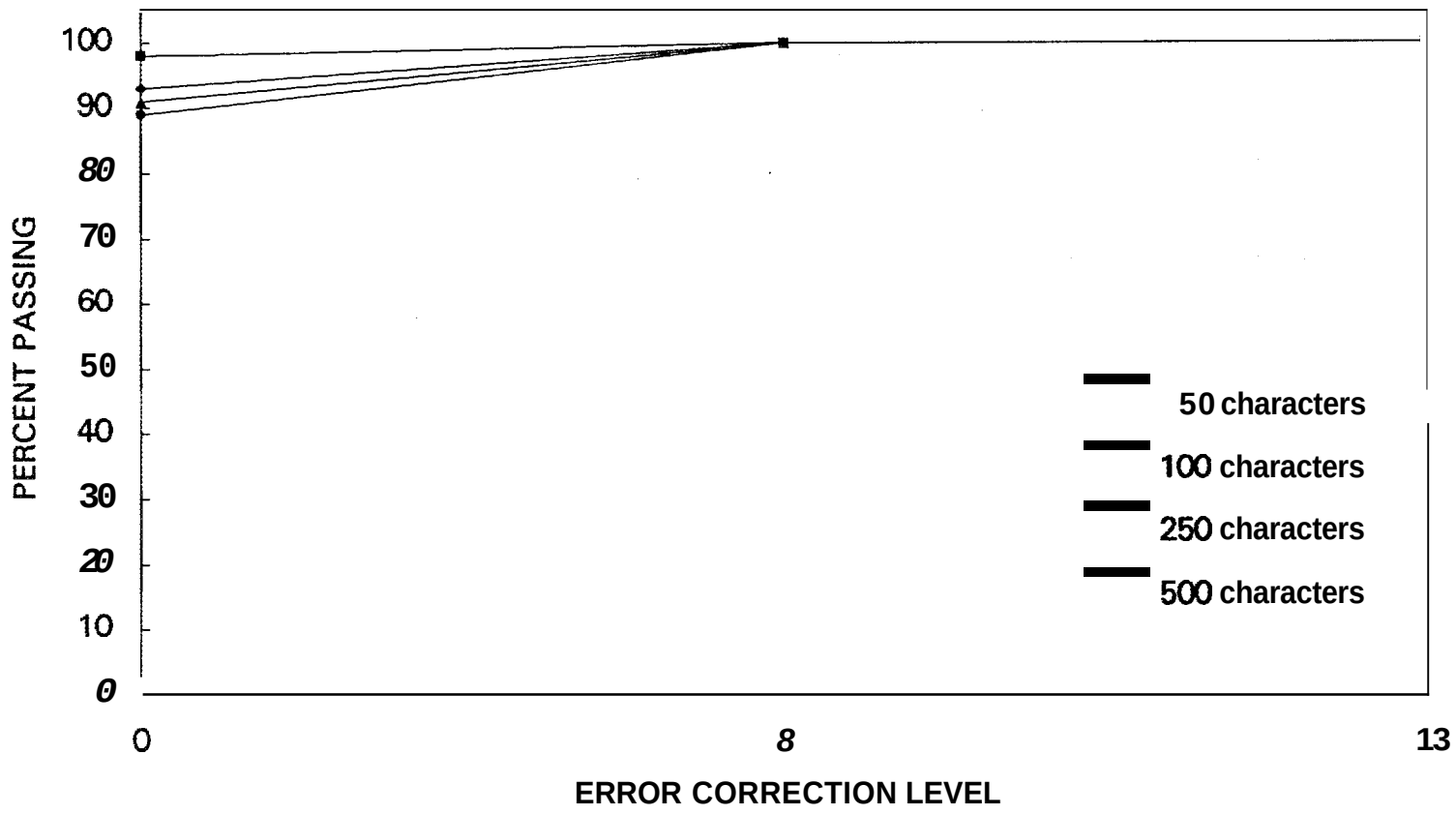


Fig. 2.10. Pass rate results for Datamatrix symbols with a cell size of 0.0233 In. and decoder hints provided.

Table 2.4. Pass rate results for the Datamatrix skew angle test with decode hints provided

Error correction	Skew angle (deg)	Cell size (in.)			
		0.0200	0.0233	0.0266	0.0300
0	0	71	93	100	99
	30	17	59	74	84
	45	1	11	16	17
8	0	100	100	100	100
	30	81	99	100	100
	45	39	77	73	43
13	0	100	100	100	100
	30	99	99	93	85
	45	51	40	16	4

2.8 MOTION TEST

Several conveyers and carousel concepts have been proposed for handling ammunition in the future. For most ammunition rearm applications, it is desirable to scan and decode machine-readable data while objects are in motion. The objective of this test was to determine what effect symbol motion has on the tendency of the Datamatrix system to read successfully.

The Pulnix camera uses two interlaced scans to construct a single video frame with a pixel resolution of 768 (h) by 480 (v). To capture a sharp image of a moving object, only one of the interlaced scans of the camera is used and the pixel resolution is changed to 768 (h) by 240 (v). To stop motion at higher velocities, the frame rate of the camera can be varied from 60 to 10,000 frames/s. However, as the frame rate is increased, more ambient light is required. Ambient light was increased to 10,000 lx for all motion tests.

Two sets of test symbols were printed onto 3-in.-square polyester labels using a 0.03-in. cell size. The first set used 50 data characters, and the second set used 100 data characters. Three levels of error correction (levels 0, 8, and 13) were used for each set. The test procedure required attaching each symbol to a motor-driven turntable. Test velocities from 0 to 120 in./s were verified by tachometer measurements. An optical trigger wired into the decoder's general purpose input port was used to initiate each scanner reading. Tests were performed using horizontal and vertical sweep motions. The horizontal sweep moved the test symbol across the camera view from left to right, while the vertical sweep moved the symbol from top to bottom. Decoder hints were provided, and 100 readings were made at each test velocity.

Several determinations can be made from the results presented in Figs. 2.12, 2.13, and 2.14. The tendency of the system to read symbols in motion is better for symbols with smaller data lengths. Some error correction improves the reading success; however, high error correction may degrade system performance. Also, horizontal symbol motion provides better reading results at higher velocities. This final observation is probably caused by the reduced vertical camera resolution used for stop motion video. To verify this assumption, a 100-character symbol with a

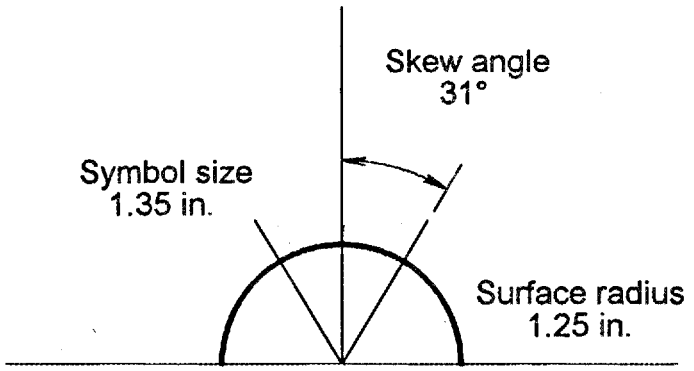


Fig. 2.11. The worst case for skew angle in the Datamatrix curved surface test.

Table 2.5. Pass rate results for the Datamatrix substrate curvature test with decode hints provided (100-character symbols)

Error correction level	Radius (in.)	Symbol cell size (in.)			
		0.0200	0.0233	0.0266	0.0300
0	3.25	100	97	24	100
	2.25	97	51	53	100
	1.25	53	100	8	100
	Conical	100	57	71	100
8	3.25	91	99	100	100
	2.25	100	100	100	100
	1.25	100	67	99	100
	Conical	17	100	78	100
13	3.25	100	100	100	100
	2.25	97	100	100	100
	1.25	99	100	100	100
	Conical	99	100	100	88

3:2 aspect ratio was tested using vertical motion. The comparison of the test results with a previous test using a 1:1 aspect ratio verifies that vertical elongation of the symbol improves reading performance during vertical motion scanning (see Fig. 2.15).

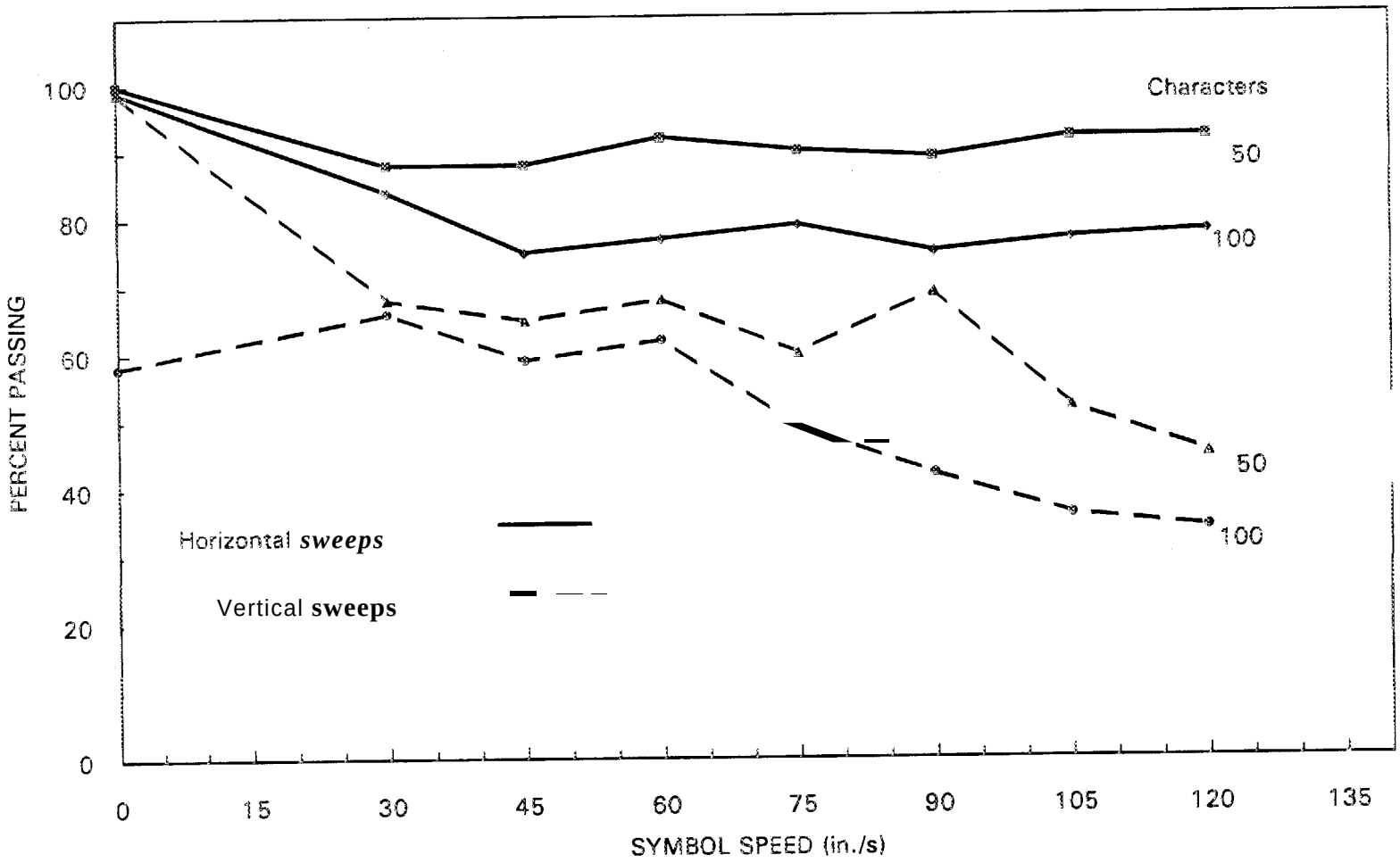


Fig. 2.12. Horizontal and vertical motion results for 50- and 100-character Datamatrix symbols without error correction.

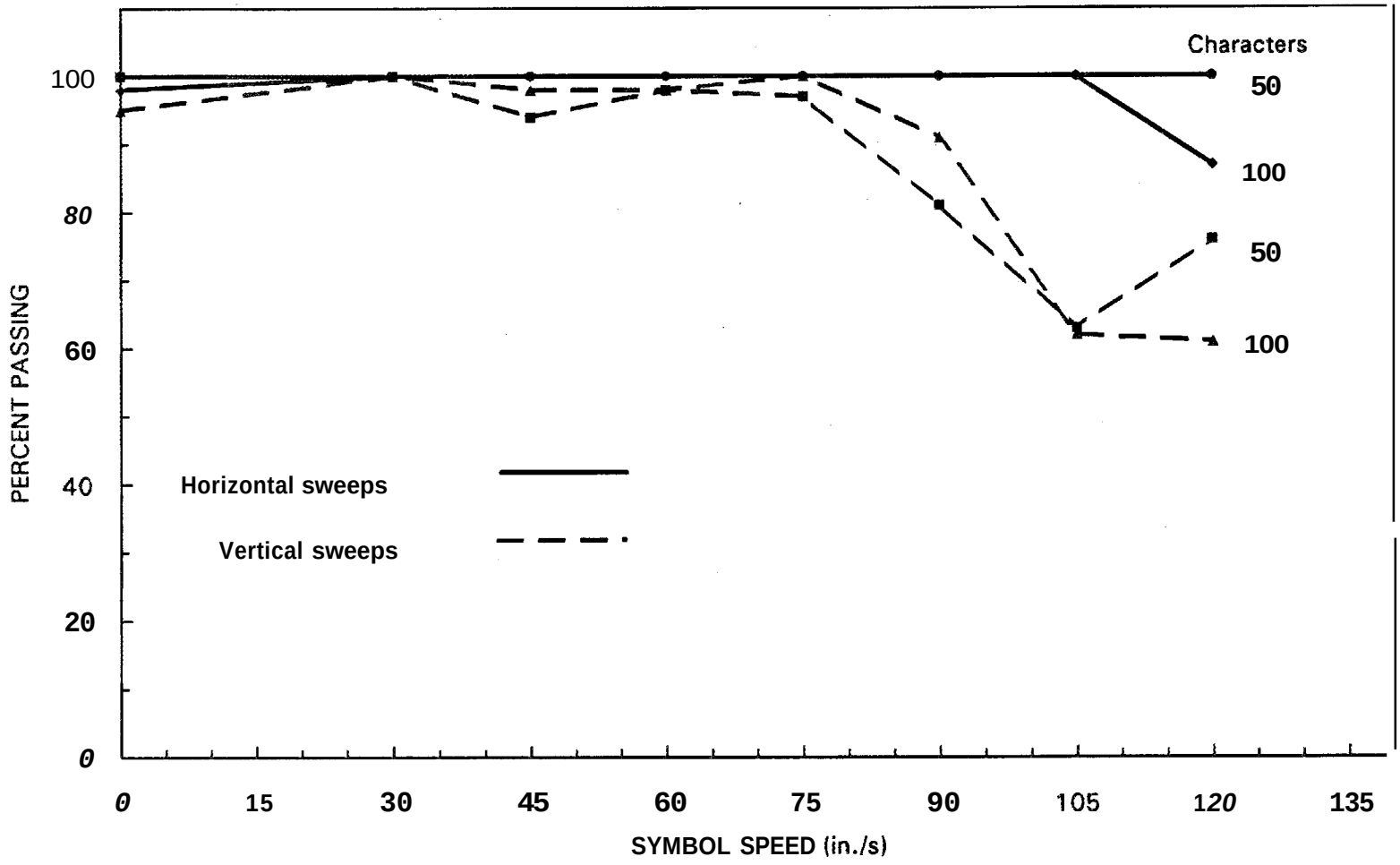


Fig. 2.13. Horizontal and vertical motion results for 50- and 100-character Datamatrix symbols using error correction level 8.

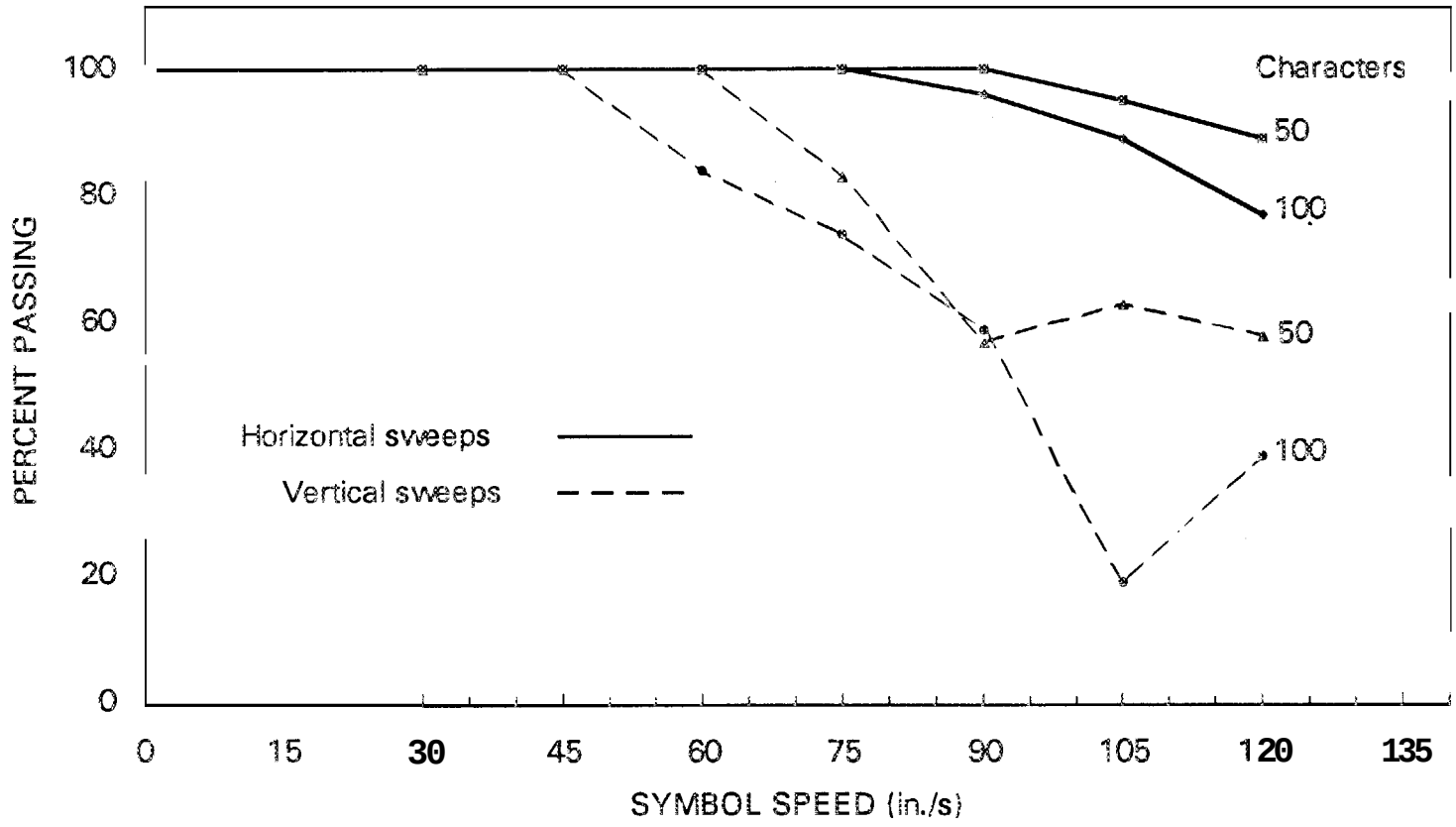


Fig. 2.14. Horizontal and vertical motion results for 50- and 100-character Datamatrix symbols using error correction level 13.

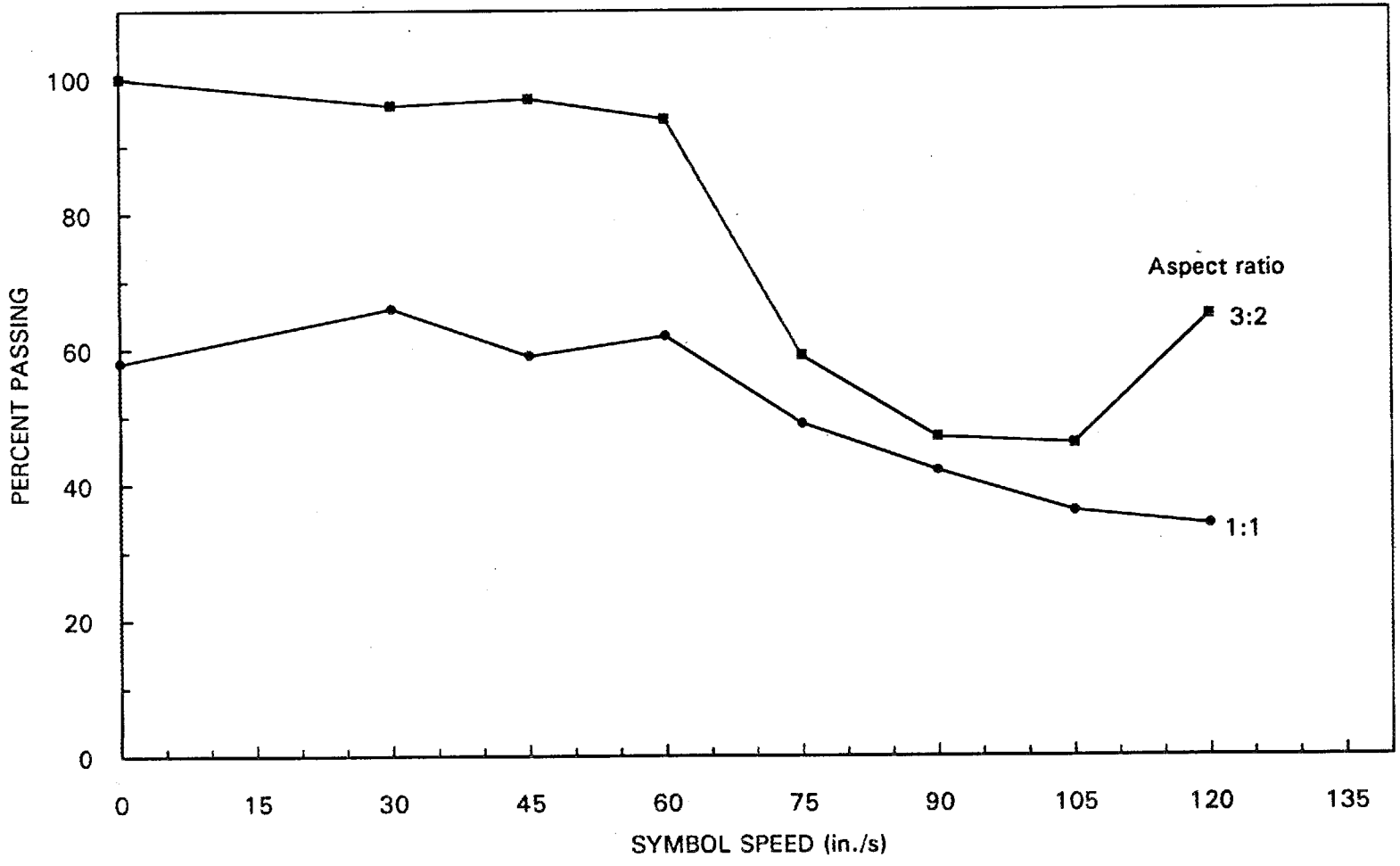


Fig. 2.15. Vertical motion results for 100-character Datamatrix symbols with aspect ratios of 1:1 and 3:2 without error correction.

2.9 IMAGE CONTRAST TEST

Most symbol scanners require minimum contrast ratio for reliable operation. Printed material, like bar code labels, may become sun bleached and lose contrast. ID Matrix claims reliable operation for the Datamatrix system with contrast ratio as low as 20%. Since most ammunition is painted either green, gray, or blue, applying black data symbols directly to these substrates will also create a low-contrast condition. The objective of the image contrast test was to determine the tendency of the system to successfully read Datamatrix symbols from surfaces painted with typical ammunition colors.

For this test, a 1-in.-square black symbol encoding 50 characters with error correction level 8 was printed onto clear plastic overlay film. Six painted and two unpainted test substrates were also prepared for the test. The painted surfaces tested were typical 155-mm ammunition colors, and the unpainted surfaces were samples of as-received stainless steel and aluminum sheet. Table 2.6 describes the specific color chip numbers used as per Federal Standard 595 for the painted test samples.

Table 2.6. Paint colors used for the Datamatrix image contrast test

Projectile type	Color	Federal standard No.
Practice	Blue	35109
Illumination	White	37875
White smoke	Light green	34558
Gas	Gray	36231
High-explosive	Green	24079
White smoke	Light green	24449

Initially, a test was performed using 1000 and 10,000 lx of ambient light while the camera's automatic sensitivity control was active. During this test, the data collection system logged the results of 100 readings for each contrast (black to white) value over a broad test range. Each bar in the chart of Fig. 2.16 represents the range of black/white cut-off values that gave 100 successful readings. The black symbol on the dark green painted substrate could not be read under any tested condition. Since the largest percentage of artillery ammunition is painted dark green, the test results suggest that a white substrate will be required on dark green, gray, and blue ammunition. However, the results indicate that higher ambient lighting conditions improve the image contrast for all other substrates and, therefore, extend the successful operating range of the Datamatrix system.

A second test was designed to determine the effect of automatic camera gain on the Datamatrix system. As the results of Fig. 2.17 show, automatic camera gain also extends the operating range of the Datamatrix system.

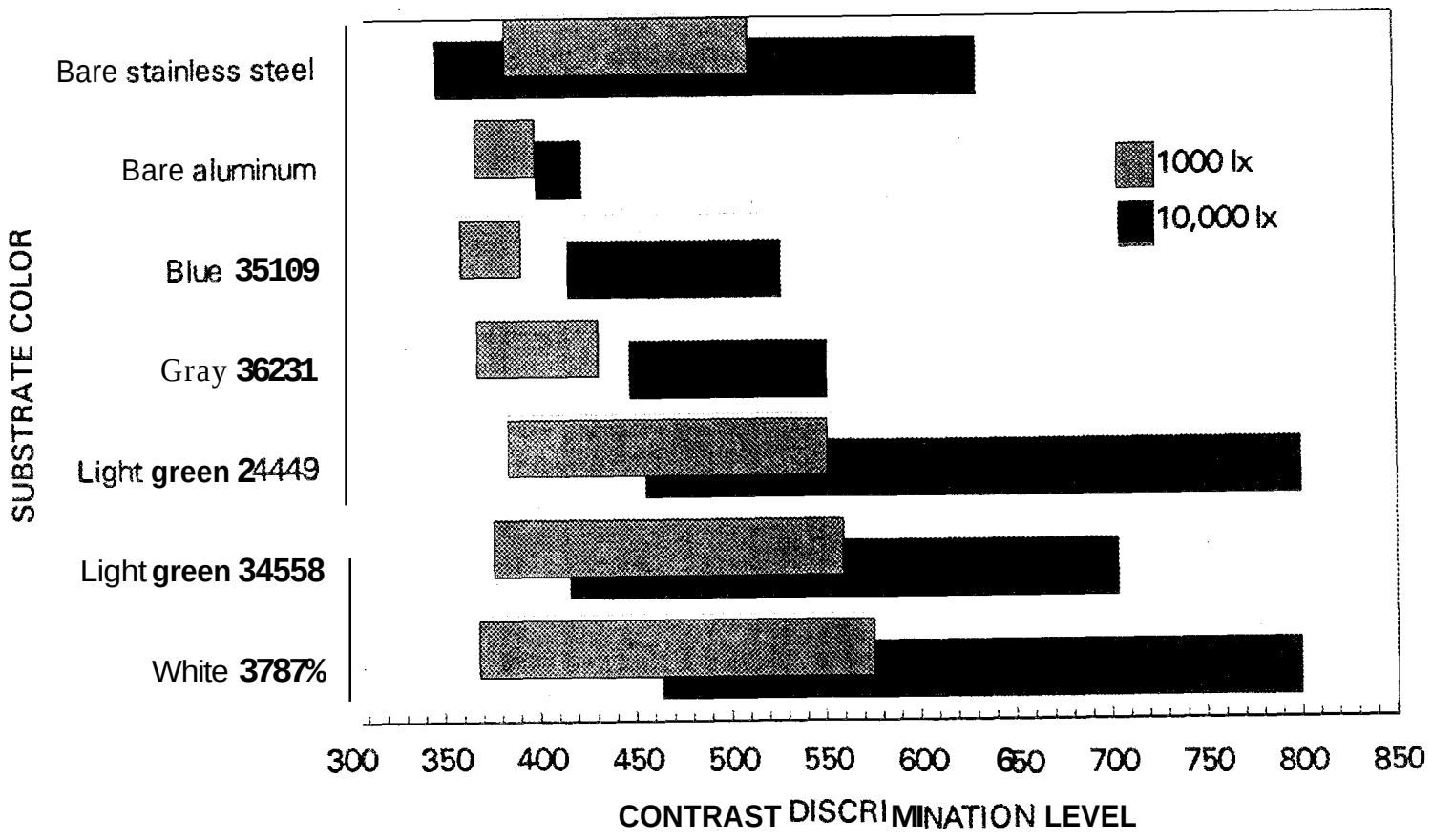


Fig. 2.16. Datamatrix image contrast results with decoder hints provided at 1000 and 10,000 lx and automatic camera gain active.

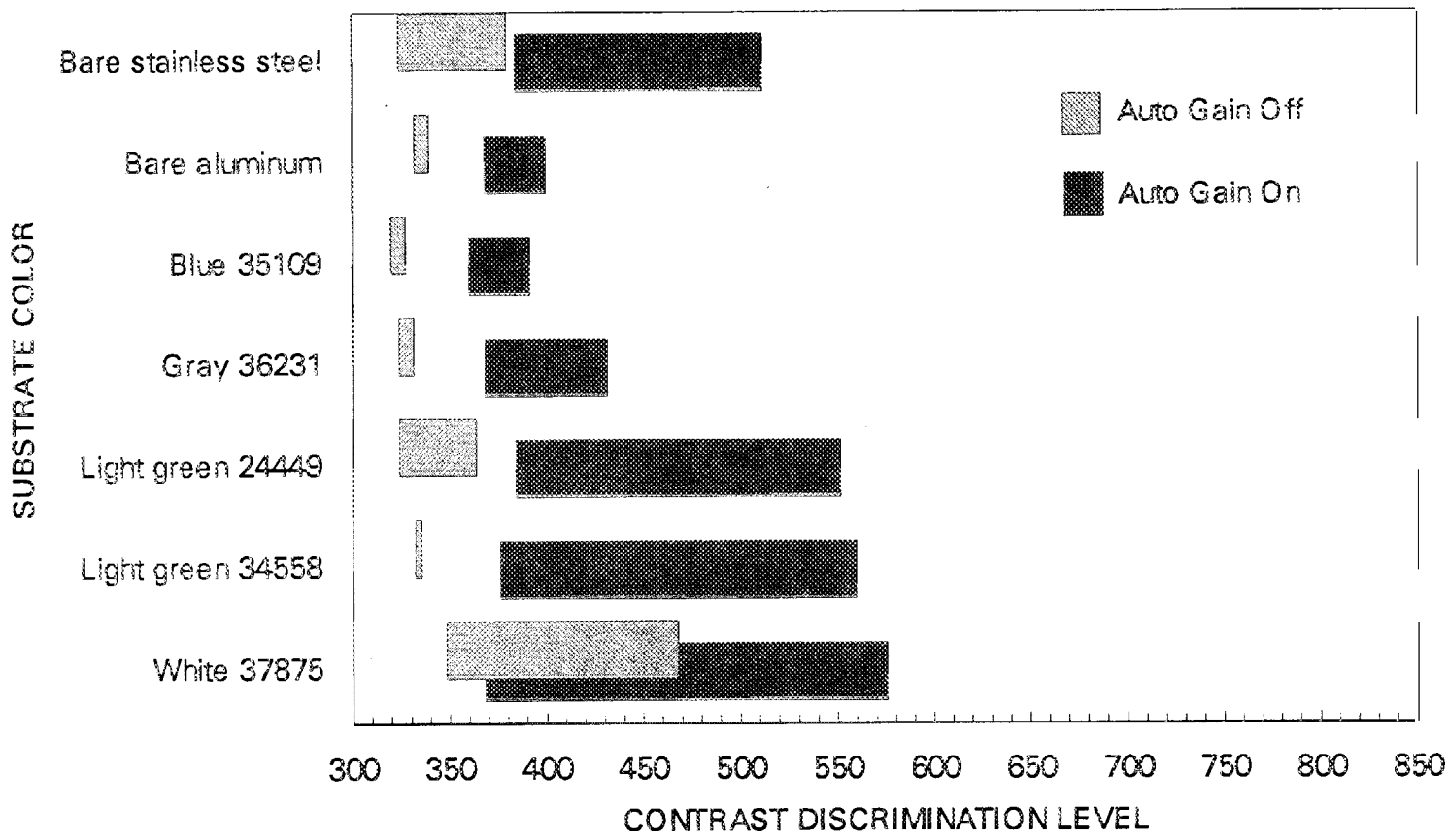


Fig. 2.17. Datamatrix image contrast results with decoder hints provided at 1000 lx.

2.10 DUPLICATION TEST

Photocopy and facsimile processes do not create a perfect duplicate. Image quality degrades for each generation of duplication. Since ammunition logistics records management will certainly require document duplication, printed data symbols should remain readable after several generations of duplication. The objective of the duplication test was to determine the sensitivity of the pass rate response to symbol degradation caused by duplication processes.

For this test, the twelve 100-character symbols from the data base in Appendix A were printed onto sheets of paper (6 symbols per sample sheet). As a control symbol, a LOGMARS bar code was also printed onto each sample sheet. The ANSI X3.182-1990 print quality grade for the original control symbol was grade B. The original sample pages were photocopied six times and duplicated by facsimile two times. After the first photocopy generation, the ANSI grade of the control symbols dropped to grade D but the symbol was still readable with a hand-held scanner. After the second generation, the symbol grade dropped to a still readable grade F. After the third photocopy generation, the LOGMARS control symbol could not be read. Appendix B provides the scan profiles for the control symbol after each photocopy generation.

The results in Table 2.7 indicate that adequate cell size and error correction are required for the Datamatrix symbols to remain readable after photocopy or facsimile duplication processes.

Table 2.7. Pass rate results for duplicated Datamatrix symbols encoding 100 characters with decoder hints provided

Error correction level	Duplication degradation	Cell size (in.)			
		0.0200	0.0233	0.0266	0.0300
0	Original	10	100	96	100
	Third photocopy	0	97	99	97
	Sixth photocopy	0	0	0	0
	First facsimile	0	0	0	0
	Second facsimile	0	0	0	0
8	Original	99	100	100	100
	Third photocopy	64	100	100	100
	Sixth photocopy	0	100	98	100
	First facsimile	0	0	1	2
	Second facsimile	0	0	0	0
13	Original	100	100	100	100
	Third photocopy	100	100	100	100
	Sixth photocopy	5	100	100	100
	First facsimile	0	0	0	100
	Second facsimile	0	0	0	0

2.11 UNIFORM WEAR TEST

Under severe conditions (e.g., blowing sand and rain), data symbols on ammunition will degrade from wear damage or erosion. Edge quality, contrast, defects, and modulation could be affected. We assumed that this damage affects the symbol, not the substrate, and that this form of degradation will be uniformly distributed. A test was designed to determine the tendency of the Datamatrix system to successfully read symbols that were degraded by uniform wear. Sandblasting was chosen as the method to create uniform symbol wear, and a sandblasting chamber was constructed.

For this test, the six 100-character symbols with adequate cell sizes (0.026 and 0.030 in.) were printed onto 3-in.-square polyester labels. Since no print quality verifier exists for Datamatrix symbols, a LOGMARS bar code was also printed onto each label as a control symbol. The ANSI X3.182-1990 print quality grades and scan profiles for each control symbol were measured before and after each sand exposure using a Quickcheck 500 print quality verifier. The scan profiles are provided in Appendix C. In addition to scan profiles, an attempt was made after each exposure to read the LOGMARS control symbols with an Intermec 1545 scanner. During the test, all control symbols were decoded after 4 min of sand exposure, but after 8 min the LOGMARS control symbols could not be decoded.

Despite a significant loss of print contrast, which rendered the LOGMARS bar codes unreadable, Datamatrix symbols incorporating error correction were successfully decoded (see Table 2.8). The gradual loss of symbol contrast was offset by adjusting the contrast discrimination (black/white cut-off) value. The original symbols were scanned with a light level of 1000 lx using a discrimination value of 500. After 4 and 8 min of sand exposure, discrimination values of 550 and 600 were used respectively.

Table 2.8. Print quality grades and pass rate results using decoder hints for sandblasted Datamatrix symbols

Error correction level	Sandblasting time (min)	Cut-off value	Cell size (in.)	
			0.026	0.030
0	None	500	B/100	B/99
	4	550	F/0	F/52
	8	600	F/80	F/94
8	None	500	B/100	B/100
	4	550	F/100	F/99
	8	600	F/96	F/93
13	None	500	B/100	B/100
	4	550	F/100	F/94
	8	600	F/91	F/80

2.12 SMOKE OBSTRUCTION TEST

Light traveling from a source to the scanner will be obstructed to some degree in environmental conditions such as fog, mist, or smoke. Significant obstructions from fog and mist usually require long distances; however, smoke can be a significant obstruction at very short distances. The tendency of a scanner to read successfully is expected to decrease as the optical density of a smoke obstruction increases. Optical density is defined by the following equation:

$$\textit{Optical density } (OD) = \log \left(\frac{\textit{Clear intensity } (I_0)}{\textit{Obstructed intensity } (I)} \right) . \tag{1}$$

Therefore, optical densities of 1, 2, and 3 represent light transmissions of 10, 1, and 0.1% of the unobstructed light intensity. Figure 2.18 plots the relationship between optical density and light transmission. A bar code system which can operate at higher optical densities of obstruction or lower values of transmission is more desirable.

For this test, a smoke chamber and laser photometer were used to measure the effect of optical obstruction on the tendency to read Datamatrix symbols successfully. Commercial smoke bombs producing zinc-chloride particles were used to generate the smoke. Laser light from a helium-neon laser was carried into the smoke chamber by an optical fiber. The light was expanded to a collimated light beam and projected through approximately 12 in. of chamber space. The light beam was collected and focused into another optical fiber which carried the light out of the chamber to a photo-optic multimeter. The laser photometer was calibrated with neutral density filters.

Three 100-character symbols having error correction levels 0, 8, and 13 were printed onto 3-in.-square white polyester labels. The cell size for each symbol was 0.030 in. The labels were attached to a sliding metal plate and placed inside the smoke chamber approximately 12 in. from the CCD scanner camera. The symbols were illuminated by a 100-W incandescent spotlight, and light levels were determined before each test by a hand-held light meter. Tests were performed using light levels at 1000 and 10,000 lx, and all tests were performed with decoder hints provided.

The test procedure involved igniting a 30-s smoke bomb, recording photometer measurements, and attempting scanner readings. Initially, the smoke obstruction was so dense that the symbols could not be decoded. The smoke obstruction was gradually vented from the chamber, and as the smoke cleared, the symbols could be decoded. The results in Figs. 2.19, 2.20, and 2.21 show that a higher ambient light level allows the system to successfully decode symbols at higher obstruction levels. At 1000 lx Datamatrix symbols could be read successfully up to a 40% loss of light. At 10,000 lx the symbols could be read up to a 75% loss of light. Also, there was no noticeable effect on system performance resulting from the use of error correction.

2.13 SYMBOL CORRUPTION TEST

To improve the reliability of data storage in symbols subjected to damage or corruption, several levels of optional error correction are available in the Datamatrix symbology. Several corruption scenarios such as tearing, marking, corrosion, contamination, and fungus and mold growth have been suggested. Without error correction capability, damaged symbols can not be decoded; with error correction, the ability to recover data from damaged symbols improves with

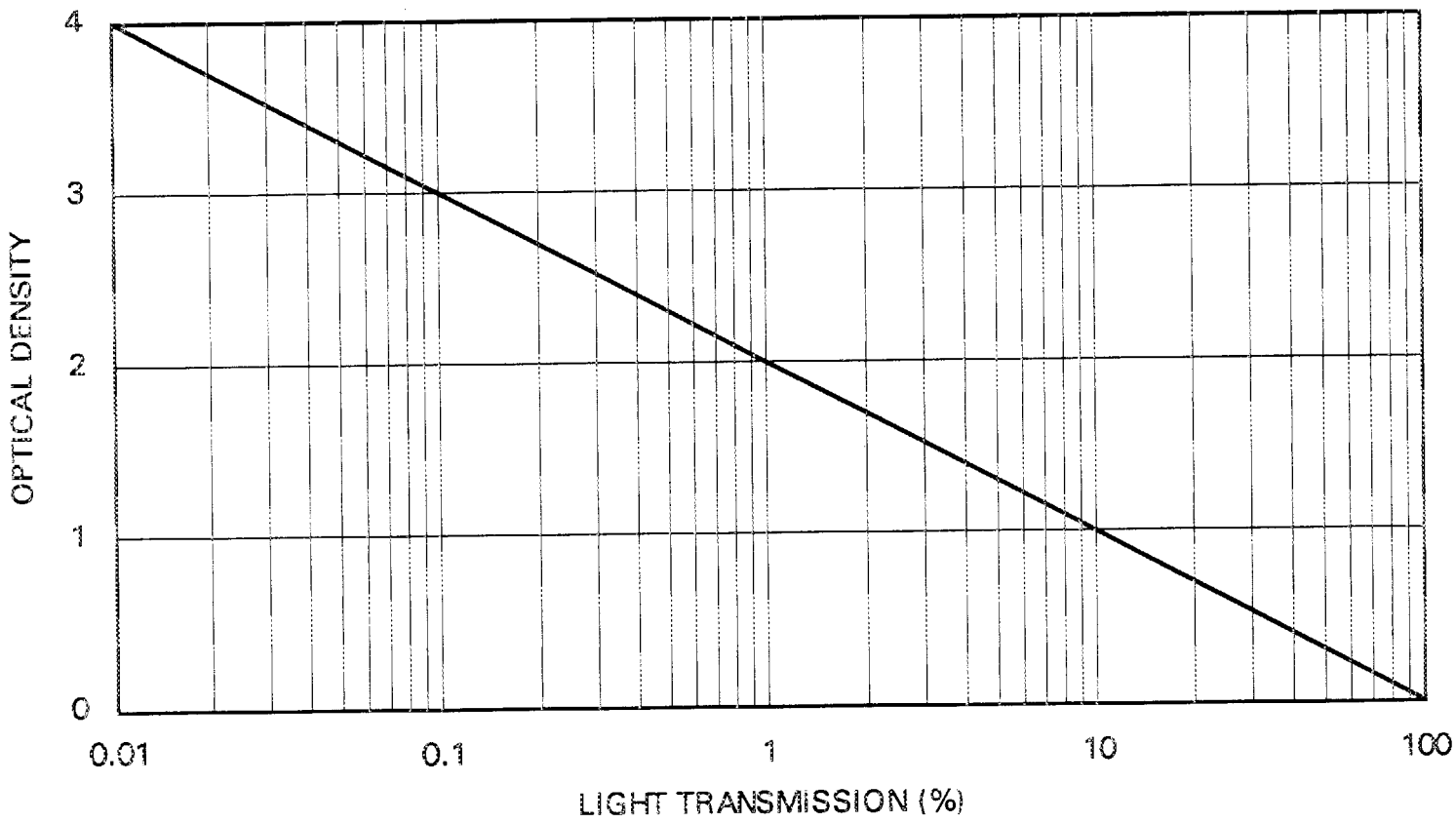


Fig. 2.18. Relationship between optical density and light transmission.

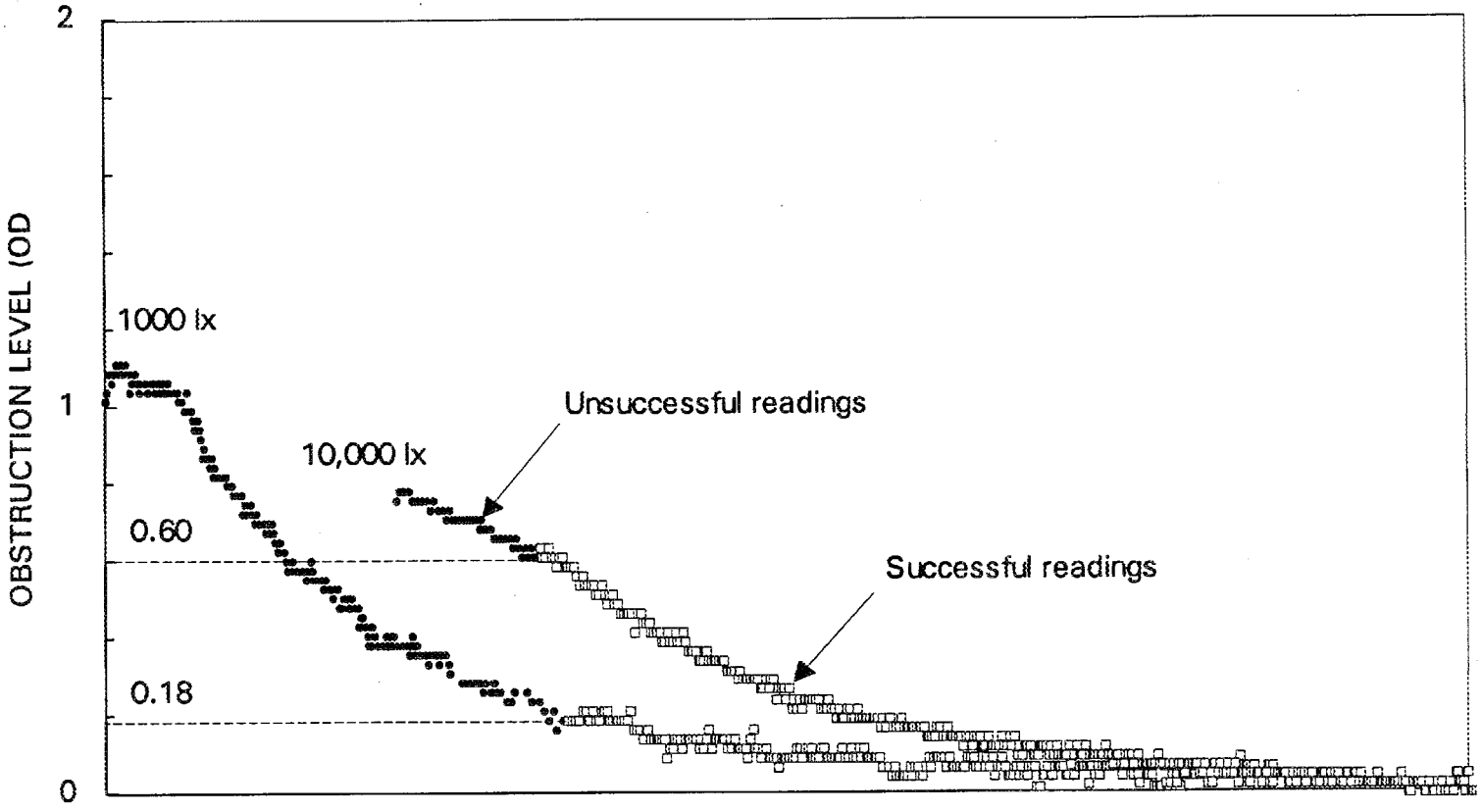


Fig. 2.19. Smoke obstruction results for a 100-character Datamatrix symbol using error correction level 0, decoder hints, and automatic camera gain.

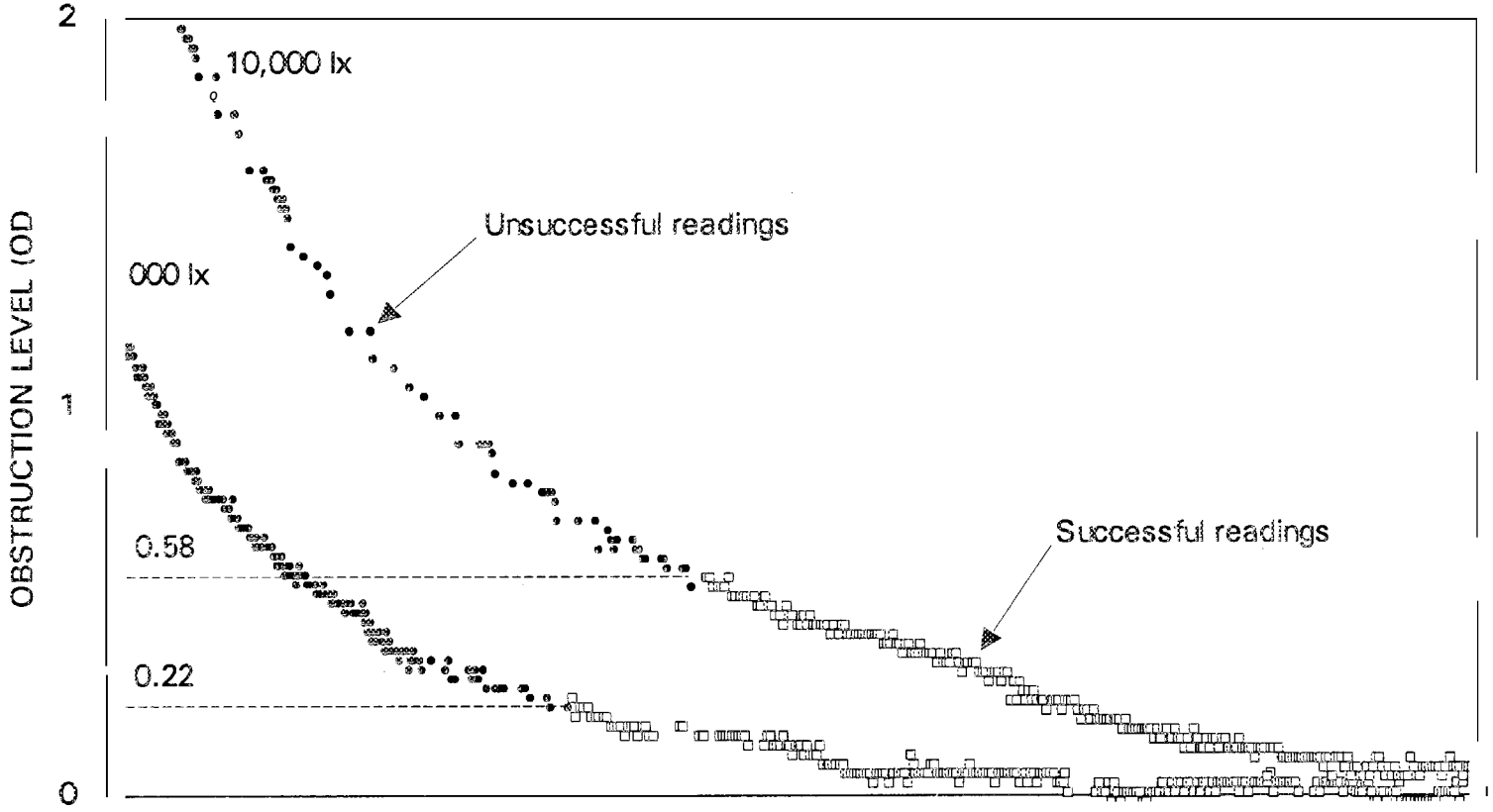


Fig. 2.20. Smoke obstruction results for a 100-character Datamatrix symbol using error correction level 8, decoder hints, and automatic camera gain.

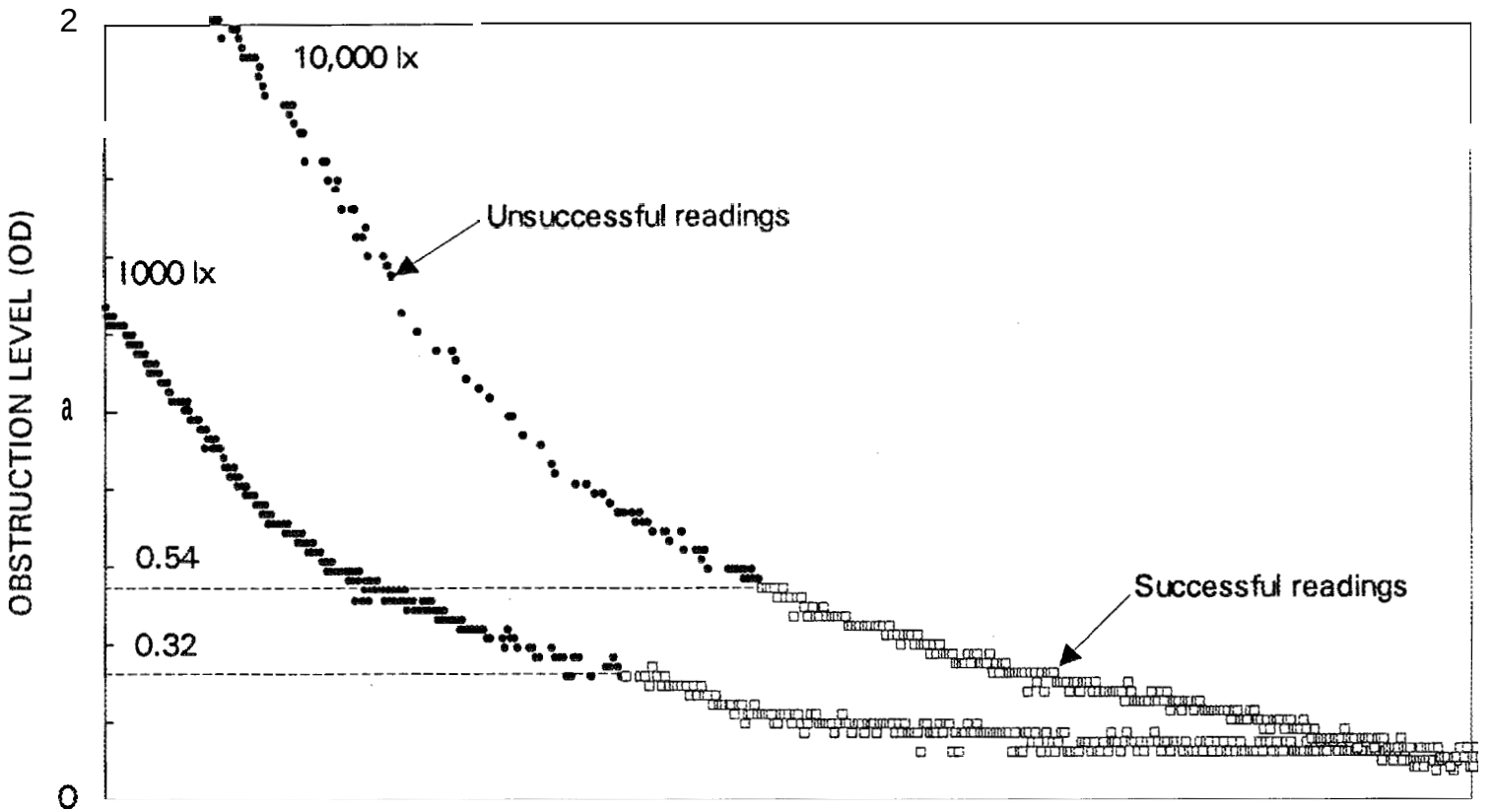


Fig. 2.21. Smoke obstruction results for a 100-character Datamatrix symbol using error correction level 13, decoder hints, and automatic camera gain.

each level of correction employed. The disadvantage of error correction is that additional data must be encoded into a symbol, and this overhead increases the size of the symbol. The most efficient error correction levels are 5, 8, 12, 13, and 14, which have overhead requirements of 25, 33, 50, 66 and 75% respectively.

A series of tests was designed to determine the tendency of the Datamatrix system to successfully read corrupted data symbols. A 50-character message was encoded with the most efficient error correction levels (5, 8, 12, 13, and 14). Each test symbol was printed approximately 1 in. square, and all symbols exceeded the 5 by 5 pixels-per-cell requirement for camera magnification. Twelve corruption scenarios were used to evaluate the error correction capability of the Datamatrix symbology (see Table 2.9).

The results in Table 2.9 contain several unexplained data trends which were probably caused by the random positions of corruption used for each test. The results show that some level of symbol corruption can be tolerated by the Datamatrix system when error correction is used; however, the symbology should not be considered totally fault tolerant. If enough of any matrix code is lost, it will be impossible to convey the encoded data. However, increasing the error correction level of Datamatrix symbols improves the resistance to corruption. Further study of the Datamatrix error correction feature is recommended.

Table 2.9. Pass rate results for corrupted 1-in.-square Datamatrix symbols encoding 50 characters using various error correction levels

Error correction	Level 5	Level 8	Level 12	Level 13	Level 14
Matrix density	23 by 23	25 by 25	28 by 28	34 by 34	38 by 38
Cell size	0.043 in.	0.040 in.	0.036 in.	0.030 in.	0.027 in.
Corruption	Pass rate results				
None	100	100	100	100	100
	100	99	40	97	53
	97	100	100	100	100
	0	99	0	100	0
	79	91	59	59	0
	4	0	96	6	0
	100	100	100	100	100
	14	100	83	100	100
	0	14	0	0	0
	0	4	30	100	100
	0	0	100	100	100
	0	0	0	100	100
	0	0	100	100	100

3. CODE 49 EVALUATION TESTS

3.1 SYMBOLOGY DESCRIPTION

Code 49 is a multirow, continuous, variable length symbology encoding the full ASCII 128-character set. It is ideally suited to applications where large amounts of data are required in a small space. A Code 49 symbol consists of 2 to 8 rows, each with 18 bars and 17 spaces. Each row contains a row number, and the last row contains information indicating how many rows are in the symbol. Each row consists of a leading quiet zone, a start pattern, four data words encoding eight characters, a stop pattern, and a one-digit trailing quiet zone. There is one check character per row plus 4 or 6 check characters per symbol. Rows can be scanned in any order. The rows are bordered by a separator bar. The maximum message length per symbol is 49 alphanumeric characters or 81 numeric digits. The net data density is a maximum of 93.3 alphanumeric characters/in.^{2} or 154.3 numeric digits/in.^{2} when using a minimum bar dimension of 0.0075 in. Figure 3.1 shows examples of Code 49 symbols used in testing.

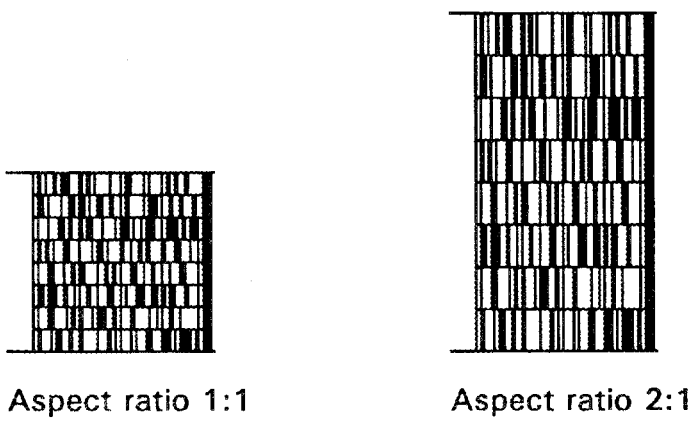


Fig. 3.1. Examples of Code 49 test symbols.

3.2 EVALUATION OF EQUIPMENT AND SOFTWARE

The scanning system employed for Code 49 testing was very simple. An Intermec Model 1545 bar code laser scanner was used for scanning symbols during all evaluation tests. The scanner incorporates a visible laser diode (nominal wavelength of 670 nm) and a single bidirectional retro-collective mirror that has a scan rate of 36 scans/s. The scanner was connected to an Intermec Model 9720 wedge reader, which provides an audible tone when each row of a

Code 49 symbol is read. It also provides a separate audible tone when the current symbol being scanned has been successfully decoded. No other read status codes are provided by the reader. During all evaluation tests, the 9600-baud serial port on the reader was used for controller communications. The controller used for all evaluation tests was an 80286-based computer with an 8-MHz clock speed. The operating system used was MS-DOS. Data were automatically acquired using the ASYST data acquisition language from Keithley Instruments, Inc., Taunton, Massachusetts.

The standard equipment setup for all tests in this evaluation is described in Table 3.1. This standard setup was used for each evaluation reported unless otherwise specified in the test description. The scanner was configured for continuous scanning operation and attached to a professional photographic copy stand above a small flat-bed plotter. Test symbols were attached to letter-sized sheets of paper and placed on the plotter. For all tests, the uppercase alphanumeric character set with punctuation was used to encode test symbols. Appendix D contains a description of the ten Code 49 symbols used during evaluation testing. Row scanning of a symbol was accomplished by moving the symbol under the scanner, and the speed of the plotter was controlled by the data acquisition system.

Table 3.1. Standard Code 49 test conditions

Scanner	Intermec Model 1545 visible laser diode scanner
Scanner rate	36 ± 2 scans/s
Scanner tilt angle	15° pitch angle from surface normal 0° skew angle from surface normal
Scanner distance	10 in. from symbol
Decoder	Intermec Model 9720 wedge reader
Lighting	Standard office level (~1000 lx) measured by light meter
Printing method	Zebra Model Z91 thermal transfer printer (300 dots/in.)
Label material	Zebra Z-Ultimate 5A 3-in.-square white polyester with permanent acrylic adhesive
Character set	Alphanumeric

3.3 EXPERIMENTAL APPROACH

A two-phase test plan was developed to determine the capabilities and limitations of the Code 49 system. The purpose of the first phase was to evaluate system variables such as minimum bar width, row scanning speed, scanner distance, scanner tilt angle, substrate curvature, and symbol contrast using high-quality symbols. The purpose of the second phase was to evaluate the effects of symbol degradation. Degradation was created by photocopy and facsimile duplication, smoke obstruction, and blowing sand abrasion.

Scanning and decoding a symbology is essentially a "go or no-go" process. During a test reading, the system will either render valid information and signal the user or it will reject the symbol. The tendency to successfully read is called the pass rate, and it is usually reported as a percentage. Statistically, if 100 successful readings are observed out of 100 attempts, then the true pass rate response at the 95% confidence level is greater than 97%. For all evaluation tests in this report, the recorded values are the number of successfully decoded readings out of 100 attempts. It was not the purpose of these tests to estimate the absolute pass rate response for each set of conditions but to indicate only the general effect of a changed condition.

3.4 SYMBOL BAR WIDTH, MOTION, AND SCANNER DISTANCE TEST

Stacked bar codes, like Code 49, require the user to manually translate the scanner over a symbol in a row-by-row motion. Since the Intermec 1545 scanner uses a constant scan rate of 36 scans/s, a limit to this translation speed is expected but might be extended by increasing the row height of the symbol. The effective range of a hand-held laser scanner is also limited and depends upon the X dimension of the symbols being scanned. (The X dimension of a bar code is the minimum bar or space width of the printed symbol.) Smaller symbols require shorter scanning distances, and larger symbols allow longer scanning distances. The Intermec 1545 scanner has an effective range from 12.7 to 38.1 cm. A single test was designed to determine the most optimum translation speed of the scanner for all subsequent tests and to evaluate the pass rate response to changes in the X dimension of printed symbols. Table 3.2 contains the pass rate results for various X dimensions and symbol translation speeds using a scanner distance of 12.7 cm.

Table 3.2. Code 49 pass rate results for various minimum bar widths (X) and symbol traverse speeds (scanner distance of 12.7 cm)

X dimension (mils)	Aspect ratio	Symbol translation speed (cm/s)									
		0.97	1.94	2.91	3.88	4.85	5.82	6.79	7.76	8.73	9.70
6.7	1:1	51	32	30	0	0	0	0	0	0	0
	2:1	97	98	97	70	68	12	5	0	0	0
10	1:1	99	100	100	30	29	0	0	0	0	0
	2:1	93	100	96	94	92	30	40	13	5	0
13.3	1:1	61	63	82	9	11	1	0	0	0	0
	2:1	96	98	99	64	49	12	11	6	2	0
16.7	1:1	20	17	21	1	2	0	0	0	0	0
	2:1	28	34	36	11	17	7	4	0	1	0
20	1:1	68	68	64	3	6	0	0	0	0	0
	2:1	41	35	41	29	33	9	5	0	1	1

The data in Table 3.2 verify that an upper limit exists for symbol translation speed. Symbols with a 1:1 (square) aspect ratio could be successfully scanned at translation speeds up to 2.91 cm/s (see Fig. 3.2). When symbol row height was doubled to a 2:1 aspect ratio, successful readings were achieved up to 4.85 cm/s (see Fig. 3.3).

Figures 3.2 and 3.3 also indicate that symbols with smaller X dimensions were more easily read than larger symbols at a scanner distance of 12.7 cm. A second test was designed to hold translation speed at a constant 2.91 cm/s and vary the scanner distance. Figure 3.4 shows that the optimum scanner distance increases proportional to the X dimension of the Code 49 symbol. In ammunition handling systems the distance from the symbol to the scanner may be constrained by mechanical interferences. Therefore, it is critical that a total systems approach be used when designing AAIT systems. The symbol size, the scanner capabilities, and the handling system requirements must be carefully considered.

3.5 SCANNER TILT TEST

For a hand-held laser scanner to operate properly, a slight pitch or skew angle is required to prevent the scanner from being blinded by a specular reflection of the laser beam from the symbol surface. Pitch angle (vertical) and or skew angle (horizontal) are defined in Fig. 3.5. A test was designed to determine the tendency of the scanner to read Code 49 symbols successfully at extreme pitch and skew angles. A subset of symbols with three X dimensions and two aspect ratios were selected from the test symbol data base. The symbol translation speed was 2.91 cm/s for all tests.

The test results indicate that symbols with larger X dimensions may be more easily scanned at extreme pitch or skew angles (see Table 3.3). The results also indicate that increased row height does not significantly affect the tendency of the scanner to read successfully at extreme angles. The maximum pitch or skew angle of 30° that could be tested was determined by limitations of the test setup. It is possible that scanning Code 49 bar codes could be successful at more extreme angles.

3.6 SUBSTRATE CURVATURE TEST

As a scanner is translated over a Code 49 symbol, it must read only one row in the symbol at a time. Therefore, careful alignment of the scanner with each row in a stacked bar code is critical for successful operation. Since a slight tilt angle is also required, scanning symbols on curved surfaces might be difficult if the height of the symbol is oriented parallel to the axis of curvature. A substrate curvature test was designed to determine the tendency of the Code 49 scanner to read symbols successfully from curved substrates.

Pieces of 6-, 4-, and 2-in. schedule 40 pipe were used to produce curved surfaces with 165-, 114-, and 63-mm diam. A conical surface identical to the fuze interface for a 155-mm artillery projectile was simulated by a 9-oz. clear plastic drinking cup. A subset of symbols with three X dimensions and two aspect ratios was selected from the test symbol data base. All symbols were oriented on the curved surfaces with the height of the symbol parallel to the axis of curvature. For all tests, the symbol translation speed was 2.91 cm/s, and the scanner distance was 25.4 cm.

The data in Table 3.4 show a reduced pass rate for the larger symbols attached to smaller diameter surfaces. The data also indicate that increasing the row height (aspect ratio) decreases the adverse effect.

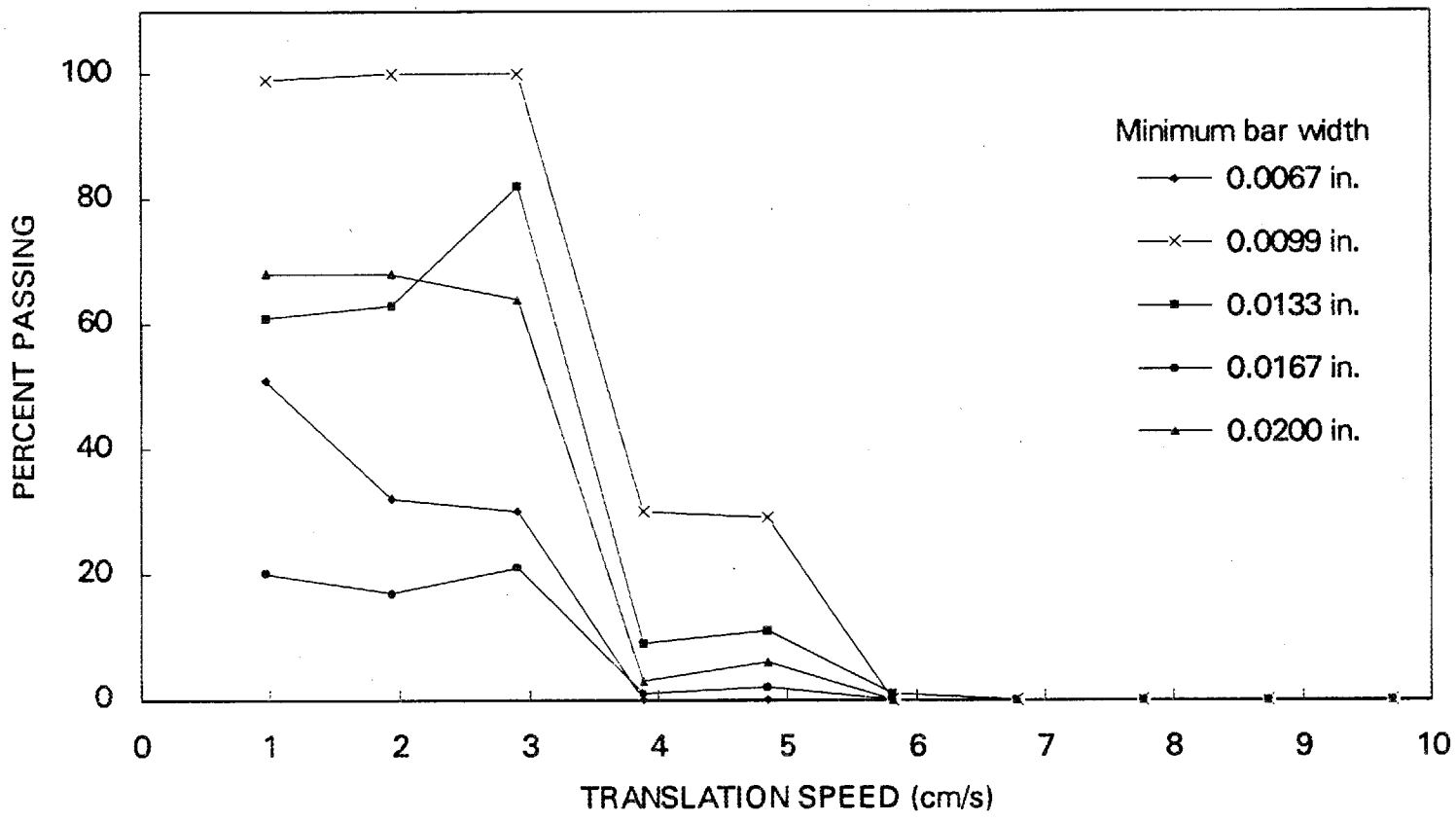


Fig. 3.2. Pass rates for various Code 49 symbols (aspect ratio 1:1) plotted against translation speed using a constant 12.7-cm scanner distance.

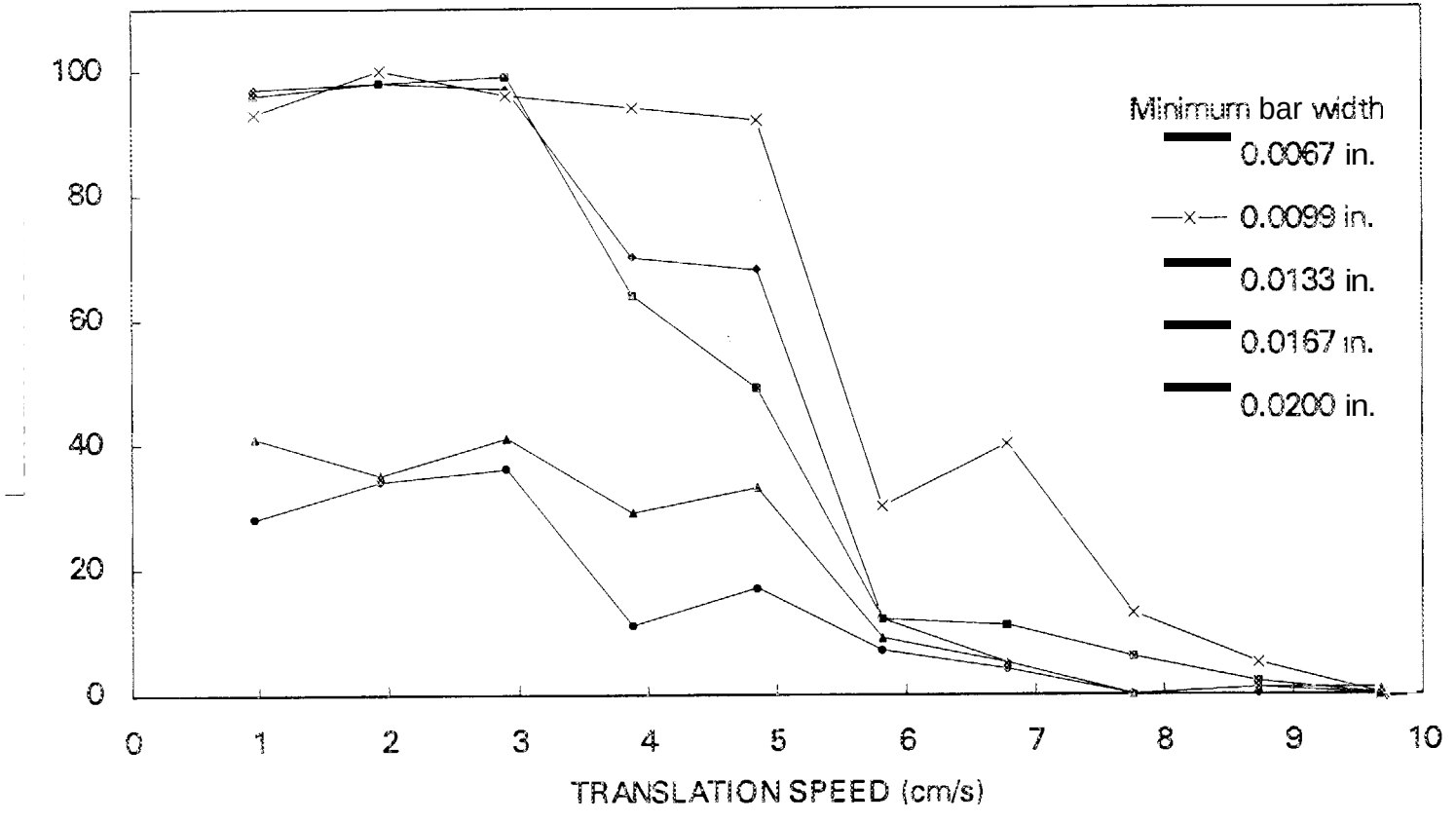


Fig. 3.3. Pass rates for various Code 49 symbols (aspect ratio 2:1) plotted against translation speed using a constant 12.7-cm scanner distance.

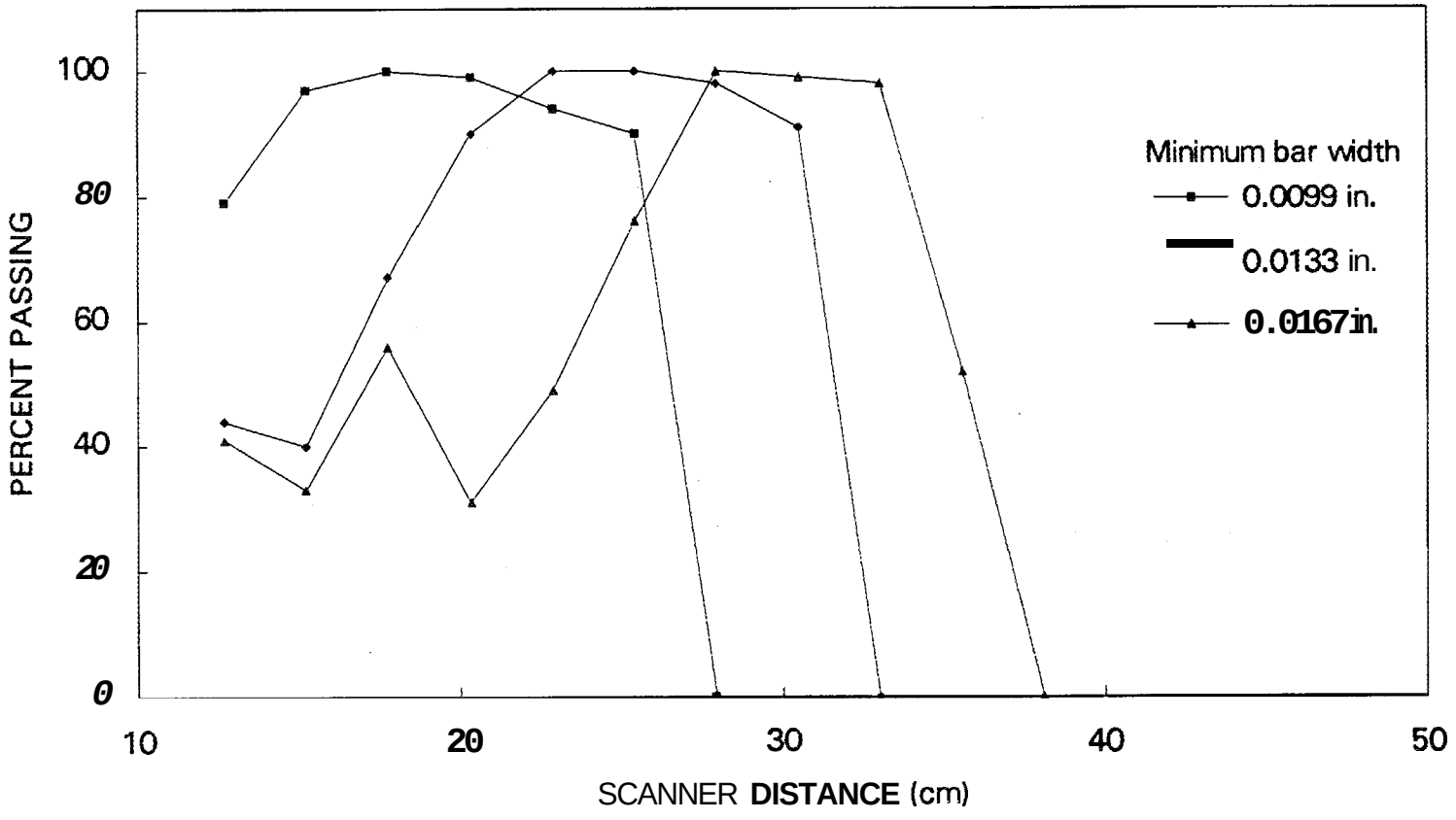


Fig. 3.4. Pass rates for various Code 49 symbols (aspect 1:1) plotted against scanner distance using a constant 2.91-cm/s symbol translation speed.

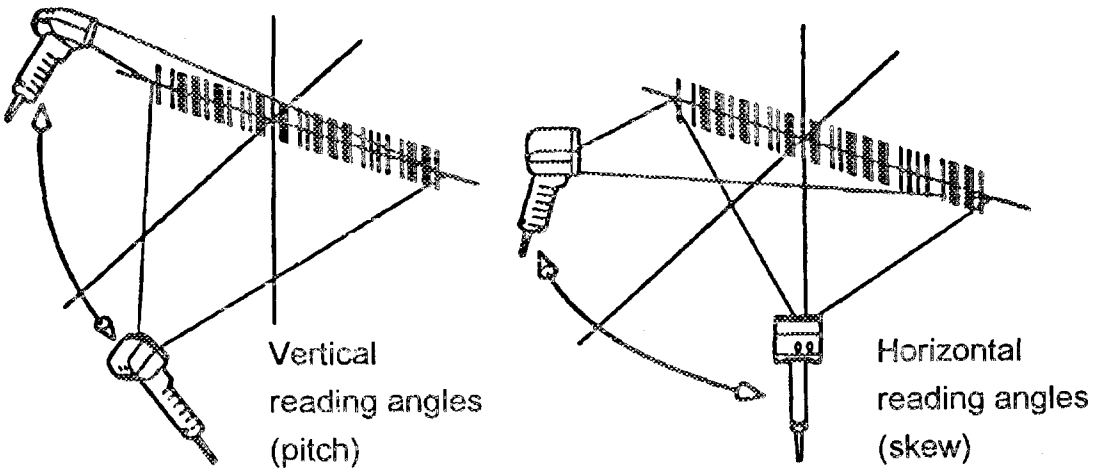


Fig. 3.5 Scanner pitch and skew angle.

Table 3.3. Pass rate results for various Code 49 symbols when changing the scanner pitch and skew angles

X dimension (mils)	Aspect ratio	Pitch angle/skew angle			
		15/0	30/0	0/15	0/30
9.9	1:1	43	0	0	0
	2:1	92	13	0	0
13.3	1:1	99	95	97	92
	2:1	100	100	86	100
16.6	1:1	74	99	100	100
	2:1	84	98	100	99

3.7 IMAGE CONTRAST TEST

Most symbol scanners require a minimum contrast ratio between the printed bar code and substrate material for reliable operation. Printed material, like bar code labels, can become bleached and lose contrast when exposed to intense sunlight for long periods. Also, most ammunition is painted either dark green, gray, or blue, and applying black data symbols directly to these colored substrates will create a low-contrast ratio. A test was designed to determine the effect that colored substrates might have on the tendency of a laser scanner to read Code 49 symbols.

Two symbols, with 49 characters encoded, were printed onto sheets of transparency film. Both symbols used an X dimension of 13.3 mils. The first symbol was printed with a 1:1 aspect ratio, while the second was printed with a 2:1 ratio. Two unpainted and five painted test plates

Table 3.4. Pass rate results for Code 49 symbols on curved surfaces

X dimension (mils)	Aspect ratio	Surface curvature: Flat	165 mm diam	114 mm diam	63 mm diam	Conical
10	1:1	43	3	25	0	0
	2:1	92	100	100	39	3
13.3	1:1	99	99	100	100	95
	2:1	100	99	100	0	99
16.7	1:1	74	96	97	44	40
	2:1	84	97	100	0	44

were also prepared for the test. The unpainted plates were samples of as-received aluminum and stainless steel. The surface of the aluminum had a slightly reflective appearance, while the stainless steel surface had a dull appearance. The colors chosen for the painted plates were typical 155-mm artillery projectile colors. (See Table 2.6 for the colors and the specific Federal Standard 595 color chip numbers.) The test procedure involved placing a symbol transparency on a test plate and scanning the combination with the scanner.

The results of the testing are presented in Table 3.5. As expected, black symbols on white and light green surfaces could be read easily. Dark green and blue are excellent absorbers of red light; therefore, symbols on these painted surfaces could not be scanned. The aluminum substrate and symbol could not be scanned because the substrate finish would not reflect enough light back to the scanner. However, the finish on the stainless steel plate was dull enough for successful scanning. The symbols on the gray painted surface were more easily scanned at a 2:1 aspect ratio than at a 1:1 ratio. This probably is because rows in the larger symbol (2:1 aspect ratio) remain under the scanner twice as long.

Table 3.5. Pass rate results for Code 49 symbols on various substrate colors

Aspect ratio	Substrate color: Aluminum	Stainless steel	Blue 35109	Dark green 34079	Gray 35231	Light green 34449	White 37875
1:1	0	100	0	0	58	99	97
2:1	0	100	0	0	100	100	100

3.8 DUPLICATION TEST

Photocopy and facsimile processes do not create a perfect duplicate. Image quality degrades for each generation of duplication. Since ammunition logistics records management will certainly require document duplication, printed data symbols should remain readable after several generations of duplication. A test was designed to determine the sensitivity of the pass rate response to symbol degradation caused by duplication processes.

Six symbols with 49 characters encoded were printed onto polyester labels which were then attached to sheets of paper. Pairs of symbols with aspect ratios of 1:1 and 2:1 used X dimensions of 13.3, 16.6, and 20 mils. Third- and sixth-generation photocopies and a facsimile were obtained for each symbol. The scanner translation speed for all symbols tested was 2.91 cm/s, and the scanner distance was 25.4 cm.

The test results, shown in Table 3.6, indicate that readability after photocopy duplication depends on the X dimension. For the 13.3-mil symbols, there was a slight loss of readability after the third generation photocopy and total failure of the symbol after six photocopy generations and the facsimile process. In contrast, the symbols with X dimensions of 16.6 and 20 mils remained readable after all duplication processes.

Table 3.6. Pass rate results for Code 49 symbols after being duplicated by photocopy and facsimile processes

X dimension (mils)	Aspect ratio	Original symbol	Third photocopy duplication	Sixth photocopy duplication	First facsimile duplication
13.3	1:1	95	87	0	0
	2:1	100	92	0	8
16.6	1:1	98	96	95	97
	2:1	94	100	100	99
20	1:1	84	99	98	74
	2:1	88	98	90	95

3.9 UNIFORM WEAR TEST

Under severe conditions, like blowing sand and rain, data symbols on ammunition will degrade from wear damage or erosion. Edge quality, contrast, and modulation could be affected. We assumed that this damage affects the symbol, not the substrate, and that this form of degradation will be uniformly distributed. A test was designed to determine the tendency of the Code 49 system to successfully read symbols degraded by uniform wear.

Sandblasting was chosen as the method to create uniform symbol wear, and the sandblasting chamber previously described in Sect. 2.11 was employed. For this test, Code 49 symbols with X dimensions of 10, 13.3, and 16.6 mil were printed onto 3-in.-square polyester labels. Since the Quickcheck 500 print quality verifier does not evaluate Code 49 symbols directly, a LOGMARS

bar code was printed onto each label as a control symbol. Print quality grades for each control symbol were determined, per American National Standards Institute (ANSI) X3.182-1990 guidelines, before and after each sandblasting exposure. During the test, all control symbols were decoded after 4 min of sand exposure; however, after 8 min the LOGMARS control symbols could not be decoded.

Recall that the ability to read bar codes with a laser scanner depends on the symbol's X dimension and distance. Similarly, Table 3.7 shows that symbol degradation has an adverse effect on the tendency to read Code 49 symbols.

Table 3.7. Print quality grades and pass rate results for Code 49 symbols with uniform wear caused by sandblasting

Sandblasting time (min)	X dimension (mils)	Aspect ratio	ANSI print quality grade	Pass rate
None	10	1:1	B	43
		2:1	B	92
	13.3	1:1	B	100
		2:1	B	100
	16.6	1:1	B	93
4	10	1:1	F	0
		2:1	F	0
	13.3	1:1		56
		2:1		100
	16.6	1:1	F	76
8	13.3	1:1		
		2:1		
	16.6	1:1		

3.10 SMOKE OBSTRUCTION TEST

Light traveling to and from a bar code scanner will be obstructed to some degree in environmental conditions such as fog, mist, or smoke. Significant obstructions from fog and mist usually require long distances, but smoke can be a significant obstruction at very short distances. The tendency of a scanner to read successfully is expected to decrease as the optical density of a smoke obstruction increases. See Sect. 2.12 for a definition of optical density and a description of the test apparatus used for this test.

During this test, a smoke chamber and laser photometer were used to measure the effect of optical obstruction on the tendency to successfully read a Code 49 symbol with a hand-held scanner. A Code 49 symbol having an X dimension of 20 mils and an aspect ratio of 1:1 was printed onto a 75-mm-square white polyester label. The test label was attached to a flat surface and suspended inside the smoke chamber approximately 25 cm from a clear glass observation window. The scanner, which could not be installed inside the smoke chamber, was held directly outside the observation window. With no smoke obstruction in the chamber, the Code 49 symbol was successfully scanned and decoded. The test procedure involved attempting scanner readings and recording photometer measurements after igniting a 30-s smoke bomb. Initially, the smoke obstruction was so dense that the symbol could not be decoded. As the smoke obstruction was gradually vented from the chamber, the symbol could only be decoded below an optical density of 0.1. This represents a 20% loss of light transmission.

4. SUMMARY AND CONCLUSIONS

A series of tests was conducted to evaluate the machine-readable two-dimensional symbologies called Datamatrix and Code 49. Two-dimensional symbols are being considered for potential use in ammunition logistics systems and automated reloading equipment. For this reason, the purpose of these evaluations was to determine the capabilities and limitations of the existing symbology and decoding hardware as they pertain to the diverse and harsh field environments in which they may be used for AAIT.

The Datamatrix system is extremely flexible and reliable, and performance can be optimized for AAIT. Testing has verified that the cell size of a printed symbol and the scanner optics must be selected to meet a minimum requirement. For reliable data capture, the scanner must digitize a 5- by 5-pixel array for each cell in a printed symbol. In a closed application, like AAIT, a standard character set, error correction level, and symbol matrix density can improve the first read rate and shorten decoding time. For ammunition reloading applications, bar coded information must be captured from moving objects at speeds up to 30 in./s. Using fast shutter speeds and high light levels, tests have verified that Datamatrix symbols moving at 120 in./s can be successfully decoded. The Datamatrix system can decode symbols on tilted or curved surfaces. Test results indicate that increasing scanner tilt angles decreases the tendency to read a symbol successfully. For AAIT applications, tilt angles should not exceed 30°. Successfully reading Datamatrix symbols from a curved surface depends upon the actual symbol size. Higher levels of error correction and longer data strings increase symbol size. Testing indicated that curved surfaces can degrade symbol readings when using small cell sizes and no error correction. For symbols encoding up to 100 characters with adequate cell size and error correction, no adverse effects were observed for surface radii down to 75 mm.

Good symbol contrast and bar edge quality are necessary for decoder systems that derive binary information from bar width measurements. The Datamatrix system is not based on this decoding scheme. Instead, the Datamatrix system is based on a coded matrix pattern of binary colored cells. The Datamatrix system simply detects a binary color at a location determined by the size of the overall symbol. This approach is less sensitive to symbol degradation since only symbol magnification and contrast assure successful decoding. The color contrasts for symbols on various painted artillery projectiles range from high-contrast black on white to low-contrast black on dark green. Ideally, the highest contrast between the symbol and its background should be provided. When marking artillery projectiles of various colors, a white substrate under a black symbol is desirable.

Error correction is a significant feature of the Datamatrix symbology. Tests have indicated that Datamatrix symbols degraded by photocopy or facsimile duplication can be decoded successfully if adequate error correction and symbol size are used. Symbols could also be successfully scanned after degradation from sandblasting. Damaged symbols with marks, tears, or voids can be read successfully if error correction is employed during data encoding and symbol printing. The Datamatrix system outperforms existing laser scanners when using machine-readable symbols in a smoke-filled environment.

Stacked bar symbols, like Code 49, are designed to be read with a moving beam scanner rather than with a fixed beam or pencil device. The rows in a stacked symbol can be scanned in any order. The reader keeps track of the row numbers and the total number of rows to expect. An audible click is sounded only when a new row is scanned, and a beep is sounded when all rows are completely decoded. The performance of any bar code system depends on the equipment. Several vendors offer equipment for printing and decoding stacked bar code symbols. Scanner raster speed, optimum focal distance, and decode algorithm can vary with different equipment vendors. The Code 49 testing conducted for this study used equipment from only one vendor (Intermec) and, therefore, the results presented in this report provide only a sample of typical Code 49 system performance.

A series of tests was conducted to evaluate the relationship between fundamental symbol characteristics and scanner distance and motion. The X dimension, or minimum bar width, is a fundamental characteristic of bar code symbols and defines the overall symbol size for any given data string. Aspect ratio, which defines the relationship of symbol height and width, is another fundamental characteristic of bar code symbols. The optimum range for a bar code scanner depends on a symbol's X dimension. Smaller symbols require shorter scanner distances, while larger symbols allow longer distances. Tests indicated that symbols printed with a 10-mil X dimension and a 2:1 aspect ratio can be scanned reliably while moving at speeds up to 4.85 cm/s from a distance of 12.7 cm. This maximum speed is still too slow for most ammunition rearm applications.

Tests were also conducted to evaluate the impact of scanner direction and curved symbol substrates on the tendency to successfully read Code 49 symbols. For a hand-held laser scanner to operate properly, a slight pitch or skew angle is required between the scanner and symbol to prevent the scanner from being blinded by a specular reflection of the laser beam from the symbol surface. Testing has determined that skew and pitch angles up to 30° can be used without adversely affecting system performance. Code 49 symbols can also be attached to curved surfaces. Tests also verified that Code 49 symbols can be successfully scanned from a curved surface if the row height of the symbol is sufficient to accommodate the line path of the scanner.

The scanner technology used for decoding LOGMARS symbols is also used for Code 49 symbols. The only difference is the algorithm employed for symbol decoding. Most moving beam scanners incorporate a visible diode laser and retro-reflective optic system. Since Code 49 does not provide any error correction capability, read success depends heavily on symbol print quality and environmental conditions. Bar code symbols are not readable if printed directly onto surfaces that completely absorb or reflect the scanning laser (e.g., dark green or blue ammunition would require a white substrate for black bar code symbols). To minimize any adverse affects of symbol degradation caused by duplication or uniform wear, Code 49 symbols should be printed with the largest X dimension feasible. Bar code reading is adversely affected when smoke is present in the scanning environment.

5. RECOMMENDATIONS

Stacked bar code symbologies, like Code 49, are not recommended for automated ammunition rearm and resupply applications. The data content for a Code 49 symbol is limited to only 49 characters. Without error correction capabilities, stacked bar code systems depend on good symbol print quality for success. Moving beam scanners used for stacked bar codes cannot reliably capture machine-readable data from symbols moving at high speed. ~~Compared to more recently developed two-dimensional symbologies, stacked bar codes have no advantages.~~

A matrix symbology and scanning system are recommended for ammunition rearm and resupply applications involving machine-readable data. One matrix symbology, Datamatrix, can encode up to 2000 characters with optional error correction capabilities. Printing and decoding equipment are available for Datamatrix, and support continues to grow. The symbology has been submitted for use in the public domain. The scanning camera used by the Datamatrix system is more appropriate than moving beam laser scanners for acquiring machine-readable data at high speeds. ~~Existing off-the-shelf machine vision equipment can decode symbols containing 100 characters with error correction moving at over 1 m/s.~~ The current Datamatrix system can decode approximately 2 symbols/s, but an improved system is currently being developed which uses a special camera and strobe to freeze high-speed symbol motion and employs a high-speed microprocessor to decode up to 15 symbols/s. It also uses gray scale image processing to decode very low-contrast symbols. ~~Other matrix symbologies, namely Vericode and Code 1, are available but have not gained as much industry support as Datamatrix.~~

REFERENCE

1. D. G. Priddy and R. S. Cymbalski, "Dynamically Variable Machine Readable Binary Code and Method for Reading and Producing Thereof," U.S. patent 4,939,354, July 3, 1990.

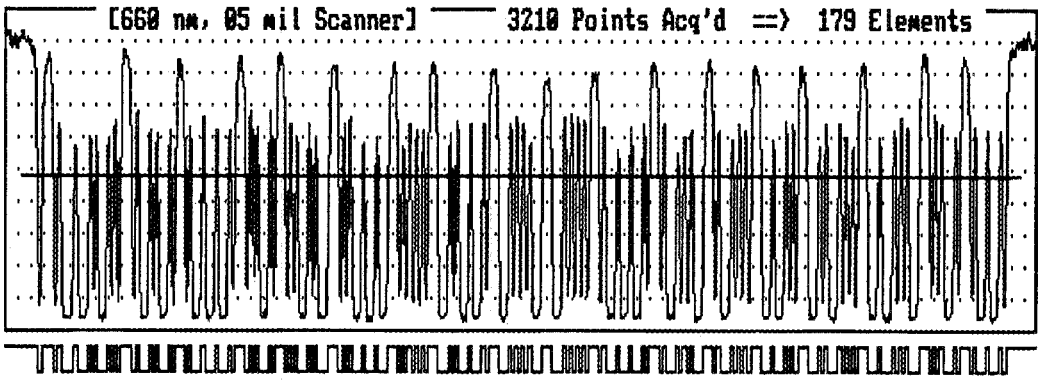
APPENDIX A
DESCRIPTION OF DATAMATRIX TEST SYMBOLS

Table A.1 gives a description of the Datamatrix test symbols.

Table A.1. Description of Datamatrix test symbols

Symbol number	Error correction level	Cell size (in.)	Characters in symbol	Matrix density	Total symbol size (in.)
1	0	0.0200	50	20	0.400
2	0	0.0200	100	27	0.540
3	0	0.0200	250	40	0.800
4	0	0.0200	500	55	1.100
5	0	0.0233	50	20	0.466
6	0	0.0233	100	27	0.629
7	0	0.0233	250	40	0.932
8	0	0.0233	500	55	1.282
9	0	0.0266	50	20	0.532
10	0	0.0266	100	27	0.718
11	0	0.0266	250	40	1.064
12	0	0.0266	500	55	1.463
13	0	0.0300	50	20	0.600
14	0	0.0300	100	27	0.810
15	0	0.0300	250	40	1.200
16	0	0.0300	500	55	1.650
17	8	0.0200	50	25	0.500
18	8	0.0200	100	33	0.660
19	8	0.0200	250	49	0.980
20	8	0.0200	500	67	1.340
21	8	0.0233	50	25	0.583
22	8	0.0233	100	33	0.769
23	8	0.0233	250	49	1.142
24	8	0.0233	500	67	1.561
25	8	0.0266	50	25	0.665
26	8	0.0266	100	33	0.878
27	8	0.0266	250	49	1.303
28	8	0.0266	500	67	1.782
29	8	0.0300	50	25	0.750
30	8	0.0300	100	33	0.990
31	8	0.0300	250	49	1.470
32	8	0.0300	500	67	2.010
33	13	0.0200	50	34	0.680
34	13	0.0200	100	45	0.900
35	13	0.0200	250	68	1.360
36	13	0.0200	500	94	1.880
37	13	0.0233	50	34	0.792
38	13	0.0233	100	45	1.049
39	13	0.0233	250	68	1.584
40	13	0.0233	500	94	2.190
41	13	0.0266	50	34	0.904
42	13	0.0266	100	45	1.197
43	13	0.0266	250	68	1.809
44	13	0.0266	500	94	2.500
45	13	0.0300	50	34	1.020
46	13	0.0300	100	45	1.350
47	13	0.0300	250	68	2.040
48	13	0.0300	500	94	2.820

APPENDIX B
PRINT VERIFIER RESULTS FOR DATAMATRIX DUPLICATION TEST



Code 39: *ABC123456789	Prnt Con Sig = 96% OK!	MessageLength = 16 OK!
0 02*	R(L)=92% R(D)=03% OK!	- No Check Character -
	Symbol Contr = 89% (A)	Message Format is OK!
W/N Ratio = 2.8 OK!	Global Thr. Passes (A)	
AverageBar = -.01X OK!	R(min)/R(max)= 03% (A)	
Ref. Decode Passes (A)	Modulation = 50% (C)	Traditional Tests PASS
Decodeability = 68% (A)	EdgeCon(min) = 44% (A)	
Symbol Totals 276 X	'Defects' = 05% (A)	Print Quality Grade (C)

Fig. B.1. Quickcheck 500 print verifier results of LOGMARS control symbol after first-generation photocopy.

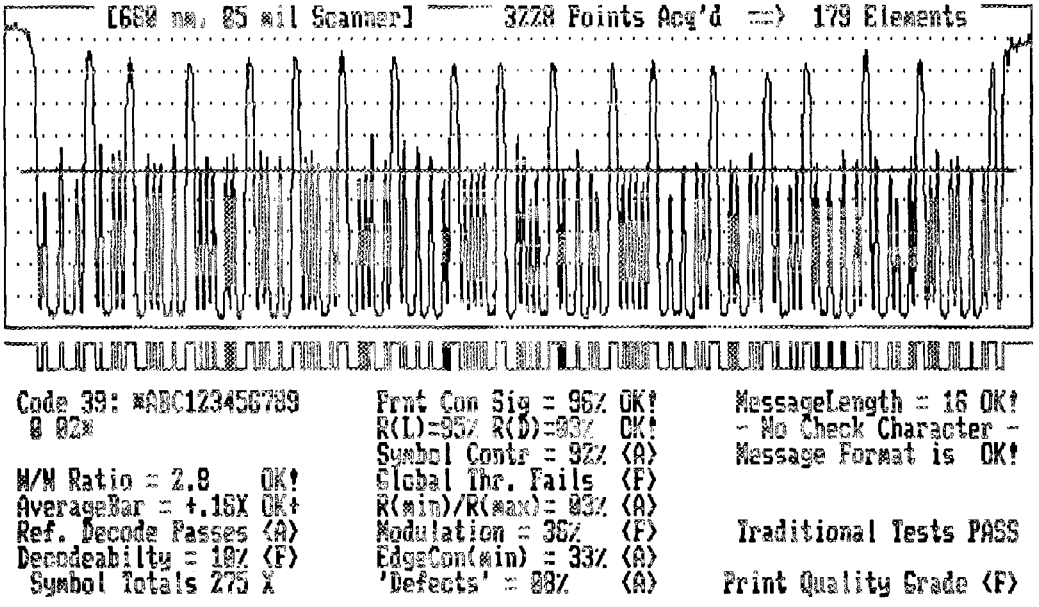


Fig. B.2. Quickcheck 500 print verifier results of LOGMARS control symbol after second-generation photocopy.

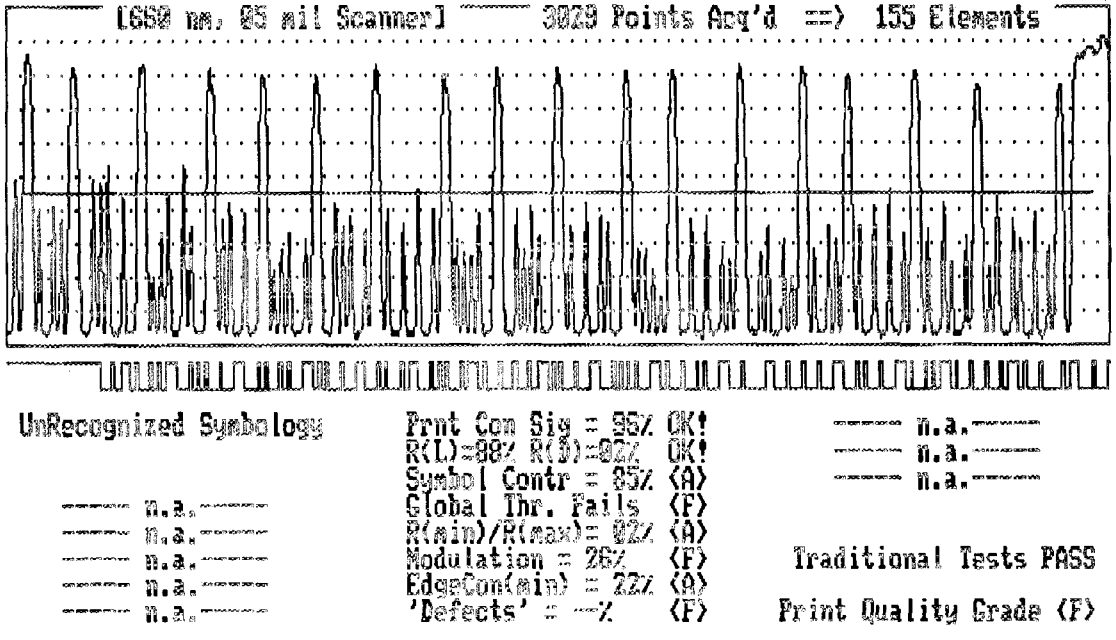
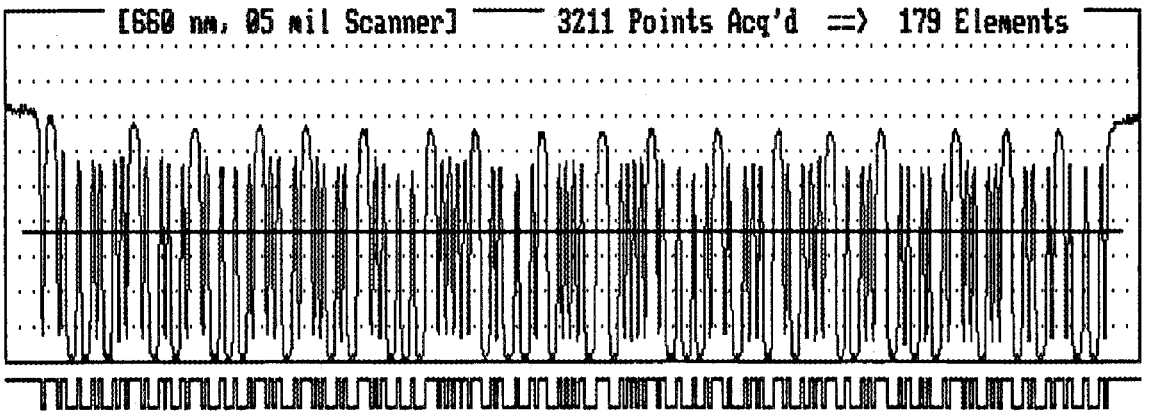


Fig. B.3. Quickcheck 500 print verifier results of LOGMARS control symbol after third-generation photocopy.

APPENDIX C
PRINT VERIFIER RESULTS FOR THE DATAMATRIX UNIFORM WEAR TEST



LOGN: *ABC1234567890 1
4*

W/N Ratio = 2.9 OK!
AverageBar = -.09X OK!
Ref. Decode Passes (A)
Decodeabilty = 67% (A)
Symbol Totals 281 X

Prnt Con Sig = 98% OK!
R(L)=73% R(D)=01% OK!
Symbol Contr = 71% (A)
Global Thr. Passes (A)
R(min)/R(max)= 01% (A)
Modulation = 66% (B)
EdgeCon(min) = 48% (A)
'Defects' = 00% (A)

MessageLength = 16 OK!
- No Check Character -
Message Format is OK!

Traditional Tests PASS

Print Quality Grade (B)

Fig. C.1. Scan profile of control symbol 14 before sand abrasion.

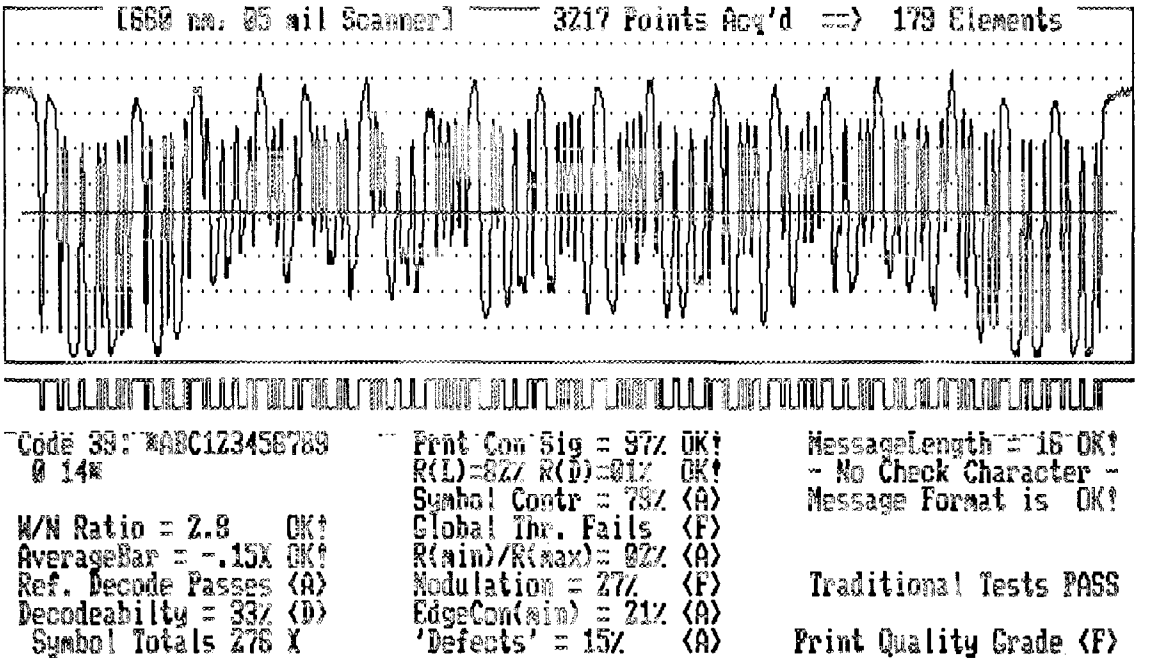


Fig. C.2. Scan profile of control symbol 14 after 4 min of sand abrasion.

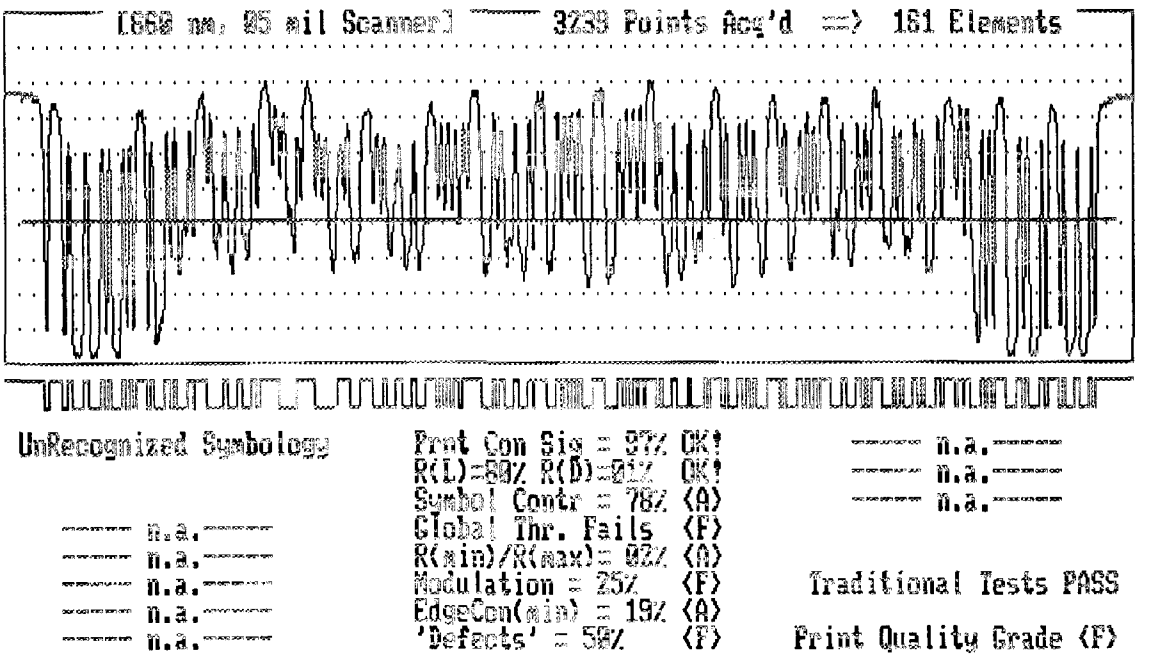


Fig. C.3. Scan profile of control symbol 14 after 8 min of sand abrasion.

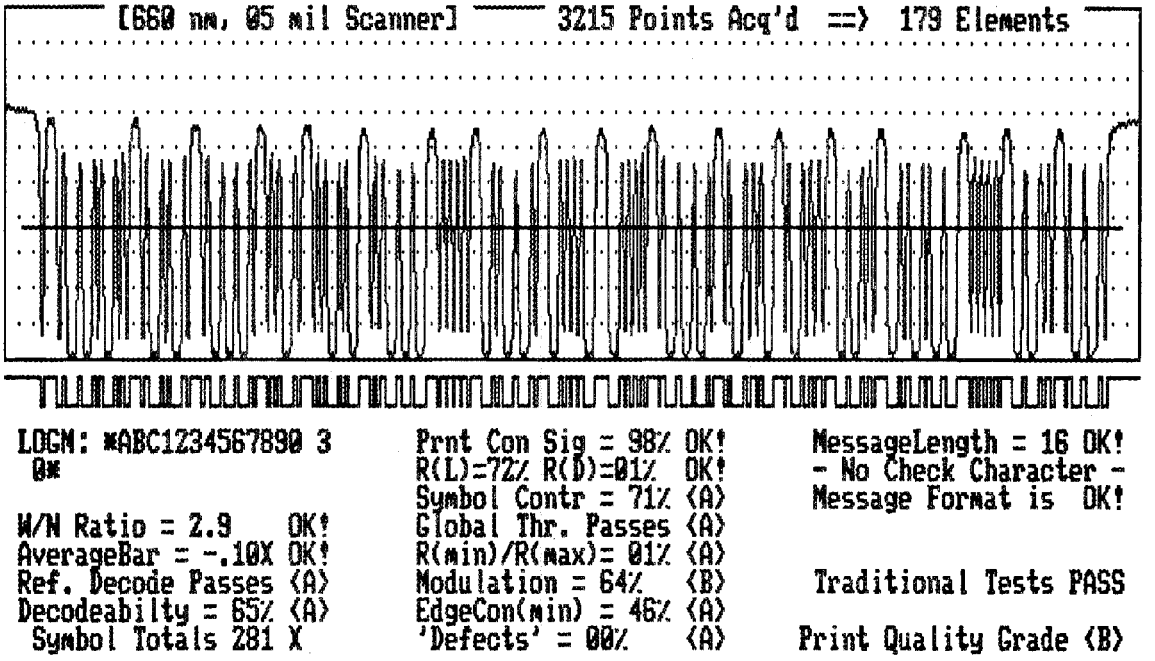


Fig. C.4. Scan profile of control symbol 30 before sand abrasion.

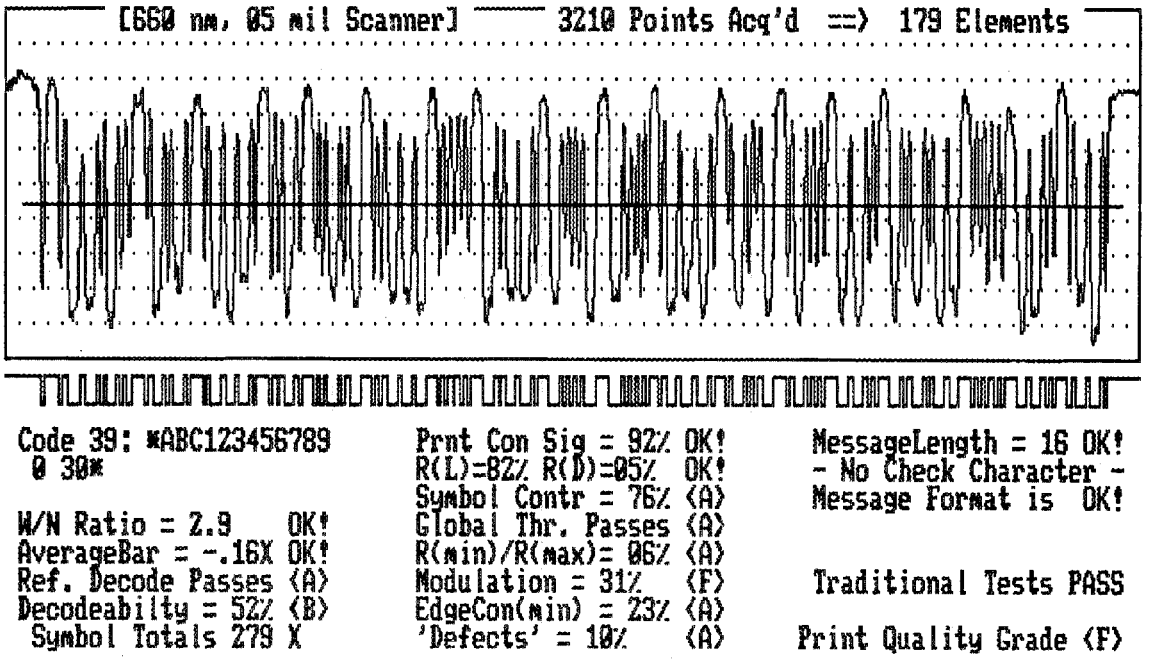


Fig. C.5. Scan profile of control symbol 30 after 4 min of sand abrasion.

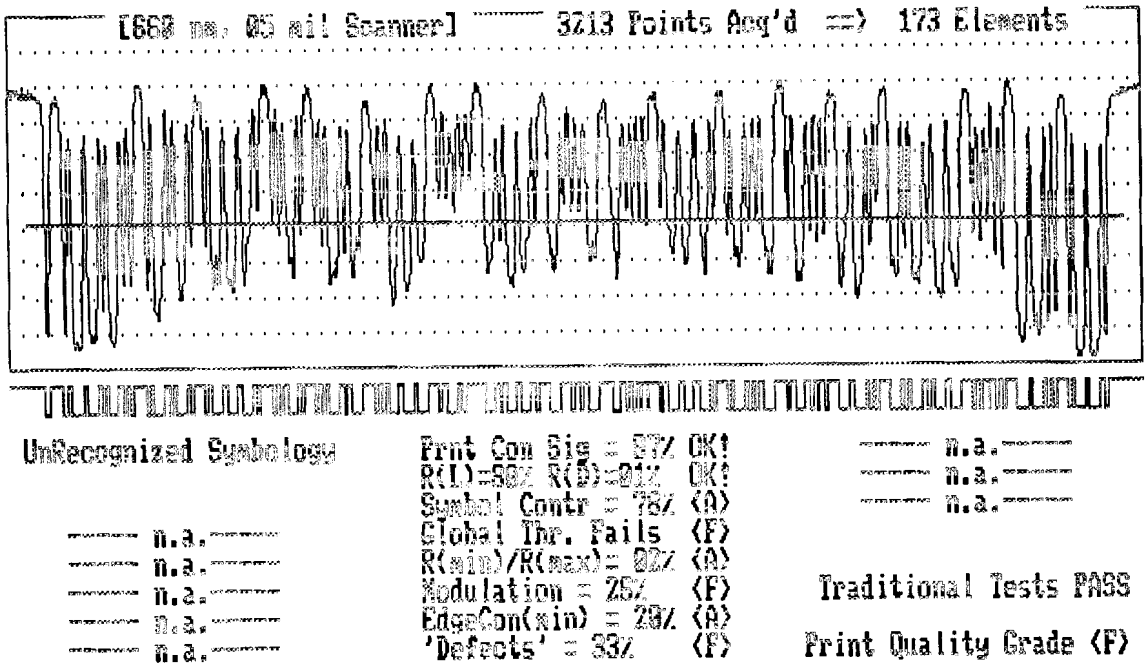


Fig. C.6 Scan profile of control symbol 30 after 8 min of sand abrasion.

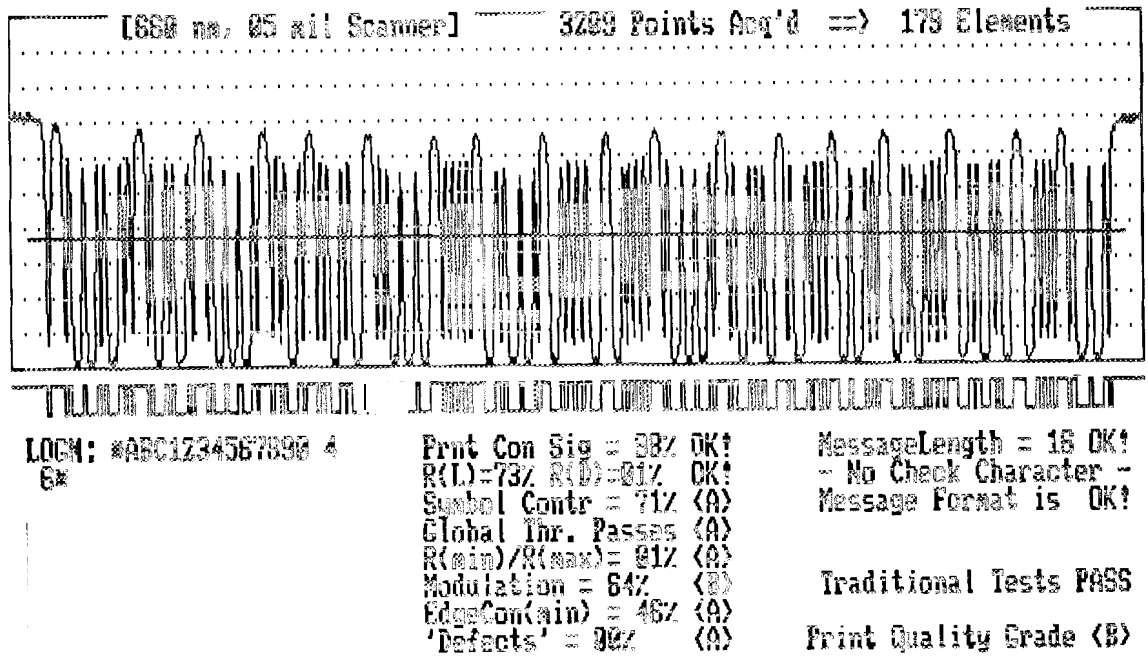


Fig. C.7. Scan profile of control symbol 46 before sand abrasion.

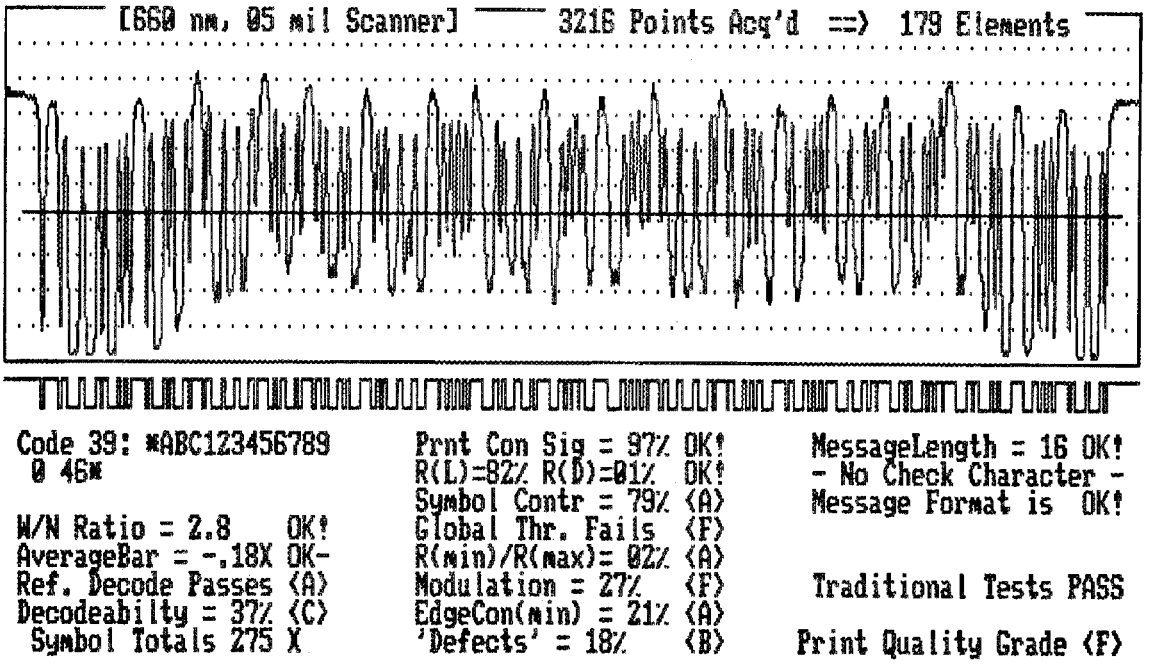


Fig. C.8. Scan profile of control symbol 46 after 4 min of sand abrasion.

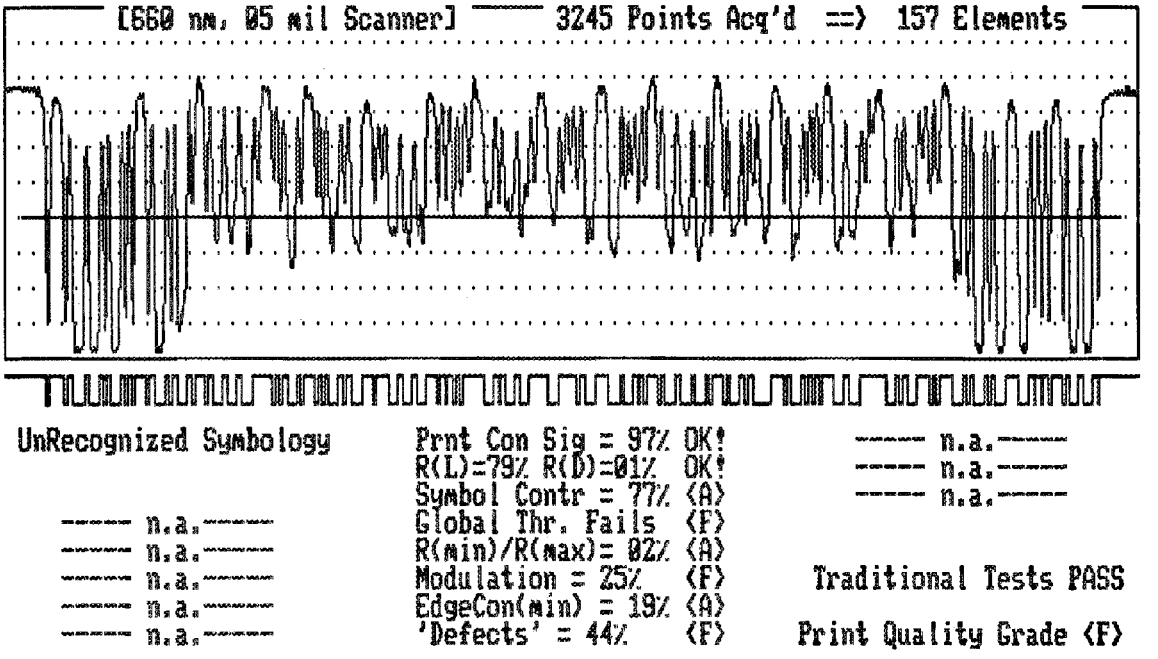


Fig. C.9. Scan profile of control symbol 46 after 8 min of sand abrasion.

APPENDIX D
DESCRIPTION OF CODE 49 TEST SYMBOLS

All Code 49 symbols used for evaluation testing were printed on white polyester label stock (Zebra Z-Ultimate 5A) using black thermal transfer ribbon. The printer used was a thermal transfer printer (Zebra Model Z91). The printer and printer supplies are available from Zebra Corporation. Table D.1 describes the printing parameters for each symbol tested. Each symbol contained the same 49-character message.

Table D.1. Printing parameters for Code 49 test symbols (using 49-character message)

Symbol No.	X dimension (in.)	Height multiplier	Aspect ratio	Symbol width (in.)	Symbol height (in.)
1	0.0066	8	1:1	0.500	0.438
2	0.0066	16	2:1	0.500	0.875
3	0.0100	8	1:1	0.813	0.750
4	0.0100	16	2:1	0.813	1.375
5	0.0133	8	1:1	1.063	0.938
6	0.0133	16	2:1	1.063	1.813
7	0.0166	8	1:1	1.375	1.188
8	0.0166	16	2:1	1.375	2.250
9	0.0200	8	1:1	1.625	1.438
10	0.0200	16	2:1	1.625	3.750

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4 WBA

AUTHOR: Thomas, Charles M.

TITLE: Radio tags, bar codes speed up supply system (automatic border checks of automotive supply trucks)

SOURCE: Automotive News (ISSN:0005-1551) p 10i December 12 '94 supp Insight

ABSTRACT: Radio frequency identification and two-dimensional (2-D) bar tags are capable of speeding up the delivery process and helping automakers and suppliers succeed at just-in-time delivery. The Automotive Industry Action Group and the U.S. and Canadian customs departments are developing a pilot program to test radio frequency identification of shipments across the border. Data on shipments would be transmitted by computer to Customs when the parts are loaded on the dock, so border clearances can be done in advance. A trial of the system is possible as early as 1995. Meanwhile, the use of bar codes and electronic data interchange is quickly moving down to first- and second-tier suppliers, says Wayne Metcalfe, president of Bar Code Solutions in Troy, Mich. The new 2-D bar code, which resembles a 1-inch square checker board, enables a shipper to put a lot more information on a package. Radio frequency identification and 2-D bar codes are discussed.

SUBJECTS COVERED:
Bar coding
Customs administration/Electronic data interchange
Radio frequency
Automotive parts industry/Electronic data interchange
Communications satellites/Transportation use

SIC CODES:
9311 (Finance, taxation, & monetary policy)
4812 (Radiotelephone communications)
3714 (Motor vehicle parts and accessories)
3663 (Radio & TV communications equipment)

2 WBA
AUTHOR: Saccomano, Ann
TITLE: Technology and logistics: move it or lose it
SOURCE: Traffic World (ISSN:0041-073X) v 241 p 36-7 January 2 '95
CONTAINS: illustration(s)
ABSTRACT: Shippers and carriers are turning to technology to improve the ways they move freight and information about that freight. The gains they can achieve from supply-chain management, intelligent transportation systems, bar coding, radio frequency technology, global positioning systems, and the Internet and online services are discussed.

SUBJECTS COVERED:
Intelligent vehicle highway system
Bar coding
Global Positioning System
Radio frequency identification system
Business logistics

SIC CODES:
3812 (Search and navigation equipment)
3663 (Radio & TV communications equipment)
4731 (Freight transportation arrangement)

3 WBA
AUTHOR: McClintock, R. S.
TITLE: The bar code revolution
SOURCE: Fueloil & Oil Heat with Air Conditioning (ISSN:1060-9725) v 54 p 40 January '95
CONTAINS: illustration(s)
ABSTRACT: Fuel oil companies should utilize the industry standard Code 39 for bar coding to greatly reduce data entry time and provide greater accuracy. Bar codes contain important information relevant to deliveries, payments, and service parts inventory, such as delivery ticket numbers, invoice numbers, account numbers, burner service work order numbers, and prices. As a result, fuel oil companies can cut their operating costs through greater productivity, improved accuracy, and improved customer service. Moreover, peak winter data entry time is reduced, and data accuracy, when combined with a check digit number, is assured.

SUBJECTS COVERED:
Oil delivery
Fuel oil industry/Data processing
Bar coding

SIC CODES:
2911 (Petroleum refining)
5983 (Fuel oil dealers)

5 WBA
AUTHOR: Kahan, Stuart
TITLE: It's not just for supermarkets anymore (bar coding)
SOURCE: The Practical Accountant (ISSN:0032-6321) v 27 p 39-41 December '94
ABSTRACT: Accountants can use bar codes to keep track of client files and the status of tax returns. Clients that must count and keep track of items in inventory or where something is in the manufacturing process can

also benefit from bar coding. A bar code is a printed pattern that contains the coding for data such as the price, warehouse location, or date of manufacture of an item. The bar code can be read by a computer by means of optical scanning, either by a laser beam or by a wand that contains a light source and a photocell. The return on investment provided by bar coding is discussed, and a sidebar lists some of the companies that are involved in supplying bar-code packages.

SUBJECTS COVERED:
Bar coding
Accounting firms/Data processing

SIC CODES:
8721 (Accounting, auditing, & bookkeeping)

7 WBA
AUTHOR: Rao, Srikumar S.
TITLE: Tomorrow's Rosetta Stones (two-dimensional bar codes)
SOURCE: Financial World (ISSN:0015-2064) v 163 p 70-2 November 22 '94
CONTAINS: illustration(s)
ABSTRACT: Two-dimensional bar coding promises to be one of those "transformational technologies" that make business processes in a wide range of industries faster, cheaper, and more reliable. Symbol Technologies, a $355 million-in-sales Bohemia, N.Y.-based manufacturer of scanning equipment, is one of the leaders in this emerging field. Selected two-dimensional bar coding applications that use Symbol equipment are described.

CORPORATIONS COVERED:
Symbol Technologies Inc./Products (SIC 3577)

SUBJECTS COVERED:
Bar coding

9 WBA
AUTHOR: Cooke, James Aaron
TITLE: A quick scan of bar codes' future (use by almost all American warehouses by year 2000 predicted in interview with D. Anderson)
SOURCE: Traffic Management (ISSN:0041-0691) v 33 p 76S-78S September '94
CONTAINS: portrait
ABSTRACT: In an interview, Don Anderson, executive director of the bar-code industry trade group AIM USA, discusses where the bar-code industry is going and how those changes will affect warehousing professionals. Anderson also talks about the new symbologies or codes under development; the role that bar codes play in cross docking and continuous replenishment; the use of radio frequency, 2-D bars, and portable databases; the outlook for voice recognition systems; and steps that warehouse managers can take to prepare themselves for the bar-code environment.

SUBJECTS COVERED:
Bar coding
Warehouses/Automation
Warehouses/Forecasting
Anderson, Don

SIC CODES:
4220 (Public warehousing and storage)

12 WBA
TITLE: Lotus follows: the bar code route through manufacturing and distribution
SOURCE: Industry Week (ISSN:0039-0895) v 243 p 3-4+ May 2 '94 supp Automatic Data Collection Management
CONTAINS: illustration(s)
ABSTRACT: Part of a supplement on automatic data collection management. By implementing a bar code automatic identification system for manufacturing and distribution, Lotus Development Corporation, a desktop productivity software maker, improved product quality and reduced defects; upgraded the accuracy of orderpicking and shipping; and implemented traceability of shipments for all distribution issues, including illegal copying. In addition to the bar coding system, Lotus uses a product called Notes, a client server platform for developing and deploying groupware applications that features security, communications, application development, and document database technologies. The combination of these two systems enables the Cambridge, Mass.-based company to run a virtually paperless enterprise. The bar coding process is described.

CORPORATIONS COVERED:
Lotus Development Corporation/Information systems (SIC 7372)

SUBJECTS COVERED:
Bar coding
Automatic identification systems

SIC CODES:
3577 (Computer peripheral equipment, nec)

13 WBA
AUTHOR: Andren, Emily A.
TITLE: Makeover gives warehouse more store-power (bar coding, automation technology adopted at YoungWorld facility)
SOURCE: Transportation & Distribution (ISSN:0895-8548) v 35 p 96+ May '94
CONTAINS: illustration(s)
ABSTRACT: In an effort to cope with increasing demand, YoungWorld, a growing children's apparel and furniture retailer, has augmented its warehouse merchandising system to use bar code scanning and eliminate paperwork and duplication. In doing so, YoungWorld contracted IBM to review its plans for its distribution center, complete a requirements study and benefits analysis, and assume overall responsibility for the management and satisfactory delivery of the project. IBM, in turn, hired Logistics Solutions, a warehouse software and consulting firm, to reconfigure the distribution center and develop a warehouse automation system that would tie into the existing IBM AS/400 system. With the new system, YoungWorld has been able to reduce its warehouse overhead by 25 percent with a pay-back period of slightly over 2 years.

CORPORATIONS COVERED:
YoungWorld (Firm)/Automation (SIC 5641)

SUBJECTS COVERED:
Bar coding

Warehouses/Automation

SIC CODES:
4220 (Public warehousing and storage)

19 WBA
TITLE: UPS adds technology, hikes rates
SOURCE: Transportation & Distribution (ISSN:0895-8548) v 35 p 18 February '94
CONTAINS: illustration(s)
ABSTRACT: United Parcel Service, which has invested $2 billion in technology over the last five years, has recently put two new devices, DIAD II and MaxiCode to work. DIAD II is a more compact, powerful, and efficient version of DIAD, a device that electronically captures both package information and a signature. MaxiCode, a new two-dimensional machine readable code, will initially be used on package labels to carry destination and tracking information and data for providing additional customer services. The carrier has also announced that it will raise overall rates for domestic ground and air shipments by 3.9 percent.

CORPORATIONS COVERED:
United Parcel Service of America, Inc./Rates (SIC 4215)

SUBJECTS COVERED:
Parcel delivery service/Rates
Bar coding

SIC CODES:
4513 (Air courier services)
4215 (Courier services, except by air)

20 WBA
AUTHOR: Bonney, Joseph
TITLE: Bar codes and logistics
SOURCE: American Shipper (ISSN:0160-225X) v 36 p 62-4 January '94
ABSTRACT: Black-and-white printed symbols, known as bar codes, that are designed to be decoded by electronic scanners will play an increasingly important role in the future of logistics. Bar codes allow for improved tracking, tighter inventory control, more accurate sales data, and better productivity through the elimination of manual data entry. In order to achieve the maximum benefits through the supply chain, companies must develop common bar code systems with vendors and suppliers. Many consider 2-dimension bar codes such as the one recently introduced by the United Parcel Service to be the way of the future.

SUBJECTS COVERED:
Business logistics/Electronic data interchange
Bar coding

SIC CODES:
4731 (Freight transportation arrangement)

4 WBA
AUTHOR: Levy, Clifford J.
TITLE: A product code leaves the straight and narrow (new U.P.S. code, Maxicode)
SOURCE: New York Times (Late New York Edition) (ISSN:0362-4331) p D4

November 16 '93

ABSTRACT: United Parcel Service yesterday introduced a new kind of product code that can hold 100 characters of data in a square inch, considerably more than a typical bar code. The Maxicode, which is slightly larger than a stamp and looks like a bull's-eye surrounded by an array of black hexagons, is part of a new generation of codes that are read in two dimensions.

CORPORATIONS COVERED:
United Parcel Service of America, Inc. (SIC 4215)

SUBJECTS COVERED:
Bar coding

25 WBA
AUTHOR: Jancsurak, Joe
TITLE: Bar coding/electronic data interchange (applications in the appliance industry; special report)
SOURCE: Appliance Manufacturer (ISSN:0003-679X) v 41 p 89-93 November '93
CONTAINS: illustration(s)

ABSTRACT: A special report on automated testing systems for appliances features articles on the applications of bar-coding, electronic data interchange, automatic identification systems, and modular-distributed data-acquisition and control systems for appliance manufacturers.

SUBJECTS COVERED:
Bar coding
Household appliance industry/Electronic data interchange

SIC CODES:
3630 (Household appliances)

29 WBA
AUTHOR: Bonney, Joseph
TITLE: Lusk creates documents from bar codes (automated shipping data system for Maritrop Trading)
SOURCE: American Shipper (ISSN:0160-225X) v 35 p 44 July '93
CONTAINS: diagram

ABSTRACT: Lusk Shipping, a New Orleans-based freight forwarder and customs broker, has introduced a system that combines bar coding and computers to automate documentation and manage data connected with imports and exports. The Luskcom system is used to control and monitor the southbound freight shipped by Maritrop Trading, the Chiquita Brands subsidiary, to points in Central and South America. With Luskcom, cargo arriving at the consolidation warehouse is bar coded and scanned-in by workers using portable data terminals. Once the basic data are scanned into the system, the documentation is basically a byproduct, according to Lusk vice-president Eric Vargas. The automated system is scheduled to be extended to cover Maritrop's exports of linerboard, with bar code labels to be affixed to the linerboard; documentation would then be handled electronically. A diagram of how the Luskcom system manages Maritrop's exports is presented.

CORPORATIONS COVERED:
Lusk Shipping Co./Contracts (SIC 4731)
Maritrop Trading Corporation/Export-import trade (SIC 7389)

SUBJECTS COVERED:
Shipping/Electronic data interchange
Export-import documentation
Bar coding

SIC CODES:
4412 (Deep sea foreign trans. of freight)

30 WBA
AUTHOR: Robins, Gary
TITLE: Label program update (UCC-128 Serial Shipping Container Label)
SOURCE: Stores (ISSN:0039-1867) v 75 p 57 July '93
ABSTRACT: At least 6 of the top retailers in the U.S. will begin receiving against the UCC-128 Serial Shipping Container Label (SCL) in the second quarter of 1994. Among the retail chains that have developed applications to use UCC-128 are Kmart, JCPenney, Mercantile, and K-G Men's Stores; together, these retailers have a volume in excess of $50 billion. VICS came up with the concept of the SCL as part of its vision for streamlining the order cycle. The label, which is applied by the vendor, is an integral part of implementing the cross-docking of containers in retail distribution centers. Several retailers' UCC-128 plans are discussed.

SUBJECTS COVERED:
Bar coding

31 WBA
AUTHOR: Goltz, Rick
TITLE: 2-D bar codes put carriers in your EDI loop
SOURCE: Transportation & Distribution (ISSN:0895-8548) v 34 p 76+ May '93
CONTAINS: illustration(s)
ABSTRACT: A successful EDI program benefits every partner in the distribution chain. Customers receive more accurate deliveries, shippers get more accurate billing, and carriers benefit from more efficient acquisition of bills of lading. Symbol Technologies' PDF417 symbology provides a paper media technique to encode an entire bill of lading. The bill can be printed directly on an existing laser-printed form, and the receiving organization uses a hand-held device to scan the symbol into its computer system. Software developer Vocam Systems is field-testing PDF417 in cooperation with Consolidated Freightways.

CORPORATIONS COVERED:
Consolidated Freightways, Inc./Information systems

SUBJECTS COVERED:
Bar coding
Bills of lading
Trucking industry/Electronic data interchange

SIC CODES:
4731 (Freight transportation arrangement)
4213 (Trucking, except local)

36 WBA
AUTHOR: Pavely, Richard W.
TITLE: Automation bringing changes to USPS (Delivery Point Barcoding; transition to 11-digit ZIP code)

SOURCE: The Office (ISSN:0030-0128) v 117 p 42 January '93
ABSTRACT: The U.S. Postal Service's move to full automation has reached a significant stage that will affect mailroom management. The USPS is making the transition to Delivery Point Barcoding, which involves moving from the 9-digit ZIP+4 code to an 11-digit ZIP code. This transition will go unnoticed by the public, however, as the extra 2 digits will be represented only within the POSTNET barcode and not in the human-readable address block. Mailroom managers will have to comply with this new address system to obtain or keep their pre-barcoding discounts. Meanwhile, several aspects of automation are likely to negatively affect mailroom operations this year. It is expected that the same machinery that speeds the flow of automation-compatible mail will have a tendency to reject mail that is not prepared properly. In light of the high costs associated with returned mail, mailroom managers should ensure that their firm's mail is properly addressed before it enters the postal system.

SUBJECTS COVERED:
Mailrooms/Automation
Bar coding
Mailrooms/Management

38 WBA
TITLE: Mailrooms go on-line for USPS incentives
SOURCE: Purchasing (ISSN:0033-4448) v 113 p 109-10 December 10 '92
ABSTRACT: In an effort to make processing mail as efficient as possible and to keep postal costs down, the U.S. Postal Service (USPS) is encouraging businesses to automate their mailrooms by offering sizable postage discounts to companies that pre-sort, pre-barcode, and use zip+4 codes. The USPS believes that if businesses do not have a method to barcode or sort they need to get one so that the USPS can meet its objectives of controlling costs, improving productivity, and providing consistent, reliable service at or below the rate of inflation. According to the USPS, it costs $35 to process 1,000 letters by hand. This cost drops to $15 when mechanized equipment is used. By using optical character readers and barcode sorters, however, the cost of processing 1,000 letters drops even further, to only $3. By 1995, the USPS expects to have companies place barcodes on 40 percent of all mail. These businesses would receive lower postage rates for barcoding their own mail.

SUBJECTS COVERED:
Mailrooms/Automation
Mailrooms/Cost control
Bar coding