Department of the Navy IUID Marking Guide

APPLYING DATA MATRIX IDENTIFICATION SYMBOLS TO LEGACY PARTS

23 November 2010

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FOREWORD

This technical guide is published by the Department of the Navy (DON) to provide uniform engineering and technical information for applying Item Unique Identification (IUID) markings to DON hardware.

BACKGROUND

Many items within the DON inventory are required to be marked with a Unique Item Identifier (UII) encoded into a two-dimensional (2-D) Error Correction Code[1] (ECC) 200 data matrix symbol per MIL-STD-130.

IUID requirements dictate markings:

- Remain readable throughout the items' normal life cycle
- Withstand all environmental conditions to which the item will be exposed under normal operating conditions
- Provide no detrimental effects on the functional performance, reliability, or durability of the item

Applying these markings can be technically involved because of the variety of factors to consider before choosing an acceptable methodology and procedure. Key factors when selecting an appropriate marking solution include: a detailed knowledge of the item's function; available marking area; material type; color; hardness; surface roughness/finish; surface thickness; and the operating environment.

Tests have established marks formed by intrusive marking processes such as abrading, compressing, burning, cutting, melting, scripting or vaporizing may require one or a combination of the following to safely mark legacy parts:

- Appropriate engineering drawings and specifications
- Approved marking device settings used within manufacturing to mark the parts
- Appropriate clamping fixtures
- Depth measurement and microscopic evaluation equipment
- Quality, safety, and engineering personnel on site to certify and monitor marking operations
- Procedures established to evaluate and disposition improperly applied markings
- Procedures established to assess the cumulative effects of multiple marking removal and re-applications

A practical guide to producing intrusive markings on legacy equipment is beyond the scope of this document except to underscore the difficulties, complexity, and possible safety issues related to the task.

[1] ECC is also known as Error Checking and Correction by some.

1 Organization

This guide is organized as a relatively short body supported by extensive appendices.

2 Scope

The information within this guide is provided for DON personnel and contractors to facilitate identification of items using IUID compliant ECC 200 data matrix symbols.

Information within the guide was created by representatives from the major Automatic Identification and Data Capture (AI/DC) manufacturers, government, and aerospace user groups under a collaborative agreement with National Aeronautics and Space Administration (NASA) and the United States Coast Guard (USCG).

3 Purpose

The purpose of this guide is to consolidate and present information needed to effectively mark legacy items with IUID compliant 2-D data matrix symbols.[2] Figure 1 shows an example of an ECC 200 data matrix symbol.

Figure 1. ECC200 Data Matrix Symbol

4 Applicability

This marking guide applies to DON organizations responsible for the use, maintenance, servicing, and/or storage of legacy parts. This guide only applies to hardware owned by the Department of the Navy and does not authorize the marking of hardware owned by other government organizations. The guidance provided by this document may be referenced or incorporated into detailed maintenance guides as approved by the item manager(s) responsible for the legacy items to be marked.

IUID markings applied to legacy parts shall be made using non-intrusive marking methods unless specifically authorized by quality assurance, safety and engineering. In all cases when identification cannot be applied in close proximity to the existing permanent mark, the responsible technical authority shall approve the location of the mark.

5 Permanent Data Matrices

A foundational requirement within IUID policy is that its data matrices remain readable throughout an item's normal life cycle. Achieving this is a matter of designing and executing the marking process properly.

[2] Other documents exist which explain facets of IUID not covered herein. See Appendix A for more details.

5.1 Marking Process Design

Designing the marking process for legacy items requires familiarity with relevant policy, the lifecycle environmental exposure and intended use of the items, as well as requirements for producing technically sound data matrix marks.

5.1.1 Engineering Change Requests and Drawing Revisions

Given the tremendous burden in terms of cost, workload, and schedule associated with engineering change requests and drawing revisions, it is useful to take advantage of the broad scope of DON policy providing conditional exemption from engineering change requests and drawing revisions when affixing labels and/or data plates for IUID purposes delineated within SECNAVINST4440.34. (See section 5f of the SECNAVINST, and also section 3.34 of MIL-STD-130N; Appendix B has applicable excerpts.)

In some cases the conditions for the above exemption will not be met and alternative plans must be made. *The Guidelines for Engineering, Manufacturing and Maintenance Documentation Requirements for Item Unique Identification (IUID) Implementation*, version 1.2 published April 20, 2007 has different strategies for minimizing the impacts of cost, workload and schedule associated with performing engineering and updating technical documentation for IUID marking. (See the section titled "Leveraging Existing Marking Processes"; Appendix C has the applicable excerpt.)

5.1.2 Placement of the Mark

Where the IUID mark is placed on the item strongly influences its durability and usefulness. The following are general considerations when determining placement:

- Apply marks in protected areas when possible
- The mark should be readable when the marked item is in-service
- The mark should be readable when the marked item is stowed
- Apply marks on flat areas when possible
- IUID policy permits multiple ***identical*** marks to be applied to the same item

Unless directed to the contrary by the technical authority. Do not place marks/labels:

- Over vents and/or air intakes
- Over other information
- Covering windows, view ports, access ports or fastener holes
- Over seams between separable pieces of the item
- In direct air streams (e.g., leading edge of wings, helicopter rotors, exposed portions of turbine blades, etc.)
- On sealing surfaces
- On wearing surfaces
- Near high heat sources
- Over lenses, optics, or sensors
- On surfaces with dimensional tolerance requirements
- On precision cleaned parts in hermetically sealed packaging

Other placement considerations become important in specialized circumstances (e.g. marking curved, rough or shiny surfaces, marking items sensitive to electro-static discharge). Many considerations follow directly from a technical understanding of how two-dimensional barcode readers (also referred to as scanners) decode symbols and efforts to maximize the reliability of decoding the data matrix. For information about mark placement on curved, rough, or irregular shaped items see Appendix D.

5.1.3 Readable Marks

Understanding what makes a data matrix readable is helpful in achieving a permanent mark. There are four basic categories of techniques to help make a mark permanent:

- Make the modules big
- Make the dark parts as black as possible, make the light parts as white as possible
- Match the dimensions, as closely as possible, to the specification
- Protect the mark with a cover or coating

The ECC 200 data matrix specification is documented in *ISO/IEC 16022 Information technology – International symbology specification – Data Matrix*.

5.1.3.1 Module Size

The data matrix symbol is made from a collection of small black or white squares[3] referred to as either "cells" or "modules". In practice, damage to data matrices do not scale up or down with the module size. Smaller modules receive a higher proportion of damage given similar damage from scratches as example. Damaged symbols with large cell sizes are therefore more likely to be reconstructed by the decoding software. Consequently, cell sizes must be enlarged to overcome damage anticipated in harsh manufacturing, operational, and overhaul environments. See Appendix E for suggested cell sizes for different operational environments. For techniques and more general information to optimize module size see Appendix F.

5.1.3.2 Contrast

Dark colored markings are generally applied to light surfaces and light markings applied to dark surfaces. The minimum contrast difference between the symbol and its substrate that can be reliably read is 40 percent as shown on a typical gray scale comparator (see Figure 2). The minimum acceptable contrast level difference is 20 percent at the point of marking to allow for degradation over time in the operational environment. Care must be taken to apply marks in an area of uniform color in situations where surface colors change (such as camouflage patterns). AIM DPM-1-2006 mark quality verification requirements call for a minimum contrast level of ≥2.0 (C) or better.

[3] Some marking methods produce small circles as opposed to squares. Dot peening is one such method.

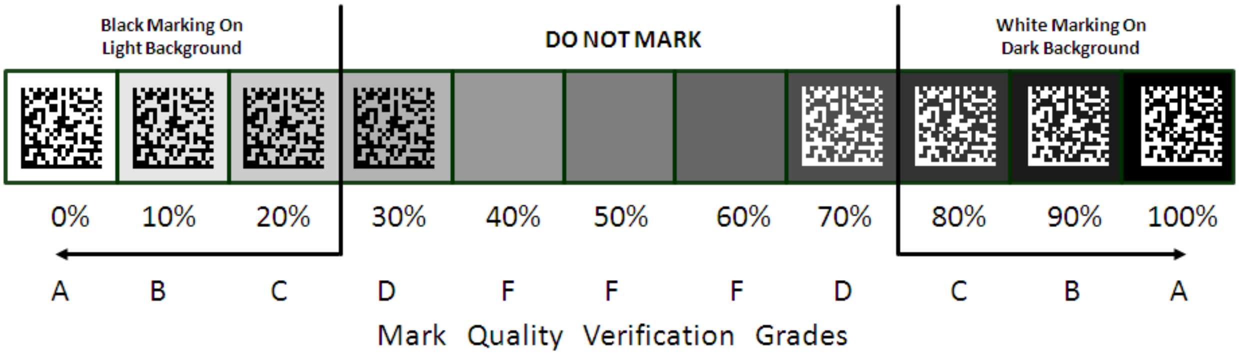


Figure 2. Mark/Substrate Symbol Contrast

5.1.3.3 Quiet Zone

A clear space (quiet zone) must be left around the outside of the symbol in order to successfully decode a data matrix. A minimum of one module width of quiet zone must be left around the symbol. However, due to variations in surface finish, extending this area is very helpful. If possible DON programs should allow an additional 10 percent of the longest symbol side. Encroachment into the quiet zone occurs when the data matrix is applied too closely to the edge of the designated marking area or when other information is applied too closely to the data matrix, both problems are shown on the left side of Figure 3.

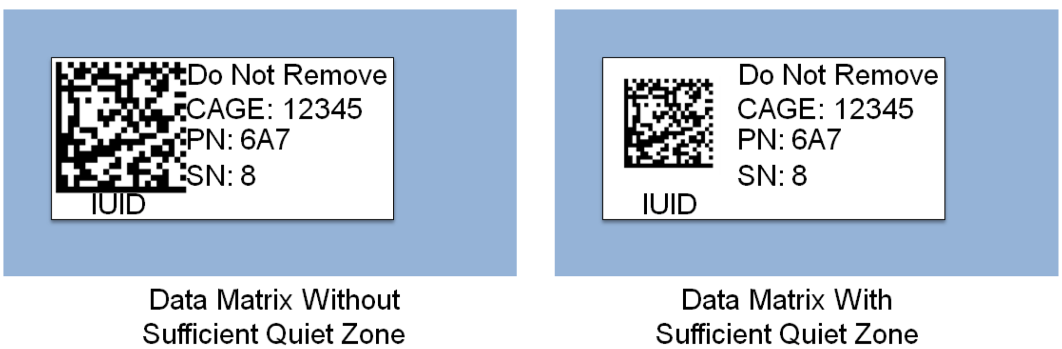


Figure 3. Examples of Both Proper and Improper Quiet Zone Allocation

5.1.3.4 Protective Coatings and Covers

Protective coatings and covers can promote more resilient marks by protecting the mark, substrate, and possibly adhesive from light and/or chemical induced damage. The coatings and covers should have a matte finish to minimize unwanted reflection off the surface. When using clear adhesive labels care should be taken to avoid trapping air-bubbles between the cover and the mark.

5.1.4 Minimizing Attachment Failures

Attachment failures occur for a variety of reasons. In some cases the strength of attachment declines over time in others the initial strength of attachment is insufficient.

Loss of attachment strength over time occurs because of slow persistent degradation of materials. Adhesives/epoxies are often damaged by ultra-violet (UV) radiation. Choosing UV blocking label stock minimizes this failure mode. Rigid adhesives/epoxies physically degrade if attaching two rigid materials to each other, which grow and shrink by different amounts as they heat and cool (almost always, different materials have different coefficients of thermal expansion). This is prevented by using flexible adhesives/epoxies. Lastly, if two different types of metals are attached to each other so that electricity can flow from one to the other, they will corrode over time. This is a particularly bad problem for aluminum data plates riveted to large steel items. Keeping the metals separated from each other with a non-conductive layer (often an adhesive tape) prevents this problem.

Insufficient initial attachment strength is due to either a bad choice of marking materials (i.e. ill-suited to the environmental requirements of the item) or to the marking process. Useful environmental requirements should include authorized as well as unauthorized maintenance procedures the item is subjected to. Adhesives/epoxies are at risk of failure when they become brittle at low temperatures or soften at high temperatures. They break down completely if the temperature is high enough. Improper surface preparation (poor cleaning) will lead to lower attachment strength and can be a prevalent, persistent and perhaps critical problem. For more information on surface preparation see Appendix G.

5.1.5 Choosing the Right Marking Method

As mentioned in section 5.1.1, it may be possible to utilize established marking processes and procedures. Provided these processes support the creation of a high quality data matrix symbol, they are likely the best choice.

When a new marking method is required, a survey of methods and materials is appropriate. Although marking technologies have existed for a long time, new materials and techniques continue to emerge.

In general, intrusive marks are the most durable types of marks available. These marks also prove to be the riskiest to use. They should not be used unless adding material to the item is unacceptable. See Appendix H for more information.

The next most durable marks fuse rugged material directly to the item's surface to form the mark. These types of additive marks vary in their inherent risks but can be nearly as durable as intrusive marks. Available materials and application techniques continue to evolve rapidly in this area. Many of the newest techniques and materials utilize lasers to fuse the mark to the surface. See Appendix I for more information.

Although applying labels is considered the least durable type of marking method, it should not be considered inherently weak. As a case in point, Post-It-Notes are likely the least durable type of label whereas a welded stainless steel plate could be among the most durable. Label application has a very great diversity of materials and methods some of which are the cheapest and most convenient marking methods available. See Appendix J for more information.

5.2 Proper Execution of the Marking Process

Proper execution of the marking process requires that the information encoded into the data matrix is both formatted correctly and applied to the correct item. Although independent software exists to evaluate the formatting of the data matrix symbol to check that it meets IUID requirements[4], most verification systems validate a mark's syntax at the same time it verifies its production quality.

Ensuring IUID marks are placed on the appropriate items is a matter of training, proper management, and faithful adherence to quality assurance procedures. Procedures should be devised to correct items after they have been marked incorrectly. These procedures should focus on detecting errors within 30 days because of the 30 day window of opportunity to correct information sent to the IUID Registry. Should a data matrix mark need to be removed there are several techniques for doing so listed in Figure 14.

<u>Production Quality of the Mark</u>

Department of Defense (DOD) and DON policy requires the verification of IUID data matrix marks. Verification is the process which checks the production quality of the mark which is different than checking the information encoded within the mark. See Appendix L for more details.

Verification can be performed on each data matrix or as part of a sampling plan. Appendix M provides a workable sampling plan for IUID verification. It may be used in the absence of direction to the contrary from the technical authority.

Verification of the symbol quality requires both specialized hardware (a verifier) and software. Even so, there are a number of checks which can be done without a verifier to evaluate the production quality of the mark. See Appendix N for details.

[4] A useful example of syntax-checking software is the Quick Compliance Tool Suite available at www.qcts.org.

Appendix A. Applicable Documents

Government Documents

DFARS 252.211-7003	Item Identification and Valuation
DoD Dir. 8320.03	Unique Identification (UID) Standards for a Net-Centric Department of Defense," March 23, 2007
DoD Guide	Department of Defense Guide to Uniquely Identifying Items
DoD Guide	Guidelines for Engineering, Manufacturing and Maintenance Item Unique Identification (IUID) Standards for Tangible Personal Property
DoD Instr. 4151.19	Serialized Item Management (SIM) for Materiel Maintenance
DoD Instr. 5000.02	Operation of the Defense Acquisition System
DoD Instr. 5000.64	Accountability and Management of DoD-Owned Equipment and Other Accountable Property
DoD Instr. 8320.04	Documentation Requirements for Item Unique Identification (IUID) Implementation
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-C-38736	Sealing And Coating Compound, Corrosion Inhibitive
MIL-DTL-15024	Detail Specification Plates, Tags, And Bands For Identification Of Equipment, General Specification For (28 Nov 1997)
MIL-DTL-19834	Detail Specification Plates, Identification Or Guide, Metal Foil, Adhesive Backed General Specification For (6 Jul 2006)
MIL-M-43719	Marking Materials And Markers, Adhesive, Elastomeric, Pigmented; (30 Sep 1992)
MIL-M-87958	Marker Blanks, Pressure Sensitive Adhesive Wire or Cable Marker and Identification Label
MIL-PRF-61002	Pressure-Sensitive Adhesive Labels For Bar Coding
MIL-PRF-87937	Performance Specification: Cleaning Compound, Aerospace Equipment
MIL-STD-129	Department Of Defense Standard Practice Military Marking For Shipment And Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-810	Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
MIL-STD-871	Electro-Chemical Stripping of Inorganic Finishes
MIL-STD-975	NASA Standard Electrical Parts List
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
NASA-STD-6002	Applying Data Matrix Identification Symbols on Aerospace Parts
NASA-HDBK-6003	Application Of Data Matrix Identification Symbols To Aerospace Parts Using Direct Part Marking Methods/Techniques
NAVAIR 01-1A-509-1 (TM 1-1500-344-23-1) (TO 1-1-689-1)	Technical manual, cleaning and corrosion (volume I & III) corrosion program and corrosion theory
SECNAVINST 4440.34	Implementation of Item Unique Identification Within the Navy

Non-Government Documents

A-A-208	Ink, Marking, Stencil, Opaque (Porous and Nonporous Surfaces)
A-A-1558	Commercial Item Description: Paint, Stencil
A-A-56032	Ink, Marking, Epoxy Base
AIM BC11-ISS	AIM Specification For Data Matrix
AIM DPM-1-2006	Direct Part Mark (DPM) Quality Guideline
ANSI MH10.8.2	Data Identifier And Application Identifier Standard
ANSI X3.182	Bar Code Print Quality - Guideline
ASME/ANSI B46.1	Surface Texture, Surface Roughness, Waviness And Lay
ATA Spec 2000 Chapter 9	Automated Identification And Data Capture
ISO/IEC 2859-1	Sampling Procedures For Inspection By Attributes - Part 1: Sampling Plans Indexed By Acceptable Quality Level (AQL) For Lot - By - Lot Inspection
ISO/IEC 15415	Information Technology—Automatic Identification And Data Capture Techniques—Bar Code Print Quality Test Specification — Two-Dimensional Symbols
ISO/IEC 15418	Information Technology—EAN/UCC Application Identifiers And FACT Data Identifiers And Maintenance
ISO/IEC 15434	Information Technology—Syntax For High Capacity ADC Media
ISO/IEC 15459-2	Information Technology—Part 2: Registration Procedures
ISO/IEC 16022	Information Technology—International Symbology Specification - Data Matrix
MBO295-005	Material Cleanliness Level, Precision Clean Packaging
SAE ARP 6002	Marking; Standard Hose, Aircraft-FSC 4720; Should Be Used Instead of MIL-M-6002A, Which Was Cancelled on 1 November 1999
SAE AS9132	Data Matrix (2D) Coding Quality Requirements For Parts Marking
TT-L-50	Clear, Acrylic Lacquer Aerosol, Type II

The documents listed above may have been revised since publication. Check for the latest version of the reference.

Appendix B. Policy For Conditional Exceptions To Engineering Analysis

SECNAVINST4440.34 of 22 December 2009 Section 5f:

Engineering change requests and drawing revisions shall not be required when affixing labels with IUID markings to legacy equipment if it does not impact form, fit or function and if the following conditions are met:

(1) The existing label is completely removed.

(a) The new label with IUID compliant data matrix is placed in the same location as the replaced label.

(b) The new label with IUID compliant data matrix has the same dimensions as the replaced label.

(c) The new label material and method of marking is the same as the replaced label or an improved and qualified media replacement. The IUID compliant data matrix must be permanent, per MIL-STD-130N of 17 Dec 07.

(d) The new label is affixed on the item in the same manner as the replaced label.

(e) The information on the replacement label may be resized or repositioned anywhere on the label to accommodate [the] IUID compliant data matrix.

(2) A replacement label is not required if sufficient space exists to place the IUID compliant data matrix or label to the right, left, up or down with respect to the existing label.

(3) A replacement label is not required if room exists on the current label to add an IUID compliant data matrix.

(4) When otherwise determined by the appropriate Technical Authority (TA) of the respective organization.

MIL-STD-130N section 3.34: (definition of **Label)**

Label. An item marked with the identification information of another item and affixed to that other item. A label may be of any similar or different material than that of the item to which it is affixed. A label may be made of a metallic or non-metallic material. Labels may be affixed to the identified item by any appropriate means. Labels are often referred to as plates (i.e. data plate, name plate, ID plate, etc.) however, label material and methods of marking and affixing have no bearing on this distinction.

Appendix C. Strategies For Minimizing The Impacts Of Non-Recurring Engineering

Excerpt quoted from *The Guidelines for Engineering, Manufacturing and Maintenance Documentation Requirements for Item Unique Identification (IUID) Implementation*, version 1.2 published April 20, 2007

- Replacing/modifying existing data plates with UII labels. Existing data plate documentation can be used. The current technical data already specifies the material and placement of the data plate. Human readable data other than IUID information can exist on the "new" data plate. The labels provide high contrast allowing interrogation of mark by lower cost readers.

- Issuing a global engineering change notice. This would provide instructions on a single drawing on how to mark qualifying items.

- Issuing IUID part-marking work orders into the existing manufacturing and enterprise resource planning processes, which minimizes the need to change drawings.

- Changing company part marking quality standards to include IUID requirements.

- When the necessary marking information and criteria do not change the form, fit, or function of the part, the change does not require an immediate drawing update, but rather can be accomplished by a coversheet with the marking instructions, thus permitting consolidation of drawing requirements.

- Direct part marking (DPM) will require more engineering analysis than labeling. The main issue that necessitates additional engineering analysis for DPM is the fact that the mark is made directly on the component rather then [sic] attached like a label. Wherever possible, the engineering decisions for location and type of application should be made on documented results from previous analysis. Currently NASA has taken the lead in this area and their documentation has provided a wealth of information that has precluded much of the testing that would normally be required when one marks directly into the material of a component.

Appendix D. Marking Location and Surface Finish Information

Sensitive Surfaces

Precision cleaned parts (MIL-STD-1246) stored in hermetically sealed packages to maintain cleanliness and electrical, electronic, and electromechanical (EEE) parts (MIL-STD-975) packaged to prevent electrostatic discharge (ESD) shall not be marked directly. These items shall be identified with labels attached to the exterior of the packaging.

Thin Surfaces

Part thickness is generally not a consideration in applying non-intrusive markings with the exception of laser bonding.

Symbol Shape

The data matrix symbol can be created as a square or a rectangle. See Figure 4. Symbol Shapes The square is preferred unless the marking area on the item is rectangular and limits the module size of a square data matrix. For some linear-shaped parts such as pipes, lines, narrow part edges, etc., it is usually desirable to use a rectangular-shaped symbol; the intent is to use a symbol shape providing the largest modules.

Figure 4. Symbol Shapes

Curved Surfaces

Flat surfaces are preferred over curved surfaces for marking when a choice is possible. A rectangular symbol is better for application to polished cylindrical parts, either concave or convex. The rectangle is sized to fit either within the reflective band of light that emanates from the spine of the curve or on 5% of the circumference, as shown in Figure 5. This band of light typically occupies 16% of the diameter of the curve under normal room light and can increase in size under bright light conditions.

Figure 5. Proper Placement of Data Matrix Symbols on a Curved Surface

Larger size symbols can be applied if the surface is textured to reduce glare or if matte finished laser markable paints are used to mark the part.

Labeling Curved Surfaces

When applying a label to a one dimensional curve (like a cylinder) dimensionally stable label stock should be used (e.g. polyethylene) to reduce module deformation due to stretching. If the shape is a 2-dimensional curve (like a ball) however, use of a dimensionally stable label material will develop creases and wrinkles when applied and should therefore be avoided. Labels which can stretch (e.g. polypropylene) should be applied with great care to minimize distortion to the modules of the data matrix. Avoid applying data matrices on labels for 2-dimensional curves if at all possible. If no alternative exists, verification can be used to check stretch-induced module deformation when performed after application rather than before.

Note that labels applied to curves with adhesives may “flag” (i.e. the edges may lift as the material resumes its normal, flat, geometry) if the label material retains its original shape and the edges are not sufficiently seated to the base material. For this reason both surface preparation and the burnishing of the label’s edges are important on curved surfaces. Adhesive thickness and softness are also important factors to flagging. Softer, thicker adhesives help prevent flagging.

<u>Surface Roughness/Finish</u>

Surface roughness poses different problems depending on whether you are trying to apply a label or are trying to apply the mark directly to the item’s surface.

Using adhesives almost always works better on smoother surfaces. When a smooth surface is unavailable, thicker adhesive can compensate as can double-sided adhesive tapes.

Structural epoxies vary in their chemistry and are optimized for a specific surface roughness. Matching the epoxy to the item’s surface roughness is an important consideration.

When applying direct surface marks, the symbol marking should be limited to surface roughness levels averaging between 8 and 250 micro-inches (millionth of an inch [0.0000254 mm]) as measured per ASME/ANSI B46.1. A typical Surface Roughness Gauge is illustrated in Figure 6. Surfaces that fall outside of acceptable surface roughness levels (see Figure 7) can be resurfaced as directed by engineering, coated with laser markable paint that fills the recesses or marked with labels, tags, or bands.

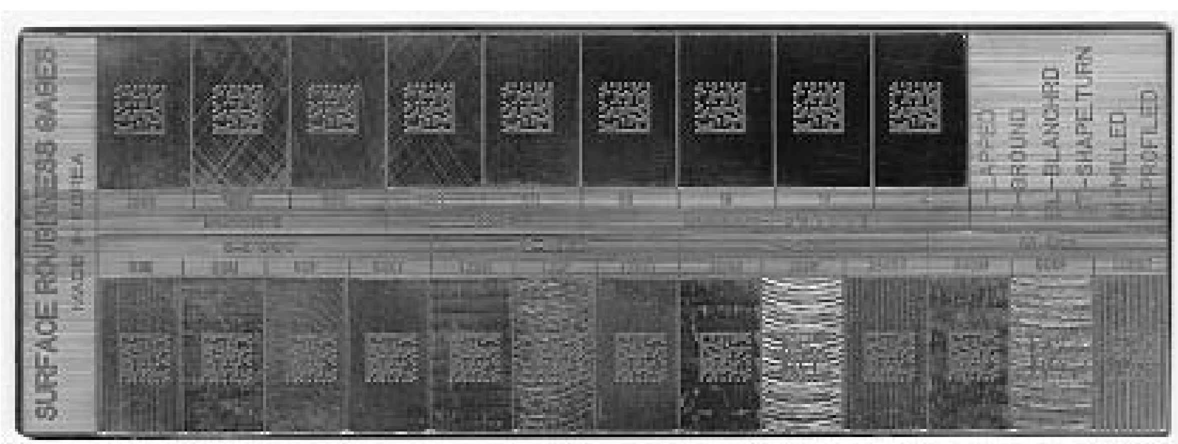


Figure 6. Typical Surface Finish Roughness Gauge

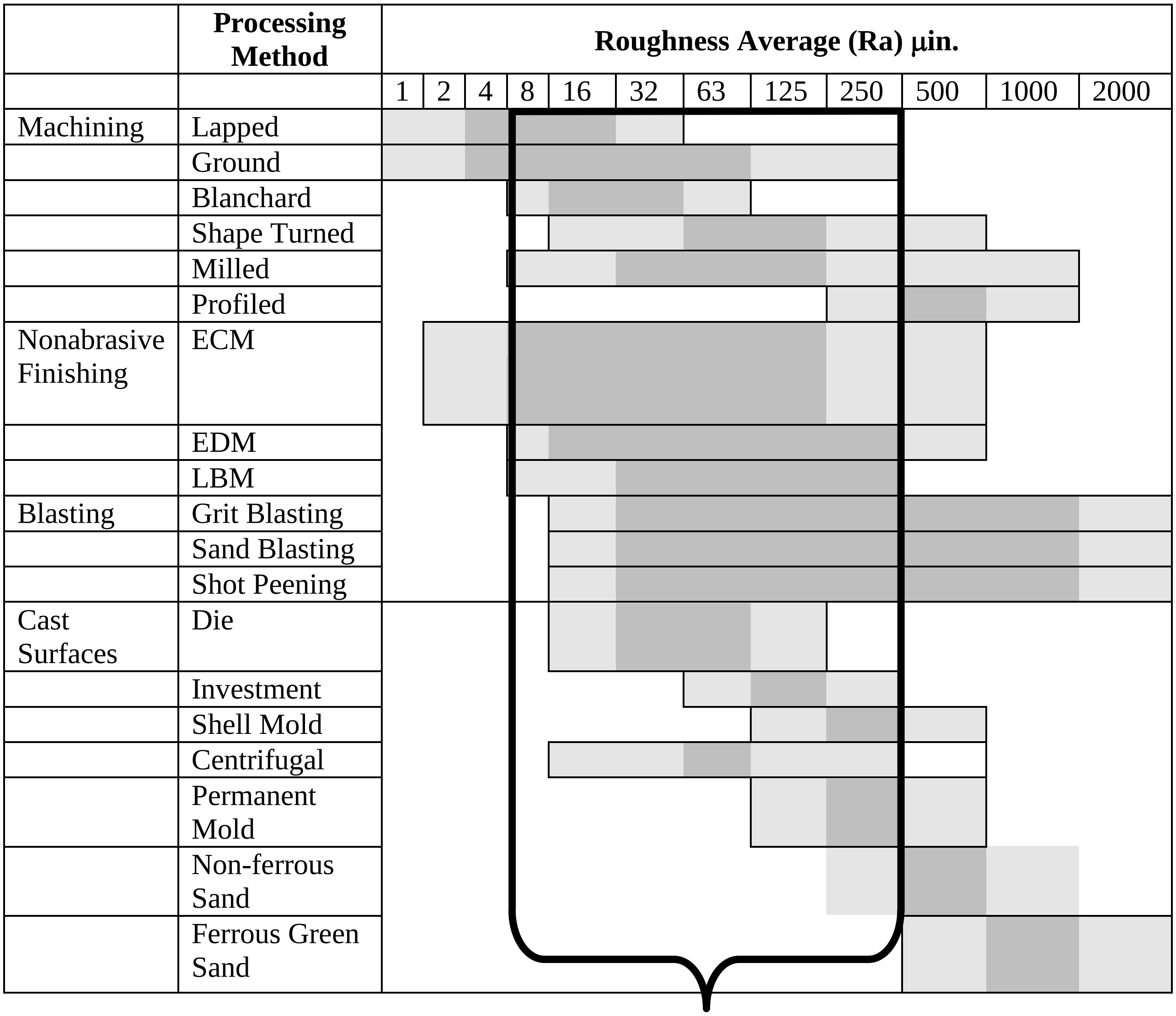
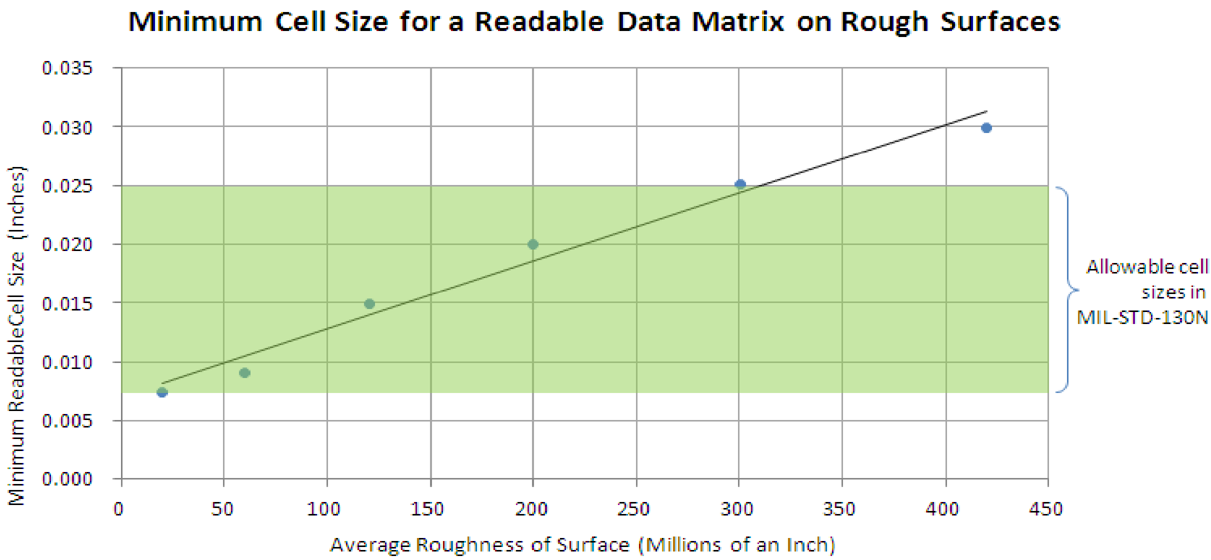


Figure 7. Average Roughness by Surface Finishing Method

Particularly smooth surfaces (0 to 8 micro-inches) are ill-suited for directly applied marks because they are reflective. Light from a reader illuminating the mark will reflect off of the surface in one direction which depends on the angle of the reader relative to the surface . If the light reflects back into the reader, it will be too bright and will make the mark difficult to decode. If the light doesn't reflect back to the reader the surface will appear dark to the reader and make the mark difficult to decode.

Particularly rough surfaces, like cast surfaces present a unique symbol decoding challenge, because the surface irregularities (pits) create shadows that can be misinterpreted by the decoding software as dark data cells.

Consequently, individual data cells in the symbol must be larger than the surface irregularities (for the decoding software to differentiate between the two features). The data cells contained in the symbol must be increased in size in direct proportion to the average surface roughness to ensure successful decoding. Figure 8 provides a formula for calculating minimum cell size restrictions to aid in determining minimum symbol sizes for cast surfaces.



Equation of best-fit line: $\textit{Minimum Cell Size (in inches)} \cong \frac{(6) \times (\textit{Average Roughness (in millionths of an inch)})}{100{,}000} + 0.0067$

Figure 8. Graph to interpolate minimum cell size for rough surfaces

Average Roughness Level (millionths of an inch)	Minimum Cell Size (inches)
20 (0.000508 mm)	0.0075 (0.19 mm)*
60 (0.001524 mm)	0.0091 (0.23 mm)
120 (0.003048 mm)	0.0150 (0.38 mm)
200 (0.005080 mm)	0.0201 (0.51 mm)
300 (0.007620 mm)	0.0252 (0.64 mm)
420 (0.010668 mm)	0.0299 (0.76 mm)

* 0.0075 inches approaches the limits of many readers regardless of surface roughness.

Table 1. Minimum Readable Cell Size by Roughness Level

An alternative to increasing symbol cell size is to coat the marking area to provide a smoother substrate.   Figure 9 illustrates the relationship between data cell size and cast surface roughness.

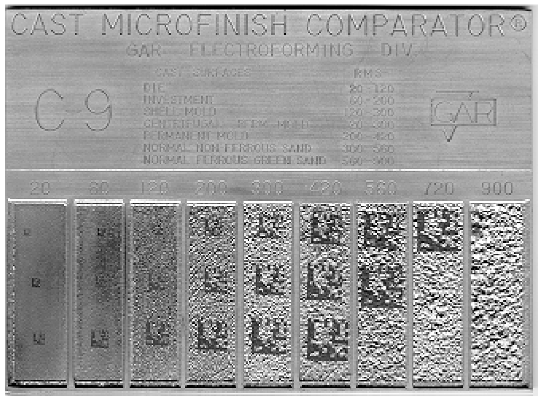


Figure 9. Comparator Showing Relationship Between Cell Size and Cast Surface Roughness

Appendix E. Data Matrix Module Size by Environment

Guidance suggesting appropriate data matrix cell sizes to overcome damage from different grades of environmental exposure can be found in Figure 10.

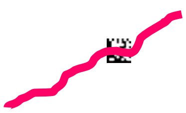
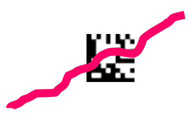
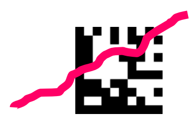
Mild Environments	Moderate Environments	Harsh Environments
General office conditions where there are moderate temperatures and minor exposure to non-abrasive cleaning chemicals. Examples include office furniture, calculators, computers, reproduction machines, etc.	Indoor or general outdoor use. Parts are exposed to some chemicals and abrasives, moderate cleaning and exposure to outdoor environments in temperate regions. Examples are in-plant fixed assets, embedded parts, internal air, sea or ground vehicle components (less engines), etc.	Harsh indoor/outdoor conditions; long term exposure to salt air, caustics; extreme temperature variations; exposure to chemicals, including petroleum products; frequent cleaning and exposure to autoclave, chemicals or abrasives. Examples of harsh environments are external aircraft components, engine parts other than internal combustion engine components, refinery equipment; work in process manufacturing, and tools.
Minimum size 0.008-inch required for successful reading.	Minimum suggested cell size 0.010 inch (0.254 mm)	Minimum suggested cell size 0.020 inch (0.508 mm) or larger
 **Minor damage can render mark unreadable**	 Error correction can reconstruct symbol	 **Less or no error correction needed**

Figure 10. Minimum Cell Sizes for Expected Use Environments

Cell sizes must be adjusted upwards to overcome anticipated environmental damage without exceeding the specification cell size limit of 0.025 inch. In general, operators should use the largest cell size practical.

Appendix F. Module Size Limits & Techniques to Overcome Size Limits

<u>Module Size Limits</u>

MIL-STD-130 requires module sizes to be no bigger than 0.025 inches and no smaller than 0.0075 inches. The upper limit of module size can be further constrained by limits on the size of the overall data matrix. MIL-STD-130 limits the longest dimension of the data matrix to be no bigger than 1inch (Since 40 modules, each 0.025 inches to a side, would consume the entire 1inch, any data matrix having data requiring more than a 40 module wide data matrix must use modules smaller than 0.025 inches.) Of course items may not have 1inch to spare for a data matrix symbol and so the maximum number of modules to a side may need to be fewer than 40.

	Rows		Columns	Maximum Module Size	Data Capacity
Square Data Matrices	10	X	10	0.025"	3
	12	X	12	0.025"	5
	14	X	14	0.025"	8
	16	X	16	0.025"	12
	18	X	18	0.025"	18
	20	X	20	0.025"	22
	22	X	22	0.025"	30
	24	X	24	0.025"	36
	26	X	26	0.025"	44
	32	X	32	0.025"	62
	36	X	36	0.025"	86
	40	X	40	0.025"	114
	44	X	44	0.023"	144
	48	X	48	0.021"	174
	52	X	52	0.019"	204
	64	X	64	0.016"	280
	72	X	72	0.014"	368
	80	X	80	0.013"	456
	88	X	88	0.011"	576
	96	X	96	0.010"	696
	104	X	104	0.010"	816
	120	X	120	0.008"	1050
	132	X	132	0.008"	1304
	144	X	144	0.0069"	1558
Rectangular Data Matrices	8	X	18	0.025"	5
	8	X	32	0.025"	10
	12	X	26	0.025"	16
	12	X	36	0.025"	22
	16	X	36	0.025"	32
	16	X	48	0.021"	49

Table 2. Data Matrix Module Size and Capacity Chart

The data matrix specification permits 30 different sizes for symbols, 6 of which are rectangular, the remaining 24 are square. The largest and smallest are not usable for IUID because of IUID size and/or data requirements (indicated with red font in Table 2.)

For large items (items which can accommodate a 1 inch mark) the amount of data encoded into the mark is not usually an issue (using more than the 114 allotted data capacity is rare). For items with severely limited marking area, limiting the encoded data or finding ways to compact the encoded data can be critical.

For example, assume an item is limited to using a 0.25 inch by 0.25 inch data matrix and exists in a harsh environment which optimally would have a 0.20 inch module size. The geometry dictates use of a 10x10 data matrix for this area and module size. A 10x10 data matrix has a data capacity of 3 which is unfortunately insufficient for IUID. This item will need to be marked with modules less than the recommended 0.20 inch. Encoding a minimum amount of data will lead to larger module sizes and a more robust mark. In this case the operator should compact the IUID data as much as possible. Note that a reduction in the encoded data does not always lead to fewer modules. There will be no size benefits to the data matrix if a particular encoded string shrinks from 29 to 23 for example. In either case a 22x22 data matrix must be used.

Encoded Data Compaction

The data matrix specification defines several encoding methods. Understanding these and how much capacity is required for each with a given string of data is complex and beyond the scope of this guide. It is made more complicated by the fact that IUID compliant data matrix symbols encode syntax specified within ISO15434. Here are the important ideas to consider when trying to optimize the compaction of any encoded data:

- Digits compact better than letters
- Digits compact when there are two of them together in the data (2 digits = 1 unit of capacity; which is also known as a "code-word" in the vernacular of the specification)
- Using "Macros" to encode the ISO15434 syntax will reduce the required capacity by 7 units
    - Macros are sometimes referred to as a "prefix" in barcode generating software
    - Macros are not supported by all marking devices/but are supported by all readers
    - "Macro05" is available when using Application Identifiers (GS1 data qualifiers)
    - "Macro06" is available when using Data Identifiers (MH10.8.2 data qualifiers)
    - A Macro usable with Text Element Identifiers is not available
- The exact same UII can be encoded in different ways to optimize module size as shown in Figure 12 and Figure 13

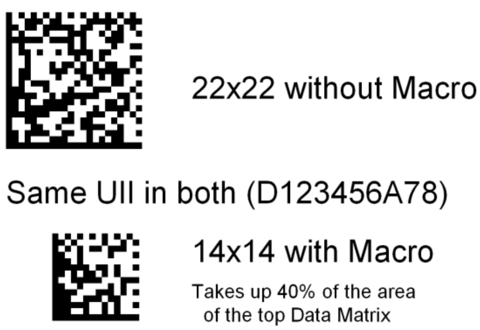


Figure 11. Minimizing Cell Count Through Optimized Encoding

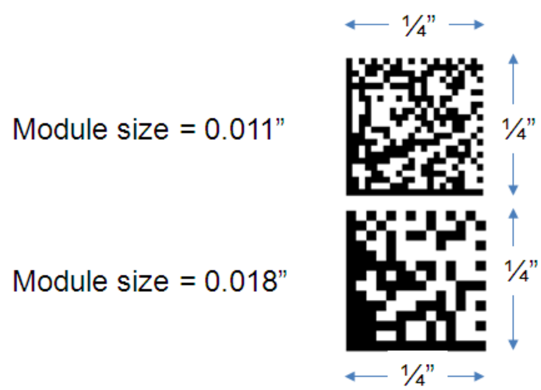


Figure 12. Optimizing Cell Size Within a Fixed Area (enlarged to show comparison)

Appendix G. Surface Preparation

Prior to applying additive markings the surface should be clean. The surface can be cleaned using either compliance wipe cleaning procedures or CO_2 laser surface cleaning.

Compliance Wipe

The purpose of the compliance wipe is to remove solid particulate contaminants (dust and dirt) as well as fluid films (oils) which would compromise the attachment strength of the mark. A supply of clean, lint-free wipes as well as a supply of an appropriate solvent is required. The surface contaminants are dissolved into the solvent and wiped off the surface with a dry clean wipe. If the solvent is permitted to dry on the item's surface before being wiped off, the contaminants will have precipitated back onto the surface making the compliance wipe ineffective. Care should be taken to enforce use of authorized solvents as many house-hold cleaning products include "shine factors" that purposefully leave problematic residues that promote the appearance of a clean surface.

Military cleaning technical instructions and procedures are defined in a multitude of different technical standards, handbooks, and guides written with reference to specific materials, products, and end item types. Cold cleaning processes shall be used for marking. This is done by immersion and soaking, spraying, or wiping with ambient temperature solvents for mechanical and structural parts.

Compliance wipe cleaning solvents used to remove contaminants are defined in MIL-PRF-87937. The specification establishes requirements for biodegradable, water dilutable, environmentally safe cleaning compounds for use on aerospace equipment such as aircraft, aerospace ground equipment (AGE), and AGE engines.

Alternative cleaning materials are identified in MIL-C-38736. These solvents are obtainable under the following commercial brand names: Exxon Corporation's Isopar C, E, G, H, K, L, M, V, and Axarel 9100 (isoparaffins) and 3M™'s PF-5050, PF-5052, PF-5060, PF-5070, and PF-5080 (perflurocarbons).

Operators should refer to the applicable engineering drawings to obtain cleaning procedures for electronic parts, delicate items, or parts that have been precision cleaned and have close tolerances, complex geometries, and/or are sensitive to contamination.

CO_2 Laser Surface Cleaning

CO_2 laser surface cleaning is typically used to produce a bare metal surface quickly and efficiently. Before compromising paint and corrosion resistant coatings consult the appropriate technical authority. Laser bonded markings can only be applied to clean bare metal. If the bare metal surface to be marked cannot be cleaned using compliance wipe procedures, (e.g., the surface is coated with difficult-to-remove carbonized soils, oxidation, or contaminated with combustion residue) the surface can be cleaned with a low power CO_2 laser (<40 watts). This can be done quickly without masking, chemicals, fear of damaging the metal, and adversely affecting material properties. CO_2 laser surface cleaning is accomplished by inputting a program into the laser controlling software that defines a surface removal patch of the appropriate size and then running the program using low power. Multiple passes are made across the area until the bare metal surface is reached. The cleared area should be sized to provide half the symbol size (longest side if a rectangle) of clear area around the mark.

Appendix H. Intrusive Marks

Intrusive marks are formed by casting, molding, or forging the mark into the part during manufacturing or added after manufacturing by burning, engraving, etching, stamp impression, vaporizing, etc. This type of marking is designed to last the life of the part and will survive overhaul in many cases.

If intrusive markings are improperly applied they can irreparably damage parts, affecting function, or in some cases, degrade material properties beyond a point of acceptability. Some intrusive marking processes, particularly visible wave length lasers, dot peen, and deep electro-chemical etch cannot be approved for use in safety critical applications without appropriate metallurgical testing.

Typical intrusive marking methods include:

- Abrasive Blast
- Direct Laser Marking using visible wavelength lasers
- Dot Peen (Stamp Impression)
- Electro-Chemical Etching (electrolytic surface coloring or metal removal processes)
- Engraving
- Fabric Embroidery
- Laser Shot Peening
- Milling

Appendix I. Additive Marks

Additive markings are processes that mark by adding material to the item's surface. Marking can be accomplished by selectively applying material to the surface as is the case in direct ink-jet techniques, or as in various stencil or silk-screen methods. Marking can also be accomplished by applying marking material over a wide area and selectively fusing it to the surface. The unfused material is removed usually by wiping the surface leaving the mark behind. Material is selectively fused typically with a laser that melts the marking material to the surface or by inducing chemical reactions that bind the marking material to the surface. Additive marks can also be produced by applying specialized marking material over a wide area which after curing is selectively discolored through a light-induced chemical reaction. Again, this is usually accomplished with a laser. Care should be taken in this last technique to ensure the chemical reaction is disabled after marking (fixed). Otherwise heat and various exposures to light will fade the mark as the rest of the material discolors.

Many additive marking processes designed to mark steel parts require all corrosion resistant coatings and paints to be removed. This should not be done without an approved procedure from the technical authority for both the removal of existing coatings as well as the re-application of replacement coatings. Unless the replacement coating is clear, it will very likely render the additive mark useless.

Typical additive marking methods include:

- Direct Ink-Jet
- Laser Bonding
- Laser Markable Paint
- Laser Coloring
- Thermal Spray
- Ink Stencil
- Ink Silkscreen
- Ink Stamping

Appendix J. Legacy Part Marking Devices

There are two primary tools available to create IUID markings in the field for non-intrusive application. These devices are: printers and laser markers to apply IUID markings directly to the parts. Industry has other options for producing IUID markings in industrial facilities which can be produced and shipped to sites for application.

Thermal Transfer Printing

A wide range of label printers are available on the commercial market. Thermal transfer printers are preferred for purposes of IUID marking. These printers produce markings by transferring ink from a ribbon to the label material using heat. Selected printers should be capable of printing on 4-inch label stock and provide the ability to print one and two-dimensional bar codes. A print resolution of 300 dots per inch or greater is preferred. The selected printers must be able to accept pre-designed label templates and variable IUID information directly from both DON information systems and/or commercially available middleware designed to produce barcodes and IUID compliant symbols. Packaging labels shall be formatted in accordance with MIL-STD-129.

Laser Marking

Laser markers can be obtained commercially configured for desktop or mobile applications (carts). Laser systems can also be obtained that contain software designed to walk a novice through marking technique selection options, provide instructions on how to mark, automatically select the appropriate marking settings, and provide links to applicable reference standards and safety documentation.

The CO_2 laser (30-40 watts) has been selected for field use because it will not damage metals as is the case with shorter wavelength lasers. Lasers in this category include Ruby-Neodymium doped: Yttrium Lithium Fluoride (Nd:YLF), Neodymium doped: Yttrium Aluminum Garnet (Nd:YAG), Neodymiumdoped: Yttrium Aluminum Perovskite (Nd:YAP), and Neodymium doped: Yttrium Vanadate Orthovanadate (Nd:YVO_4). Visible wavelength lasers are generally used to apply intrusive markings to metal substrates in controlled environments. CO_2 lasers, with light in the infrared spectrum, is effective for marking organic materials such as wood, leather, and certain plastics.

Field site marking tests have demonstrated that a CO_2 laser used in conjunction with appropriate materials can be used to safely apply IUID markings to parts typically found in a DOD depot or warehouse.

Appendix K. Marking with a Label

From MIL-STD-130N: Label. An item marked with the identification information of another item and affixed to that other item. A label may be of any similar or different material than that of the item to which it is affixed. A label may be made of a metallic or non-metallic material. Labels may be affixed to the identified item by any appropriate means. Labels are often referred to as plates (i.e. data plate, name plate, ID plate, etc.) however, label material and methods of marking and affixing have no bearing on this distinction.

The important considerations of a label are:

- How is the label attached to the item
- What material is used to make the label
- How is the data matrix mark applied to the label

<u>Attachment</u>

Labels are commonly attached with adhesives, adhesive tapes, structural epoxies, or rivets. Other more exotic means are also possible.

<u>Adhesives</u>

The chemistry of adhesives is quite advanced and continues to become refined. Adhesives come in three general categories rubber-based adhesives, acrylic Pressure Sensitive Adhesives (PSA), and silicone-based adhesives. Rubber-based adhesives degrade too easily for use in the DON for IUID. Most IUID related uses should use acrylic-based PSAs. Silicone adhesives have niche uses where high temperatures (~ 400 degree F) are found.

Specially formulated acrylic PSAs number in the tens of thousands. The reason for the large number is because of the wide variety of items marked with acrylic PSAs; each striving to find the optimum adhesive balance between two specific properties (adhesion and cohesion) to make the strongest bond. When adhesion fails the adhesive separates from either the item's surface or the label material. When cohesion fails the adhesive tears itself apart leaving some adhesive stuck to the item and some stuck to the label. In most adhesives the attraction to other things (adhesion) is in opposition to its attraction to itself (cohesion); so that as one gets stronger the other gets weaker. This is manageable when applying labels to a fixed repetitive commodity, as found on manufacturing production lines. In the case of legacy IUID marking for the DON however, this is not the case. Fortunately there are some acrylic PSAs, that defy this rule and have both high cohesion and high adhesive strength and have wide applicability over diverse surface types.

Different types of surfaces vary in their "stickiness" for lack of a better word. The technical phrase used to quantify this property is called surface energy. Higher surface energy means greater stickiness. Lower surface energy means lower stickiness. Non-stick materials like Teflon have very low surface energies around 18, whereas polished copper might have a surface energy as high as 1,100 if it were very clean. See Table 3for a partial list of surface energies for various materials. The problem areas arise for IUID marking when trying to label plastics and powder coated paints.

Surface Energy (dynes/cm^2)	Material
1103	Copper
840	Aluminum
753	Zinc
526	Tin
458	Lead
700-1100	Stainless Steel
250-500	Glass
50	Kapton® (Polymide)
47	Phenolic
46	Nylon
45	Alkyd Enamel
43	Polyester
43	Epoxy Paint
43	Polyurethane Paint
42	ABS
42	Polycarbonate
39	PVC (Polyvinyl Chloride)
38	Noryl®
38	Acrylic
38	Polane® Paint
37	PVA
36	Polystyrene
36	Acetal
33	EVA
31	Polyethylene
29	Polypropylene
28	Tedlar®
18	Teflon®

Table 3. Material Surface Energy

Adhesives are soft and never become truly hard. As such they will sag if a constant force is applied to them. Adhesives only work within a range of temperatures. Adhesives often breakdown when exposed to UV radiation. Adhesives are often susceptible to many organic solvents. The large variety of adhesives continues to grow and as it does it expands their applicability.

Adhesive Tapes

Adhesive tapes have adhesive on both the top and bottom of a carrier. They are useful if the label to apply does not come with pre-applied adhesive. The carrier can be made of differing sponge-like material, so-called foam tapes. These are useful in situations where surface roughness is high and are useful in absorbing shock and vibration.

Structural Epoxies

Like adhesives, a large variety exists and continues to grow. Epoxies have many of the same features and drawbacks as adhesives. They are different in a couple of critical areas of note. Epoxies do not completely rely on adhesion to maintain attachment. Because epoxies become hard they can mechanically bond to a surface that has a certain amount of roughness. It also means that epoxies can withstand constant forces. Because they get hard however they are susceptible to stresses and strains caused by differential expansion and contraction due to different materials having different coefficients of thermal expansion.

Rivets

When using rivets to attach labels, ensure that either all of the materials are the same (i.e. the label is made of the same material as the rivets which is the same material as the item it's attached to), or make sure the label is electrically isolated from the item.

Label Material

Labels can be made out of any suitable material. Although the most durable, intrusive marking techniques can be used on the toughest materials known to produce remarkably durable marks, the most widely used label materials will be plastics (e.g. polyester) and metal foils due to their convenience and inexpensive application. If the material is thin enough, marking can be accomplished with a thermal transfer printer quickly, conveniently, and inexpensively. These thin labels have wide application with suitable adhesive but are not durable enough for every application. Thicker label stock improves durability but increases the complexity of marking.

Application of the data matrix to the label material

Any direct part marking method can be used to apply the data matrix mark to the label material. High contrast materials can be chemically or mechanically fused to the label as is the case with thermal transfer printers, ink jet, laser printers and laser bonding. Photo-sensitive or thermally sensitive materials can be applied to the label over a large area (typically during manufacturing) before the marking process selectively induces a color change in the applied material. This is how direct thermal printing works as well as the array of laser markable products. Direct chemical or laser etching of the label can also be used to form data matrix marks creating intrusive marks in the label material.

A representative list of laser markable materials[5]

- Rubber labels
- Fabric labels
- Two-ply acrylic labels
- Stainless steel labels
- Aluminum labels

[5] The commercial availability of laser markable products continues to grow and specialize into niche applications.

Appendix L. Marking Techniques

Thermal Transfer Printing

The quality and durability of thermal transfer print depends on the label material and grade of ribbon used. Hundreds of different materials are available. In applications where thermal transfer labels are to be applied to parts, users should consider the use of a matte finish white polyester face stock top coated for thermal transfer printing and coated with high-strength permanent acrylic adhesive. The label material should be 2.0 mils (51 microns) thick or greater and print applied using a polyester resin ribbon.

For maximum bond strength, the surface should be clean and dry. For best bonding conditions, application surface and label stock should be within the manufacturer's range of application temperatures. Low temperature surfaces, normally below 50°F (10°C), can cause the adhesive to become so firm that it will not develop maximum contact with the substrate. Stronger initial bonds can be achieved through increased rubdown pressure. Rubdown pressure is best applied with a seam-roller.

Adhesives can be contaminated with skin oils unless specific precautions are used to prevent this. The easiest method to avoid this type of contamination is by using clean gloves when applying the label. Spatulas can alternatively be used to separate the label and adhesive from the label's liner to avoid direct contact with and contamination of the adhesive.

Stencils

Stencil markings are applied by depositing a marking agent onto a surface using a mask that has openings that correspond to the shape of the desired marking. Marking stencils are generated using photo-process technology, thermal printing, laser engraving and mechanical micro-cutting processes. Stencils can be created from a wide range of application-dependent materials including, but not limited to, paper, vinyl, zinc, aluminum, polypropylene, or magnetic rubber. Marking agents are applied to the part surface by spraying, rolling, or dabbing the agent through the openings in the mask. The marking agents most commonly used with stencil marking include the following:

- Abrasive blast
- Acid etch
- Chemical coloring agents
- Dip, barrier, and chemical conversion coatings
- Paint
- Plating and electro-plating
- Ink
- Thermal spray
- Vacuum and controlled atmosphere coatings, and surface modification processes

Laser and mechanically cut stencils need a symbol pattern that provides spacing between the data cells to keep the pattern together. The spacing provides a grid of interconnecting data cell elements that typically occupies approximately 36 percent of the individual data cell marking area, as illustrated in Figure 16. Interconnecting data cell elements that occupy less than 26 percent of the allotted data cell marking space can be damaged during stencil generation and handling, and those exceeding 46 percent of the allotted data cell area can adversely affect symbol readability.

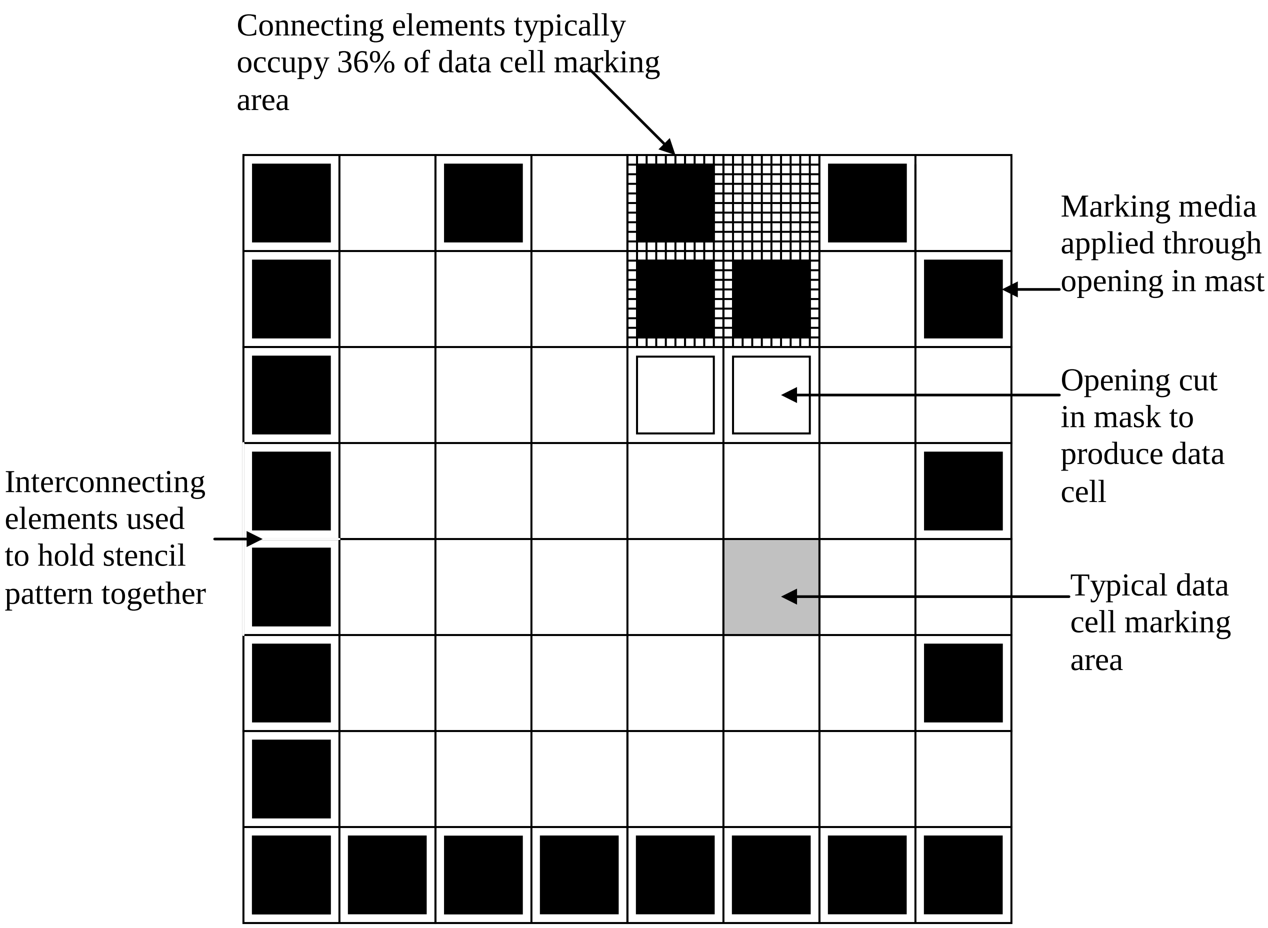


Figure 13. Data Matrix Stencil

While all of the methods described above can be made to work, the laser engraving process is the quickest and produces the highest quality stencils. The stencil material used to produce laser created stencils consists of a white 200 Mesh Polyester Screen coated with a colored thermoplastic polyester layer. This layer is removed to create the desired image without the need for interconnecting elements as shown in Figure 16. To apply the marking to the part, the surface is cleaned and the stencil taped down on the part surface. A drop of ink is the applied to the side of the marking and a squeegee or a plastic spreader used to spread the ink evenly across the opening in the stencil. One pass is usually sufficient. Some inks will tend to dissolve the thermoplastic coating, so multiple passed should be kept to a minimum.

The application of IUID symbols using stencils, regardless of the stencil type used, can be difficult because the operator must evenly press the media through hundreds of very small openings in the stencil without smearing it across the unmarked data cell areas. This can be extremely challenging for even the most experience technician.

Laser Coloring Technique

Laser coloring is a marking process that discolors (darkens) additives that are exposed to the specific wavelength produced by the laser. This process is notionally shown in Figure 17. These additives are contained in commercially available paints, epoxy films, tags and other media that can be added to parts. In most cases, laser colored markings are covered with a matte finish clear coat for environmental protection. Some products have been shown to darken over time because of intermittent exposure to heat and light.

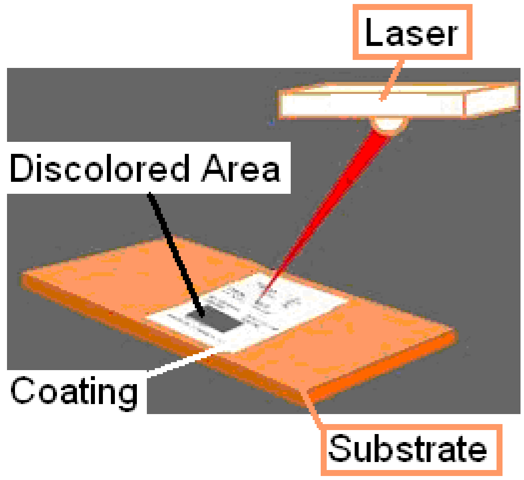


Figure 14. Coating applied to substrate and discolored with laser

Laser Bonding Technique

Laser Bonding is a process that involves a special paint applied to a part that is then marked to permanently fuse components in the paint to the surface. The unmarked paint is then removed using a lint free cloth saturated with water. The end state of this process is represented in Figure 18. Laser bonding is recommended for identifying legacy parts in the field that have been previously marked with intrusive marking processes.

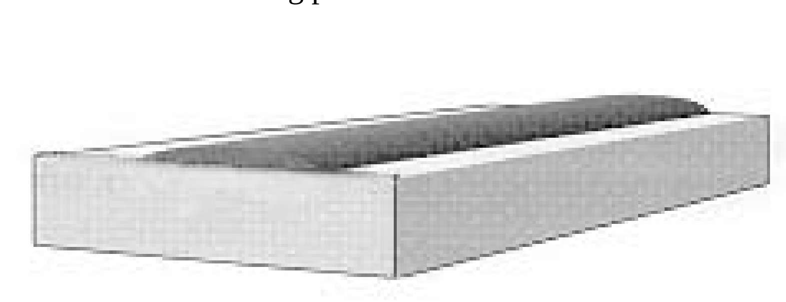


Figure 15. Material Fused To a Surface Using the Laser Bonding Process

Laser Engraving Technique

CO_2 lasers can be used to strip away organic coatings to expose an underlying substrate. For legacy applications, this can be done in three ways:

- removing the top coat of two-ply label or black anodized label.
- removing a coating of contrasting color applied over an existing coating or,
- removing the original coating applied to the part during manufacturing.

Markings made using this process expose the underlying material to corrosion, therefore approval from the cognizant technical authority is required. Approved procedures and materials to apply when marking is complete are necessary. The corrosion preventive coatings must be a clear matte finish or the mark will be ruined.

Appendix M. Removal of Data Matrix Marks

<u>OBLITERATION OF DIRECT MARKED DATA MATRIX SYMBOLS</u>**.**
Many direct part markings cannot be removed or otherwise corrected without deleterious effect to the marked item. Consequently, they should be made unreadable by crossing the symbol out as shown in Figure 14 using two diagonal lines crossing each other through the center of the data matrix and two other lines (one vertical the other horizontal) through the two interrupted frame lines (finder pattern) of the data matrix symbol.

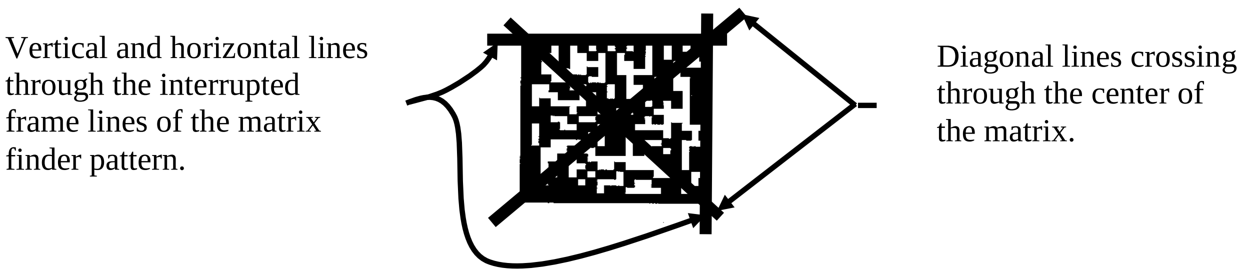


Figure 16. Obliteration of a Data Matrix Symbol

Original engineering drawings are written considering a single marking for direct part markings. Since repeated marking in the same area concentrate damage, having a cumulative effect on material properties, original engineering marking authorizations should not be used to justify additional marks. Consequently, personnel should refer unreadable direct part markings to quality assurance for resolution. quality assurance, working with engineering shall determine if the marking is to be obliterated and the part remarked.

In instances where additive markings are coated with a clear coat for environmental protection, the clear coat must be removed. Typically, if the clear coat has not fully cured (less than 24 hours since its application) the marking area is wiped with a clean lint free cloth coated with a Xylene based solvent. If the coating has been on the surface for more than 24 hours a Methylene Chloride based solvent is generally recommended. Both of these solvents are considered to be potential occupational carcinogens and health hazards by OSHA. Consequently, users are advised to use a safer substitute containing Aerostrip additive A FO606, approved by NAVAIR 01-1A-509, or similar products less hazardous solutions.

<u>Laser Engraving</u>
Laser Engraving (direct surface removal) – Markings made by removing painted surface coatings to form a mark can be repaired by painting over the mark and reapplying the marking. Surface markings made by removing anodized finishes are best corrected by removing the surface containing the marking using a laser and then replacing it with a laser bonded marking applied to the bare metal surface. The marked area shall then be coated with a clear coat for corrosion protection.

Laser Bonding

Laser bonded markings can be removed using commercially available Electronic Weld Cleaners which use AC current and chemistry to clean the surface. The unit uses a wand, saturated in a salt solution, to clean the surface using an instant electro-chemical reaction. The combination of electricity and chemistry generates heat, causing and a deoxidizing reaction called "passivation." Using this process, laser bonded markings can be removed in seconds. After cleaning, the surface is ready for immediate remarking.

Labels

The least damaging method for removing labels is done using dry ice. This is done by applying dry ice to the label for 4-5 minutes to cause the adhesive to become brittle. The label is then tapped on the edge with a blunt object, preferably a plastic scrapper, to free it from the item. Any surface exposed after label removal should be restored to its original condition before the new label is applied.

Ink and Paint

Ink and paint markings protected with a clear coat can be removed using a lint free cloth saturated with a solvent. In many cases this process will result in the part coating being damaged. Damaged surfaces shall be repainted, allowed to dry, and then remarked as defined within this guide.

Appendix N. Verification

Data matrix symbol quality can be determined using either of the following requirements:

- ISO/IEC 15415 is designed to verify high contrast (black on white) marks and should be used when evaluating such marks whenever possible.
- AIM DPM-1-2006 is designed to verify direct-part-marked items which typically have low or no inherent contrast. These marks derive contrast with shadows, which are created by illuminating irregular surface features with light at an angle. This standard should be used to verify direct part marks made by forming irregular surface features whenever possible.

ISO/IEC 15415

The symbol shall have a minimum quality grade of 3.0/05/650 measured with an aperture size of 0.005 inch (0.127 mm) with a light source wavelength of 650 nm ± 20 nm. As an exception, the ISO/IEC 15415 parameters Modulation (MOD), Symbol Contrast (SC), or both, may measure as low as 2.0, providing the overall ISO/IEC 15415 grade would be 3.0 if the MOD and SC grades are 3.0 or higher. (This allows for lower contrast substrates, high density images, printing, over-laminates and other such limiting factors to the parameters MOD, SC, or both on otherwise well produced images.) Quality (symbol validation and verification) reports shall clearly show that the MOD, SC, or both, are the only parameters measured as low as 2.0, and clearly show that the overall grade would be at least 3.0 if MOD and SC were at least 3.0. Quality reports shall also document the synthetic aperture size used. The methodology for measuring the print quality shall be as specified in ISO/IEC 15415, where the overall grade is based on a single scan (not five scans).

AIM DPM-1-2006

The symbol shall have a minimum quality grade of DPM2.0/7.5-25/650/(45Q|30Q|90|30T|30S|D) where:

i. Minimum quality grade = 2.0
ii. X dimension range of the application = 7.5-25 mils
iii. Inspection wavelength = 650 nanometers ± 20 nanometers.
iv. Lighting conditions = Medium Angle Four Direction (45Q) or Low Angle Four Direction (30Q) or Diffuse Perpendicular (90) or Low Angle Two Direction (30T) or Low Angle One Direction (30S) or Diffuse Off-axis (D).

Validation and verification shall be required at point of receipt, if previously marked with a data matrix symbol. If not, then at point of marking. Verification shall be performed after part servicing and repair where cleaning processes can degrade mark quality. Intrusive markings can be applied at refurbishment and overhaul points where required safety and engineering controls are in place. Intrusive marking verification is required on a mark per mark basis and is more involved. Requirements for mark quality verification as defined in this technical guide can be found in MIL-STD-130.

Appendix O. Quality Sampling Plans for Bar Code Creation

To ensure the quality of the barcode printed is as high as possible the mark should be verified. Verifying ensures that the mark meets the standards for contrast, shape, cell size, reflectance, etc. However, when large quantities of marks are needed verifying every mark can be very time consuming. The MIL-STD-130 allows for the adoption of a lot acceptance sampling plan as a method to test the integrity of a batch of barcodes without having to verify every barcode.

Lot acceptance sampling is an inspection procedure where a random sample is taken from a lot, and upon the results of appraising the sample, the lot will either be rejected or accepted as being of acceptable quality.

The most common lot acceptance sampling procedure to use is to have a sampling plan and decision rule. For the plan there are some parameters that are either chosen or determined and a rule that tells us when to accept or reject a lot.

Sampling Plan:
N = lot size
n = sample size (randomized)
c = acceptance number
d = number of defective items in the sample

Decision Rule:
If $d \leq c$, accept the lot; else reject the lot in which case we have to do a 100% inspection.

Since each label is not being verified, there are certain risks involved in this procedure. These risks come in two types and are called Producer's Risk and Consumer's Risk.

Producer's Risk (α) is the probability of rejecting a lot which is good.
Consumer's Risk (β) is the probability of accepting a lot which is bad.

For most sampling procedures, producer's risk is typically set at 5% and consumers risk is set at 10%.

The statistical properties of the acceptance sampling procedure can be determined by considering how the acceptance probability depends on the true proportion d of defective items in the lot. It is usual to define an Acceptable Quality Level (AQL), c say, so that a lot is considered acceptable as long as $d \leq c$. In this way the producer's risk is the probability of rejecting lots that are at an AQL. Another term often used is the Lot Tolerance Proportion Defective (LTPD). This is the worst level of quality tolerable. The consumer's risk then corresponds to the probability of accepting lots at the LTPD.

Table 4 below provides the random sample of labels that need to be verified and the maximum number of defects that are allowed in the sample in order for the entire lot to be accepted for a given lot size. For example, if 100 labels were printed 54 of them would be randomly verified. If more than 4 barcodes failed verification, the quality of the lot would be rejected and all 100 barcodes would be verified, discarding those that failed verification.

Lot Size	Sample size To Test	Max defects to accept lot
1-25	21	1
26-50	41	3
51-75	54	4
76-100	54	4
101-150	75	6
151-200	78	6
201-300	89	7
301-400	101	8
401-500	101	8
501-600	112	9
601-800	113	9
801-1000	114	9
1000-2000	125	10
2001-5000	125	10

Table 4. Sampling Plan Examples

Since the printing of barcodes is a mechanical process, one would expect print quality to begin deteriorating towards the end of a lot. To ensure this fact is taken into account, it is best to divide the number of barcodes you are printing into three batches and randomly verify 20% of the samples in the first third, 30% in the second third, and 50% in the last third always choosing the last barcode in the lot as one of the samples.

References

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Kiermeier, A., *Visualizing and Assessing Acceptance Sampling Plans: The R Package Acceptance Sampling*, Journal of Statistical Software, July 2008, Volume 26, Issue 6.

Appendix P. Useful Process Control Techniques

These techniques do not constitute a print quality check of the produced symbols required per MIL-STD-130 but nonetheless yield good indications of whether the symbol print process is creating workable symbols.

Special Reference Symbol

Figure 17. ECC Reference Symbol

For process control purposes, a 16x16 ECC 200 reference symbol can be printed which encodes the data "30Q324343430794<OQQ". As shown in Figure 15, this reference symbol has a region of parallel bars and spaces. Printing the reference symbol in different orientations allows different print alignment flaws to be seen with proper magnification. A 30x jeweler's loupe is useful for this purpose. This symbol is particularly useful if a linear barcode verifier is available as the parallel lines in the upper left can be measured for contrast and print growth. ANSI X3.182 is useful for this purpose.

Assessing Axial Nonuniformity

For any symbol, measure the length of both legs of the "L" shaped finder pattern. Divide each length by the number of modules in that dimension, e.g. a 12x36 symbol would have 12 and 36 as divisors. These two normalized dimensions are X_{AVG} and Y_{AVG} which can be used in Equation 1 to grade axial nonuniformity.

$$AN = \frac{|X_{AVG} - Y_{AVG}|}{(X_{AVG} - Y_{AVG})/2}$$

Equation 1. Axial Nonuniformity

A (4.0)	If AN ≤ 0.06
B (3.0)	If AN ≤ 0.08
C (2.0)	If AN ≤ 0.10
D (1.0)	If AN ≤ 0.12
F (0.0)	If AN > 0.12

Table 5. Axial Nonuniformity Grading Rubric

Visual Inspection for Symbol Distortion and Defects

Ongoing visual inspection of the perimeter patterns in sample symbols can monitor two important aspects of the print process.

First, 2D data matrix symbols are susceptible to errors caused by local distortions of the matrix grid. Any such distortions will show up visually in a data matrix symbol as either crooked edges on the "L" shaped finder pattern or uneven spacings within the alternating patterns found along the other two margins of the symbol. Larger ECC 200 symbols also include alignment patterns whose straightness and evenness can be visually checked. Symbols likely to fail the reference decode can be quickly identified this way.

Second, the two arms of the finder pattern and the adjacent quiet zones should always be solidly in opposite reflectance states. Failures in the print mechanism which may produce defects in the form of light or dark streaks through the symbol should be visibly evident where they infringe the finder of quiet zone. Such systematic failures in the print process should be corrected.

Appendix Q. Acronyms

A&LM	Acquisition and Logistics Management
ADC	Automatic Data Capture
AGE	Aerospace Ground Equipment
AI/DC	Automatic Identification and Data Capture
AIM	Automatic Identification Manufacturers
ANSI	The American National Standards Institute.
ASME	American Society of Mechanical Engineers
ASN	Assistant Secretary of the Navy
ATA	Air Transport Association
CO_2	Carbon Dioxide
DFARS	Defense Federal Acquisition Regulations Supplement
DOD	Department of Defense
DON	Department of the Navy
DPM	Direct Part Marking
EAN	European Article Number
ECC	Error Correction Code (equivalently Error Checking and Correction)
ECM	Electrochemical Machining
EDM	Electro Discharge Machining
EEE	Electrical, Electronic, and Electromechanical
ESD	Electro Static Discharge
EN	European Standard
FACT	Federation of Automatic Coding Technologies
HDBK	Handbook
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
IUID	Item Unique Identification
Laser	Light Amplification by Stimulated Emission of Radiation
MOD	Modulation
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Aviation
nm	Nanometer (0.000000001 meters)
P/N	Part Number
QCTS	Quick Compliance Tool Suite
OSHA	Occupational Safety & Health Administration
RDA	Research, Development and Acquisition
RMS	Roughness Measurement Scale
SAE	Society of Automotive Engineers
SEM	Scanning Electron Microscope
SIM	Serialized Item Management
S/N	Serial Number
UCC	Uniform Code Council
UID	Unique Identification
UII	Unique Item Identification
URL	Uniform Resource Locator

USCG	United States Coast Guard
UV	Ultra Violet
VOCs	Volatile Organic Compounds
WD	Working Draft
YAG	Yttrium Aluminum Garnet
YAP	Yttrium Aluminum Perovskite
YLF	Yttrium Lithium Fluoride
YVO_4	Yttrium Vanadate Orthovanadate