DEPARTMENT OF THE NAVY

ITEM UNIQUE IDENTIFICATION (IUID) MARKING GUIDE:

APPLYING DATA MATRIX IDENTIFICATION SYMBOLS TO LEGACY PARTS

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DEPUTY ASSISTANT SECRETARY OF THE NAVY
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RECORD OF CHANGES

Version	Page	Date	Description
1.0	All	12/07/2010	First Version
1.1	All	9/23/2011	Incorporated technical and editorial clarifications

FOREWORD

This Department of Navy Item Unique Identification (IUID) Marking Guide provides technical information for applying IUID data matrix symbols to legacy items owned by the Department of Navy (DON). It is intended to support better decision-making by DON marking managers, engineers, and implementers. The information contained in this guide is derived from Department of Defense (DoD) standards, International Standards Organization (ISO) standards, industrial organizations, and practical experience.

IUID marking of qualifying items is required by Defense Federal Acquisition Regulation Supplement (DFARS), and DoD and SECNAV Instructions (referenced in Appendix A). This guide does not repeat requirements; therefore, PMs and their staffs should refer to all referenced documents, and other resources such as organizational websites for overall IUID implementation planning and monitoring requirements. This guide is intended to reduce the time required by PMs and their staffs to understand the technical dimensions of planning an IUID marking effort and increase the quality and compliance of the mark symbols upon application within the framework of a larger program implementation plan.

The guide captures the expertise of many years' work by the IUID Center at the Naval Surface Warfare Center (NSWC) Corona in applying, testing, and consulting on IUID data matrices. It is not intended as directive, but shares the IUID Center's insights with the widening community of personnel involved in IUID marking to promote longevity and readability of marks.

We support efforts to improve this technical information and its accessibility to decision-makers at every level, and encourage recommendations to enhance the usefulness of this guide. Marking technologies, materials, and devices are constantly evolving, so your experiences could be helpful in improving this guide. Your recommendations may be made to NSWC Corona's IUID Center at: CRNA-IUID_gateway@navy.mil; or to the DASN (Expeditionary Programs and Logistics Management) IUID policy staff at ASNRDA_IUID@navy.mil. Comments may also be submitted to:

DASN (Expeditionary Programs and Logistics Management)
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Contents

1 Introduction

The purpose of this document is to consolidate and present technical information needed to mark legacy items effectively with Item Unique Identification (IUID) compliant two-dimensional (2-D) data matrix symbols.[1]

Information within this 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).

This guide is published by the Department of the Navy (DON), through the Office of the Deputy Assistant Secretary of the Navy (DASN), Expeditionary Programs and Logistics Management (ELM).

2 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[2] (ECC) 200 data matrix symbol (Figure 1) per MIL-STD-130 (latest version), *Department of Defense Standard Practice: Identification Marking of U.S. Military Property*.

Figure 1. ECC200 Data Matrix Symbol

The Department of Defense's (DoD) IUID requirements dictate an item's mark:

- Remains readable throughout the item's normal life cycle
- Withstands all environmental conditions to which the item will be exposed under normal operating conditions
- Provides no detrimental effects on the functional performance, reliability, or durability of the item.

IUID markings applied to legacy parts should be made using non-intrusive marking methods unless intrusive marking is specifically authorized by quality assurance, safety, and engineering competencies of the relevant program. A non-intrusive marking method adds material to the surface of the item either directly as with stenciling, laser bonding, or direct ink jet, or indirectly as a label or data plate. An intrusive marking method either deforms or removes material from

[1] Other documents explain facets of IUID not covered herein. See Appendix A for references.

[2] ECC is known as Error Checking and Correcting by some.

the surface of the item, as with dot peening, stamping, abrading, scribing, or etching.

While labeling is often the easiest method to implement, it may not always be the best solution. To determine the best marking solution, the following factors about the item to be marked must be considered:

- Function
- Available marking area
- Material type
- Color
- Hardness
- Surface roughness/finish
- Surface thickness
- Operating environment.

If it is determined that intrusive marking is required and such marking has been authorized by quality assurance, safety, and engineering competencies for an item, then one or a combination of the following may be required to safely mark legacy items:

- Appropriate engineering drawings and specifications
- Approved marking device settings
- Appropriate clamping fixtures
- Depth measurement and microscopic evaluation equipment
- On-site quality, safety, and engineering personnel to certify and monitor marking operations
- Procedures to evaluate and disposition improperly applied markings
- Procedures to assess the cumulative effects of multiple marking removal and re-applications.

There are a number of details and factors to take into consideration when selecting and utilizing intrusive marking; the full discussion is beyond the scope of this document. An overview of some common intrusive, direct part marking methods is presented in Appendix B.

3 Organization

This guide is organized as a relatively short body, supported by extensive appendices on individual technical issues.

4 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. 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 methods for marking 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.

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.

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 a variety of requirements for producing technically sound data matrix marks.

5.1.1 Policy Options for Engineering Change Requests and Drawing Revisions

Given the tremendous burden in terms of cost, workload, and scheduling associated with engineering change requests and drawing revisions, it is useful to take advantage of the broad scope found in DON policy. SECNAVINST4440.34 provides conditional exemption from engineering change requests and drawing revisions when affixing labels and/or data plates for IUID purposes (see Appendix C).

If conditions for the above exemption cannot be met, then alternative plans must be made. *The Guidelines for Engineering, Manufacturing and Maintenance Documentation Requirements for Item Unique Identification (IUID) Implementation*, version 1.2 provides different strategies for minimizing the impact of cost, workload, and schedule associated with performing engineering and updating technical documentation for IUID marking (see Appendix D).

5.1.2 Placement of the Mark

Where the IUID mark is placed on the item strongly influences the mark's durability and usefulness. Therefore, when determining where to place the mark, consider the following:

- Apply marks in protected areas when possible
- Apply marks on flat 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
- Multiple **identical** marks can be applied to the same item.

Unless directed to the contrary by the technical authority, do not place marks/labels:

- On components or pieces authorized to be replaced during field maintenance
- 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 (for example, leading edge of wings, helicopter rotors, exposed portions of turbine blades, and so forth)
- 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, such as when marking curved, rough, or shiny surfaces or marking items that are sensitive to electrostatic discharge. Many placement considerations stem from a technical understanding of how 2-D barcode readers (scanners) decode symbols as well as understanding efforts taken to maximize the reliability of decoding the data matrix. For information about mark placement on curved, rough, or irregularly shaped items, see Appendix E.

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 legible:

- Make the individual cells (modules) of the data matrix large
- 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[3]
- Protect the mark with a cover or coating.

5.1.3.1 Cell Size

The data matrix symbol is made from a collection of small black or white squares[4] called "cells" or "modules." It is easier to fatally damage a small data matrix than it is to fatally damage a larger data matrix containing the same data. In other words, if a small data matrix is scratched, the likelihood that matrix will be rendered unreadable is greater than if the same scratch were made to a larger data matrix. Damaged symbols with large cell sizes are 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 F for suggested cell sizes for different operational environments. For techniques and

[3] The ECC 200 data matrix specification is documented in ISO/IEC 16022 Information Technology – International Symbology Specification – Data Matrix.

[4] Some marking methods, such as dot peening, produce small circles as opposed to squares.

more general information to optimize module size see Appendix G.

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% as shown on a typical gray scale comparator (Figure 2).

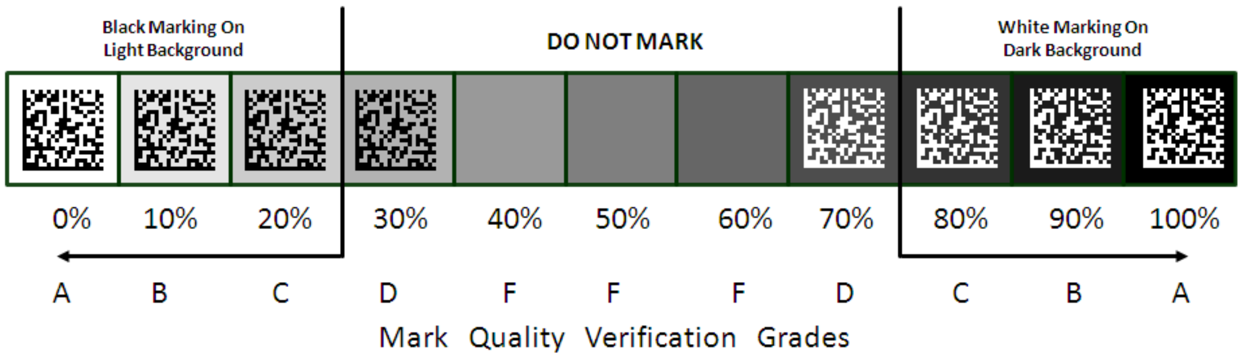


Figure 2. Mark/Substrate Symbol Contrast

The minimum acceptable contrast level difference is 20% 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.

5.1.3.3 Quiet Zone

A clear space (quiet zone) must be left around the outside of the symbol in order for the scanner to successfully decode the data matrix. A minimum of one cell width of quiet zone must be left around the symbol. However, due to variations in surface finish, it is helpful to extend this area. If possible, allow an additional 10% of the longest symbol side.

Encroachment into the quiet zone occurs when (1) the data matrix is applied too closely to the edge of the designated marking area; or (2) other information is applied too closely to the data matrix (Figure 3). Both problems are shown on the right side of Figure 3.

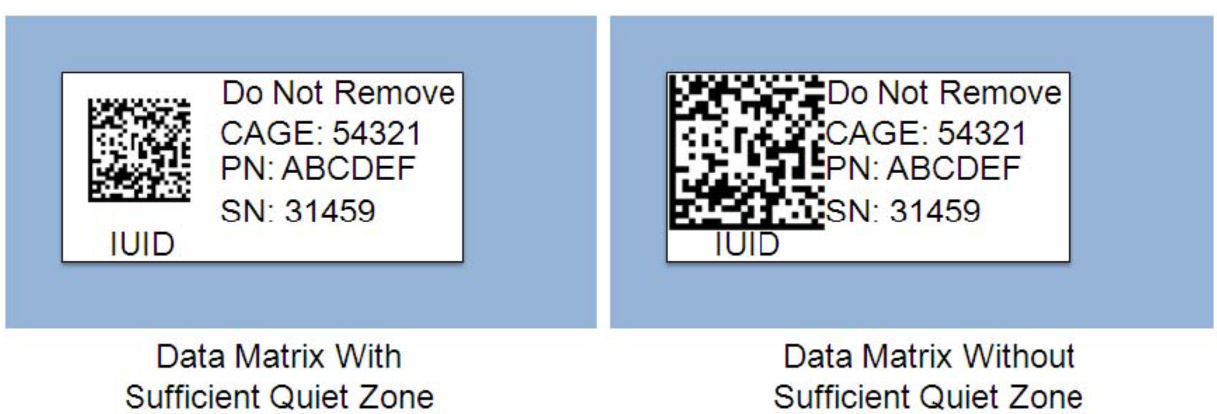


Figure 3. Example of Proper and Improper Quiet Zone Allocation

5.1.3.4 Protective Coatings and Covers

Protective coatings and covers can add resilience to 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, avoid trapping air bubbles between the cover and the mark.

5.1.4 Minimizing Attachment Failures

Failures of labels to maintain attachment to the item occur for a variety of reasons. In some cases, the strength of attachment declines over time, while in other cases, the initial strength of attachment is insufficient.

Attachment strength weakens over time due to the slow, persistent degradation of materials, which can be caused by ultraviolet (UV) light, thermal expansion, or corrosion. Adhesives/epoxies are often damaged by 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 (different materials almost always 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 serious 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 using marking materials ill-suited to the item's environmental requirements, or to the marking process. Therefore, select marking materials based on the item's environmental requirements as well as any maintenance procedures—both authorized and unauthorized—to which the item is subjected. Adhesives and epoxies are at risk of failure when they become brittle at low temperatures or soften at high temperatures, and they break down completely if the temperature is high enough. Finally, improper surface preparation (poor cleaning) leads to lower attachment strength and can be a prevalent, persistent, and perhaps critical problem. For more information on surface preparation, see Appendix H. For more information on the application of labels see Appendix I.

5.1.5 Choosing the Right Marking Method

As mentioned above, it may be possible to use established marking processes and procedures. They are likely the best choice, providing these processes support the creation of a high-quality data matrix symbol.

However, 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. For an overview of some of the available marking techniques see Appendix J.

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

The next most durable marks fuse rugged material directly to the item's surface to form the mark. These 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 use lasers to fuse the mark to the surface. See Appendix K for more information on additive marks. See Appendix L for more information on common part marking methods.

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. The use of labels, which are available in a variety of materials and can be applied using many different methods, is often the cheapest and most convenient marking method available. See Appendix I for more information.

5.2 Proper Execution of the Marking Process

Proper execution of the marking process requires the information encoded into the data matrix be both formatted correctly and applied to the correct item. Although independent software exists to evaluate the formatting of the data matrix symbol to check it meets IUID requirements[5], most verification systems validate a mark's syntax at the same time as verifying the mark's 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 60 days because there is only a 60 day window of opportunity to correct information sent to the IUID Registry. See Appendix M for information about how to remove a data matrix mark from an item.

5.2.1 Production Quality of the Mark

DoD and DON policy requires the verification of IUID data matrix marks. Verification is the process that checks the production quality of the mark—this is different from checking the information encoded within the mark. See Appendix N for more details.

Verification can be performed on each data matrix or as part of a sampling plan. Appendix O 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 P for details.

[5] A useful example of syntax-checking software is the government-owned 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 Documentation Requirements for Item Unique Identification (IUID) Implementation
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	Item Unique Identification (IUID) Standards for Tangible Personal Property
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 Department of 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 in this appendix may have been revised since publication. Check for the latest version of the reference.

Useful Websites

DASN (ELM) IUID website:
https://acquisition.navy.mil/rda/home/acquisition_one_source/item_unique_identification_iuid
Director of Defense Procurement and Acquisition Policy website:
http://www.uniqueid.org

Appendix B. 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, and so forth. An intrusive mark is designed to last the life of the part and will survive overhaul in many cases.

However, if intrusive markings are applied improperly, 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 electrochemical 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 short wavelength lasers
- Dot peening (stamp impression)
- Electrochemical etching (electrolytic surface coloring or metal removal processes)
- Engraving
- Fabric embroidery
- Laser shot peening
- Milling.

Direct Part Marking Engineering and Test Database

Extensive engineering and metallurgy test data are available to the government and public in the "Direct Part Marking Engineering and Test Database," to allow wide distribution of expensive engineering results. The database contains many test results of different methods of intrusive marking on different metals and surfaces. The test results can be accessed at: http://rsesc.uah.edu/DPM.

Three considerations are addressed:

- IUID marking methods (dot peen, laser/ chemical etch, direct ink, label, engraving, coating)
- Material types & finishes (80% common to most of industry – aluminum, titanium, steel, copper/nickel)
- Environmental criteria (80% common to most of industry or use worst case - ultraviolet, heat, cold, lubricants, humidity).

All DoD organizations conducting controlled tests are encouraged to submit their testing for public availability in this resource. University testing facilities are available to interested parties for additional testing on a cost basis.

Appendix C. Policy for Conditional Exceptions to Engineering Analysis

SECNAVINST 4440.34 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."

For configuration management purposes, the details of this replacement label must be conveyed to the technical authority for later incorporation into the technical drawings for any item with a technical drawing package.

For purposes of applying the policy above, the definition of "label" is below.

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 D. 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 E. Marking Location and Surface Finish Information

Symbol Shape

The data matrix symbol can be created as a square or a rectangle (Figure 4). The square is preferred unless the marking area on the item is rectangular and limits the cell size of a square data matrix. For some linear-shaped parts such as pipes, lines, narrow part edges, and so forth, it is usually desirable to use a rectangular-shaped symbol; the intent is to use a symbol shape that provides the largest cells.

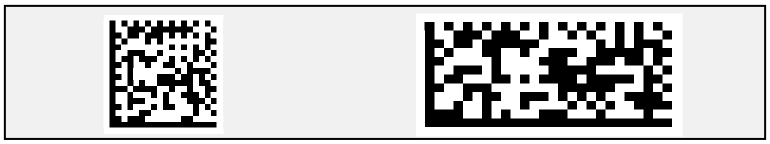


Figure 4. Symbol Shapes

Sensitive Surfaces

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

Thin Surfaces

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

Curved Surfaces

Flat surfaces are preferred over curved surfaces for marking when a choice is available. A rectangular symbol, rather than a square symbol, is better for application to polished concave or convex cylindrical parts. 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.

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

Under normal room light, this band of light typically occupies 16% of the diameter of the curve but can increase in size under bright light conditions. To apply larger symbols, the surface should be textured to reduce glare or matte-finished, laser-markable paints should be used to mark the part.

<u>Labeling Curved Surfaces</u>

When applying a label to a one-dimensional curve (such as a cylinder), use dimensionally stable label stock (for example, polyethylene) to reduce cell deformation due to stretching. However, if the shape is a 2-D curve (like a ball), a dimensionally stable label material will develop creases and wrinkles when applied and should therefore be avoided.

Labels that can stretch (such as polypropylene) should be applied with great care to minimize distortion to the cells of the data matrix. If possible, avoid the use of labels for 2-D curves. If no alternative exists, verify the marks after application to ensure the mark is remains readable. Verification can be used to check stretch-induced cell deformation when performed after application rather than before.

Labels applied to curved surfaces using adhesives may "flag" (that is, the edges may lift as the material resumes its normal, flat, geometry). Flagging occurs when the label material retains its original shape but the edges were not sufficiently seated to the base material. Therefore, both surface preparation and burnishing the label's edges are important when working with curved surfaces. Note also the use of softer, thicker adhesives help prevent flagging.

Surface Roughness/Finish

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 (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.

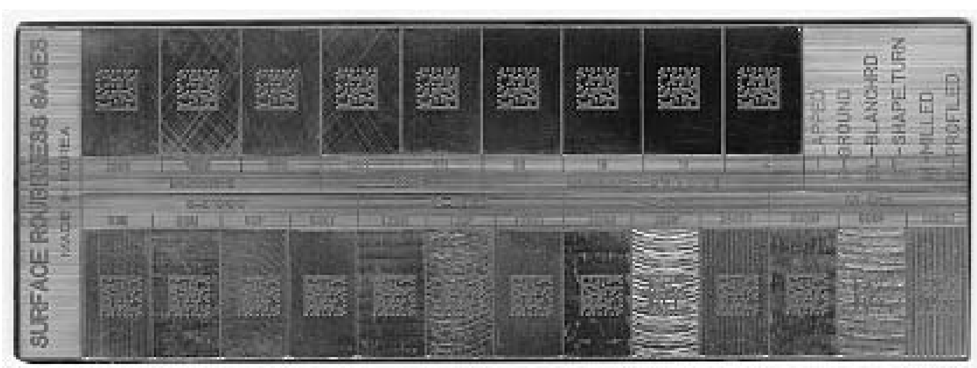


Figure 6. Typical Surface Finish Roughness Gauge
Note: Data matrices in Figure 6 are not IUID compliant.

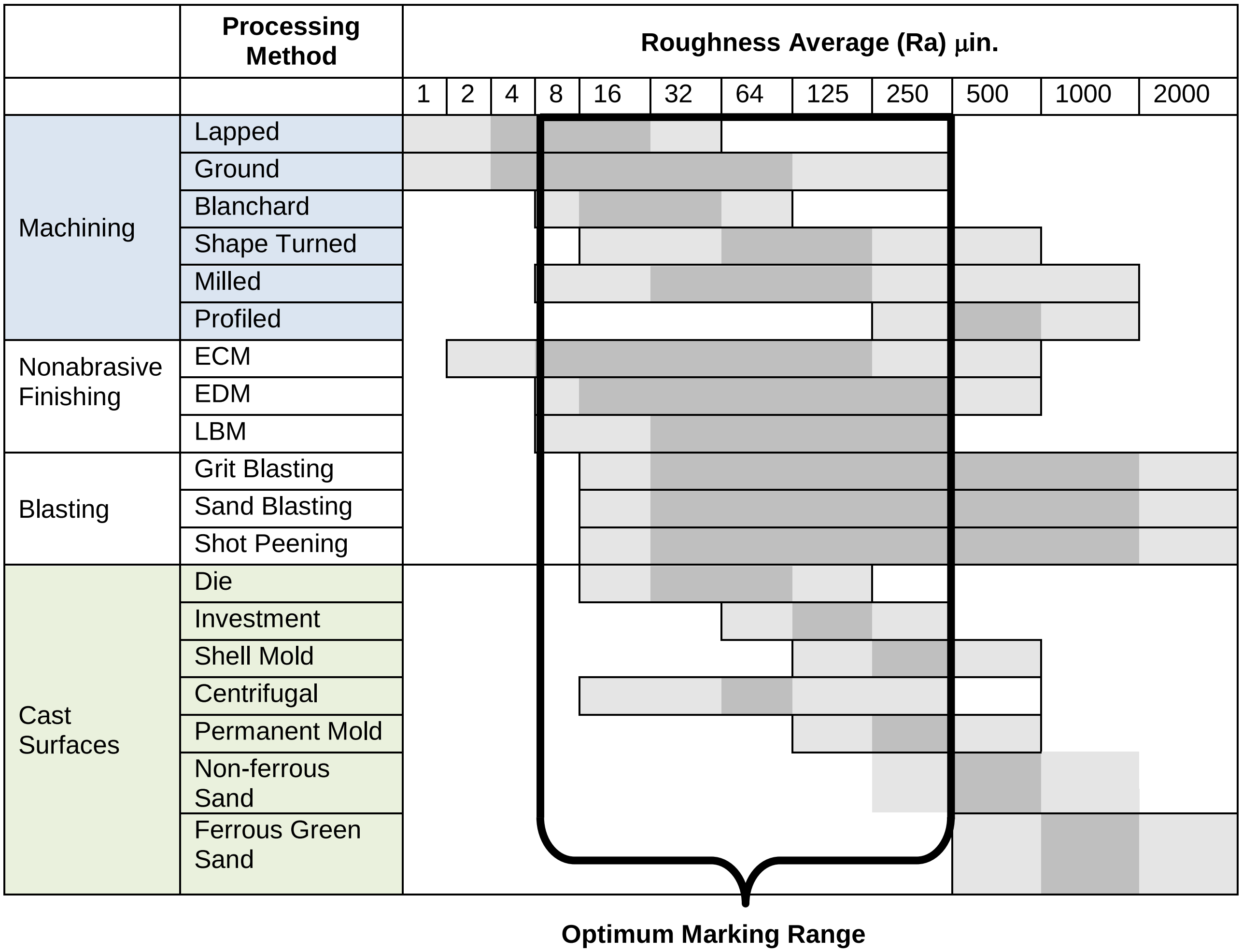
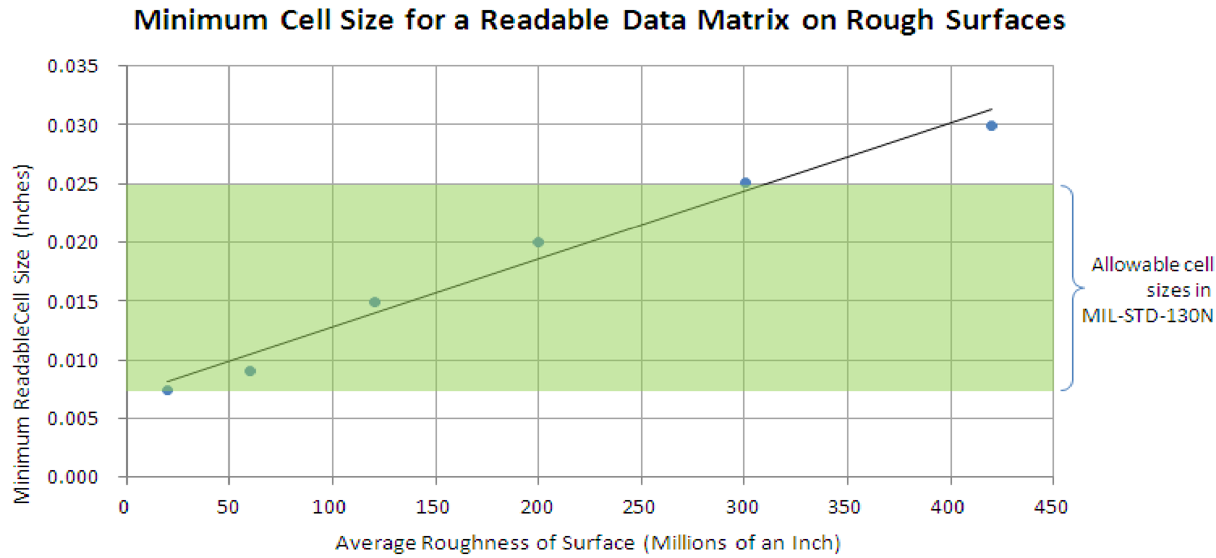


Figure 7. Average Roughness by Surface-Finishing Method

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 (the direction 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 does not reflect back to the reader, the surface will appear dark to the reader and make the mark difficult to decode.

Particularly rough surfaces, such as 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. Table 1 provides the calculated minimum readable cell size values for selected average roughness levels.



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

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)
129 (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)	0.01299 (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.

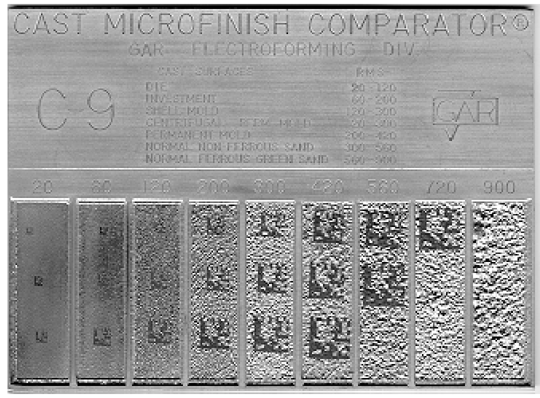


Figure 9. Comparator Showing Relationship Between Cell Size and Cast Surface Roughness
Note: Data matrices in Figure 9 are not IUID compliant.

Appendix F. Data Matrix Module Size by Environment

See Figure 10 for guidance regarding appropriate data matrix cell sizes to overcome damage from different grades of environmental exposure.

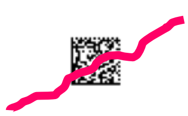
Mild Environments	Moderate Environments	Harsh Environments
General office conditions where there are moderate temperatures and minor exposure to non-abrasive cleaning chemicals. Examples include office furniture, calculators, computers, reproduction machines, and so forth.	Indoor or general outdoor use. 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), and so forth.	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 autoclaves, chemicals, or abrasives. Examples are external aircraft components, engine parts other than internal combustion engine components, refinery equipment, work-in-process manufacturing, and tools
Minimum suggested cell 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 a mark unreadable.	 Error correction can reconstruct symbol.	 Less 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 G. Cell Size Limits & Techniques to Overcome Size Limits

Cell Size Limits

MIL-STD-130 requires cell sizes to be no bigger than 0.025 inches and no smaller than 0.0075 inches unless specified by contract. Deviations outside these cell size limits are not recommended since commercially available scanners are not designed to read them without customized optics.

The upper limit of cell 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 no bigger than 1 inch. Since 40 cells, each 0.025 inches to a side, would consume the entire 1 inch, any data matrix having data requiring more than a 40-cell wide data matrix must use cells smaller than 0.025 inches. Because items may not have 1 inch to spare for a data matrix symbol, the maximum number of cells to a side may need to be fewer than 40.

The data matrix specification[6] permits 30 different sizes for symbols, 6 of which are rectangular, the remaining 24 are square. The largest and smallest sizes cannot be used for IUID due to IUID size and/or data requirements[7] (indicated with ***<u>bold, italic, underlined</u>*** font in Table 2).

For large items (items that can accommodate a 1-inch mark), the amount of data encoded into the mark is not usually an issue. However, 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 that optimally would have a 0.20 inch cell size. The geometry dictates use of a 10x10 data matrix for this area and cell size. A 10x10 data matrix does not have enough data capacity for IUID. This item will need to be marked with cells less than the recommended 0.20 inch. Encoding a minimum amount of data will lead to larger cell 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. For example, there will be no size benefits to the data matrix if a particular encoded string shrinks from a data capacity of 29 to 23. In either case, a 22x22 data matrix must be used.

[6] ISO/IEC 16022

[7] MIL-STD-130N, ISO-IEC 15434

	Rows		Columns	Max. 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
	40	x	40	0.025”	86
	44	x	44	0.023”	114
	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	0.009”	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 Cell Size and Capacity Chart

Encoded Data Compaction

The data matrix specification defines several encoding methods. Explaining these methods and the capacity required for each with a given string of data is complex and beyond the scope of this guide. It is made more complicated in that IUID compliant data matrix symbols encode syntax specified within ISO15434. The following are the important ideas to consider when optimizing 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
    - o Macros are sometimes referred to as a "prefix" in barcode-generating software
    - o Macros are not supported by all marking devices but are supported by all readers
    - o "Macro05" is available when using Application Identifiers (GS1 data qualifiers)
    - o "Macro06" is available when using Data Identifiers (MH10.8.2 data qualifiers)
    - o A macro that can be used with Text Element Identifiers (ATA data qualifiers) is not available.
- The exact same UII can be encoded in different ways to optimize cell size (see Figure 11 and Figure 12).

22x22 Data Matrix
Non-optimized encoding

Same UII in both (D123456A78)

14x14 Data Matrix
Optimized encoding

Figure 11. Minimizing Cell Count Through Optimized Encoding

¼"

Module size = 0.011" ¼"

Module size = 0.018" ¼"

¼"

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

Appendix H. 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 compliance wipe removes solid particulate contaminants (dust and dirt) and fluid films (oils) that 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 to perform a compliance wipe. Use a solvent to dissolve the surface contaminants, and then wipe off the surface with a clean, dry wipe. If the solvent is permitted to dry on the item's surface before it is wiped off, the contaminants will precipitate back onto the surface, thus rendering the compliance wipe ineffective. Take care to enforce use of authorized solvents—many household cleaning products include "shine factors" that purposefully leave problematic residues that promote the appearance of a clean surface. General purpose solvents like water and isopropyl alcohol are useful in many but not all situations. For example, isopropyl alcohol is known to react with hydraulic fluid to create a sticky acrylic resin. If this resin should be introduced into a hydraulic system it is possible to cause a variety of problems.

Military cleaning technical instructions and procedures are defined in a many different technical standards, handbooks, and guides written with reference to specific materials, products, and end-item types. Use cold-cleaning processes for marking mechanical and structural parts. Cold cleaning is done by immersing and soaking, spraying, or wiping the parts to be marked with ambient temperature solvents.

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; Axarel 9100 (isoparaffins); and 3M™'s PF-5050, PF-5052, PF-5060, PF-5070, and PF-5080 (perfluorocarbons).

Operators should refer to 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 be applied only to clean bare metal. If the bare metal surface to be marked cannot be cleaned using compliance wipe procedures (for example, 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, or 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 include an additional area around the mark which is as wide as half the symbol's width (longest side if a rectangle).

Appendix I. Marking with a Label

MIL-STD-130N defines “label” as:

> 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.

Before marking with a label, consider the following:

- 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.

Method of Attachment

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

Adhesives

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 to be used in IUID marking. Most IUID-related uses should use acrylic-based PSAs. Silicone adhesives have niche uses where high temperatures (~ 400°F) are found.

There are tens of thousands of specially formulated acrylic PSAs, because of the wide variety of items marked with acrylic PSAs. Each formulation strives 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. However, this is not the case when performing legacy IUID marking. Fortunately, there are some acrylic PSAs that have both high cohesion and high adhesive strength and can be applied to diverse surface types.

Different types of surfaces vary in their “surface energy” (that is, stickiness). Higher surface energy means greater stickiness. Lower surface energy means less stickiness. Non-stick materials such as Teflon® have very low surface energy—around 18 dynes/cm^2—whereas polished copper might have a surface energy as high as 1,100 dynes/cm^2 if it were very clean (Table 3). 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. Furthermore, adhesives only work within a range of temperatures and often break down when exposed to UV radiation. In addition, adhesives are often susceptible to many organic solvents. However, the large variety of adhesives continues to grow and, as it does, their applicability expands.

Adhesive Tapes

Adhesive tapes have adhesive on both the top and bottom of a carrier. They are useful if the label does not come with pre-applied adhesive. The carrier can be made of differing sponge-like material (foam tapes). These are useful in situations where surface roughness is high and are also 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, but differ in a couple of critical areas. Epoxies do not rely completely on adhesion to maintain attachment. Furthermore, because epoxies become hard, they can mechanically bond to a surface that has a certain amount of roughness. This also means that epoxies can withstand constant forces. However, because they get hard, epoxies are susceptible to stresses and strains from 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 (that is, the label is made of the same material as the rivets, which are of the same material as the item to which they are being attached), or make sure the label is electrically isolated from the item.

Label Material

Although labels can be made out of any suitable material, the most widely used label materials are plastics (such as 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. When used with a suitable adhesive, these thin labels have wide application 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. Photosensitive 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.

The following is a representative list of laser markable materials:[8]

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

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

Appendix J. Marking Techniques Overview

Only a few marking techniques are suited to producing marks on demand in the field as is required for many legacy part marking efforts. The following are some of these 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 should be 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. Excessively high temperature surfaces can cause chemical breakdown of adhesives and material stock. 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 to wear clean gloves when applying the label. Alternatively, spatulas can 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 corresponding 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, and 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 are:

- Abrasive blast
- Acid etch
- Chemical coloring agents
- Dip, barrier, and chemical conversion coatings
- Paint
- Plating and electroplating
- 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% of the individual data cell marking area (Figure 13). Interconnecting data cell elements that occupy less than 26% of the allotted data cell marking space can be damaged during stencil generation and handling, and those exceeding 46% of the allotted data cell area can adversely affect symbol readability.

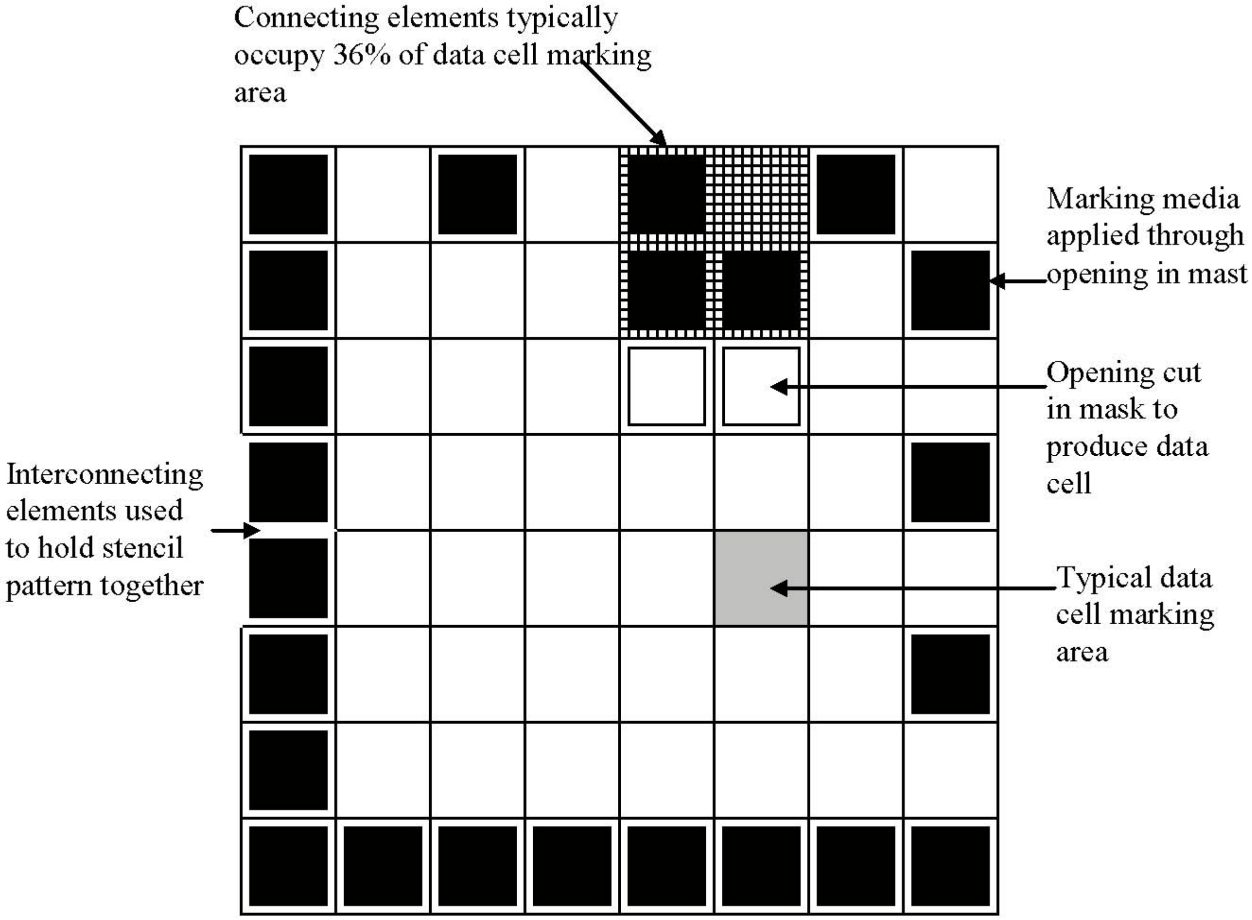


Figure 13. Data Matrix Stencil

While all of the stencil generating 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 13. 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 then applied to the side of the marking stencil and a squeegee or a plastic spreader is 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 passes 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 challenging for even experienced technicians.

Laser Coloring Technique

Laser coloring is a marking process that discolors (darkens) additives that are exposed to the specific wavelength produced by the laser (Figure 14). 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.

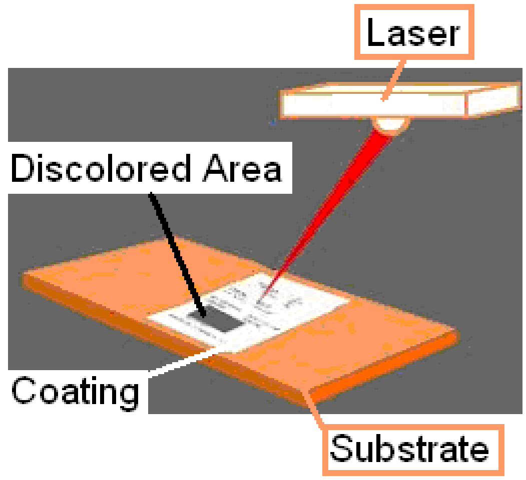


Figure 14. Coating Applied to Substrate and Discolored with Laser

Laser Bonding Technique

Laser bonding 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 15.) Laser bonding is possible for identifying legacy parts in the field that have been previously marked with intrusive marking processes.

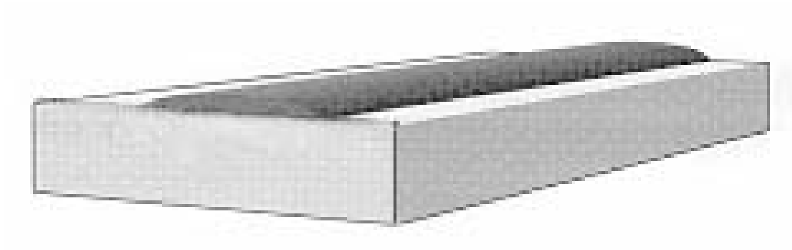


Figure 15. Material Fused to a Surface Using the Laser Bonding Process

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 by:

- Removing the top coat of two-ply label or black anodized label
- Removing a coating of contrasting color applied over an existing coating
- 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 and 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 K. Additive Marks

Additive markings are processes that mark by adding material to the item's surface.

Additive markings can be accomplished by selectively applying material to the surface such as direct ink-jet techniques, and various stencil and silkscreen methods. Additive marking can also be accomplished by applying marking material over a wide area and selectively fusing the material to the surface. The unfused material is then removed (usually by wiping the surface), leaving the mark behind. Typically, material is selectively fused 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 that, after curing, is selectively discolored through a light-induced chemical reaction. Again, this is usually accomplished with a laser. When using this last technique, take care 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 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 L. Common Part Marking Methods

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 IUID marking. These printers produce markings by using heat to transfer ink from a ribbon to the label material. Selected printers should be capable of printing on 4-inch label stock and be able to print one and two-dimensional bar codes. A print resolution of 300 dots per inch (dpi) 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 formatting is specified in 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) is an excellent choice for field use because it will not damage metals as is the case with shorter wavelength lasers. Shorter-wavelength 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, are effective for marking organic materials such as wood, leather, and certain plastics. Additionally, CO_2 lasers can thermally fuse other materials to metal to form IUID compliant markings.

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

Appendix M. Removal of Data Matrix Marks

Obliteration of Data Matrix Symbols

Many 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 using two diagonal lines that cross 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).

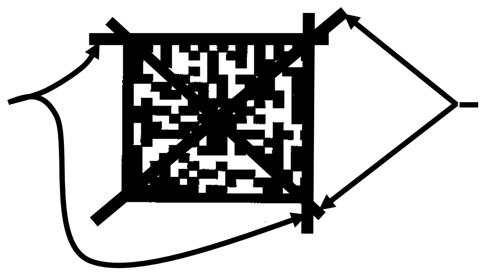


Figure 16. Obliteration of a Data Matrix Symbol

Original engineering drawings are written for a single marking for direct part markings. Since repeated marking in the same area concentrates damage which has a cumulative effect on material properties, original engineering marking authorizations should not be used to justify additional marks. As such, personnel should refer unreadable direct part markings to quality assurance for resolution. Quality assurance, working with engineering, should 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 to remove the clear coat. 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 the Occupational Safety and Health Administration (OSHA). Therefore, users are advised to use a safer substitute containing Aerostrip additive A FO606, approved by NAVAIR 01-1A-509, or similar less hazardous solutions.

Laser Engraving

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 should 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 alternating current and chemistry to clean the surface. The unit uses a wand, saturated in a salt solution, to clean the surface using an instant electrochemical reaction. The combination of electricity and chemistry generates heat, causing a deoxidizing reaction called "passivation." Using this process, laser-bonded markings can be removed in seconds.

Labels

The least damaging method for removing labels applied with adhesive is the use of dry ice. Applying dry ice to the label for 4-5 minutes causes the adhesive to become brittle. The label is then tapped on the edge with a blunt object, preferably a plastic scraper, 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. As such the appropriate Technical Authority should approve the solvent and processes employed to remove the mark.

Appendix N. Verification

Verification is necessary because of the error correction capability built into the data matrix. This error correction allows all the data within a data matrix, even one with some damage, to be quickly and consistently read with a scanner. Once the damage increases past a certain point however, the data matrix will be completely unreadable. (Note: the error correction applies to the data within the data matrix and not the quiet zone around the mark or the solid and broken lines that form the edge of the mark.)

To ensure marks with the longest useful life are used, it is not sufficient to just scan them because this gives no indication of how close the marks are to failing (i.e. how much of the error correction is already used to decode the mark). Instead, verification is needed to evaluate how close to failing the mark is. Standards and thresholds are specified within MIL-STD-130:

Data matrix symbol quality can be determined using any of the following standards: ISO/IEC 15415, AIM DPM-1-2006, or SAE AS9132

- 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 from 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.
- SAE AS9132 should be used if the above standards cannot be used.

From 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).

From 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).

Both validation and verification of machine readable information is required by MIL-STD-130. In cases where labels are produced by a vendor and require verification and validation, a report of conformance generated by verification and validation software can be used to document compliance with the standard. If the labels are produced as a batch or lot where materials and machine settings do not change and a sampling plan is employed, a set of reports of conformance can be used to indicate compliance for the entire batch/lot, provided they include the size of the batch/lot, define which labels fall within the population, and indicate which labels within the population where verified. If labels are coated or covered by a protective substance after manufacture, a sample should be verified to ensure that the coating or cover does not degrade the quality of the mark below the standards cited in MIL-STD-130. If the marks may be subjected to damage during operation, or cleaning, servicing, or repair processes, additional verification of the marks may be necessary to ensure the marks remain useful through the item's lifecycle or next major overhaul.

Appendix O. Quality Sampling Plans for Barcode Creation

To ensure the quality of the printed barcode is as high as possible, the mark should be verified. Verifying ensures that the mark meets the standards for contrast, shape, cell size, reflectance, and so forth. However, when large quantities of marks are needed, verifying every mark can be very time consuming. 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 is either 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 ≤ c, accept the lot; else reject the lot, in which case a 100% inspection must be done.

Because each label is not being verified, there are certain risks involved in this procedure: producer’s risks and consumer’s risks.

Producer’s Risk (α) is the probability of rejecting a lot that is good.

Consumer’s Risk (β) is the probability of accepting a lot that is bad.

For most sampling procedures, the producer’s risk is typically set at 5% and the consumer’s 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 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
51-100	54	4
101-150	75	6
151-200	78	6
201-300	89	7
301-500	101	8
501-600	112	9
601-800	113	9
801-1000	114	9
1000-5000	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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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

For process control purposes, a 16x16 ECC 200 reference symbol can be printed that encodes the data “30Q324343430794<OQQ.” As shown in Figure 17, 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.

Figure 17. ECC Reference Symbol (Not IUID Compliant)

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, for example, 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. Table 5 associates axial nonuniformity values to the letter grades used in the verification process.

$$AN = \frac{|X_{AVG} - Y_{AVG}|}{(X_{AVG} - Y_{AVG})/_2}$$

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, 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 checked visually. 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 that 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
ATA	Air Transport Association
CO_2	Carbon Dioxide
DASN	Deputy Assistant Secretary of the Navy
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 Correcting)
ECM	Electrochemical Machining
EDM	Electro Discharge Machining
EEE	Electrical, Electronic, and Electromechanical
ELM	Expeditionary Programs and Logistics Management
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
UV	Ultra Violet
VOCs	Volatile Organic Compounds
WD	Working Draft
YAG	Yttrium Aluminum Garnet
YAP	Yttrium Aluminum Perovskite
YLF	Yttrium Lithium Fluoride
YVO4	Yttrium Vandate Orthovandate