Environmental Security Technology Certification Program

Final Report and Joint Test Report

Alternatives to Solvent-Based Ink and Paint Stenciling for Identification Markings

Joint Group on Pollution Prevention (JG-PP)

in partnership with

Lockheed Martin Missiles and Fire Control and Information Systems Companies in Orlando, FL

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LIST OF ACRONYMS

A/E	Aramid/Epoxy Laminate
AL1	Aluminum Alloy 2024, (QQ-A-250/4)
AL2	Aluminum Alloy 6061-T6, (QQ-A-250/11)
C/E	Carbon/Epoxy Laminate
CAA	Clean Air Act
CAR	Chemical Agent Resistance
CBA	Cost Benefit Analysis
CNO	Chief of Naval Operations
CTC	Concurrent Technologies Corporation
DoD	Department of Defense
ECAM	Environmental Cost Analysis Methodology
EPA	Environmental Protection Agency
ESOH	Environmental, Safety, and Occupational Health
ESTCP	Environmental Security Technology Certification Program
FOD	Foreign Object Damage
G/E	Glass/Epoxy Laminate
HAP	Hazardous Air pollutant
HazMat	Hazardous Material
HQ AMC	Headquarters Army Materiel Command
ID	Identification
IR	Infrared Reflectance
JG-PP	Joint Group on Pollution Prevention
JTP	Joint Test Protocol
JTR	Joint Test Report
LM	Lockheed Martin
NADEP JAX	Naval Aviation Depot, Jacksonville
NASA	National Aeronautics and Space Administration
NAVSEA	Naval Sea Systems Command
NDCEE	National Defense Center for Environmental Excellence

NNSY	Norfolk Naval Shipyard
NR	Neoprene Rubber, (AMS 3208)
NT	Not Tested
OEM	Original Equipment Manufacturer
PAR	Potential Alternatives Report
PPEP	Pollution Prevention Equipment Program
RCRA	Resource Conservation and Recovery Act
SR	Silicone Rubber, (AMS 3347
SS	Stainless Steel 302, (ASTM-A-240)
STRICOM	Simulation Training and Instrumentation Command
TACOM-ARDEC	U.S. Army Tank-Automotive and Armaments Command, Armament Research, Development and Engineering Center
TADS/PNVS	Target Acquisition and Designation site/Pilot Night Vision System
TO	Technical Order
TTP	Thermal Transfer Printing
TYAD	Tobyhanna Army Depot
USMC	United States Marine Corps
UV	Ultraviolet
VOC	Volatile Organic Compound

1. Introduction

1.1 Background Information

Ink and paint formulations currently used for identification marking at acquisition and sustainment facilities contain solvents that provide desirable properties, such as reduced viscosity for easier application. Some of the solvents present in baseline ink and paint formulations, as well as the liquid and solid wastes generated as a result of using these ink and paint formulations, are considered to be hazardous and are subject to environmental regulation. For example, baseline inks and paints contain volatile organic compounds (VOCs) such as methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylene. In addition to increased operating costs caused by environment regulations (e.g., hazardous waste disposal), ink and paint stenciling, stamping, and silk screening are very labor intensive, result in a relatively high fraction of illegible or erroneous markings, and may be associated with potential operator health issues. These driving forces, which directly impact operating costs and may affect production schedules, are causing industry to identify, evaluate, and implement acceptable alternatives to ink and paint stenciling with solvent-based materials.

This project is led by the Joint Group on Pollution Prevention (JG-PP). The Joint Logistics Commanders and Headquarters National Aeronautics and Space Administration (NASA) co-chartered the JG-PP to coordinate joint service/agency activities affecting pollution prevention issues identified during system and component acquisition and sustainment processes. The primary objectives of the JG-PP are to:

- Reduce or eliminate the use of hazardous materials (HazMats) at manufacturing, remanufacturing, and sustainment locations
- Avoid duplication of efforts in actions required to reduce or eliminate HazMats through joint service cooperation and technology sharing.

JG-PP projects typically involve an original equipment manufacturer (OEM) producing multiple systems for more than one of the Services or NASA, as well as at least one facility, such as a military depot, servicing one or more of the systems. The OEMs involved in this project include Lockheed Martin (LM) Missiles and Fire Control (previously LM Electronics & Missiles) and LM Information Systems Companies in Orlando, Florida. The depots involved with the demonstration include Norfolk Naval Shipyard (NNSY) in Portsmouth, Virginia; Tobyhanna Army Depot (TYAD), Pennsylvania; and Naval Aviation Depot, Jacksonville (NADEP JAX). Environmental Security Technology Certification Program (ESTCP); JG-PP; Simulation, Training and Instrumentation Command (STRICOM) Program Office; and Apache Attack Helicopter Program Office jointly funded this project.

The ink and paint formulations used for identification marking at the OEM and depot facilities are stenciled or stamped onto mechanical hardware and electronic components for a broad spectrum of applications. The purpose of this project was to validate and demonstrate two potential alternatives to the currently used epoxy resin-based inks and high-VOC paints: low- or no-VOC alternative stenciling inks and self-adhesive labels. Benefits of the alternative identification marking methods include:

- Reduced VOC emissions
- Reduced hazardous waste
- Reduced raw material costs
- Minimal capital investment
- Reduced waste management costs
- Reduced regulatory financial liabilities
- Enhanced environmental leadership role.

1.2 Objectives of the Demonstration

The objective of the demonstration was to validate one or more alternative identification marking materials that reduce or eliminate VOC emissions from the process, while performing as well as or better than current marking materials. Validation testing was monitored and reported by the NDCEE/*CTC*. Field demonstrations of validated alternatives occurred at NNSY, TYAD, and NADEP JAX. Sustainment facilities such as NNSY, TYAD, and NADEP JAX that repair or refurbish equipment are mainly governed by Technical Orders (TOs) that require client approval prior to implementing an alternative. Therefore, if the client resists converting to an approved alternative, a facility could only implement very limited conversion to the alternative process. Upon successful validation and subsequent client approval, appropriate TOs and work instructions will be changed at the shipyard and depots. Additionally, LM Missiles and Fire Control and LM Information Systems Companies, already having a Single Process Initiative (SPI) block change in place for alternative marking systems, immediately implemented label-based marking into all existing affected contracts. At least 22 defense system programs such as LANTIRN, Hellfire, Javelin, Longbow, Patriot, and Predator are affected at the two LM facilities.

1.3 Regulatory Issues

Alternatives may be governed, to a greater or lesser extent, by federal environmental laws and regulations. Therefore, a regulatory review of each viable alternative was conducted. Regulatory issues at LM Orlando and DoD sustainment facilities include regulation under the CAA, RCRA, Clean Water Act, Emergency Planning and Community Right-to-Know Act, and Comprehensive Environmental Response, Compensation, and Liability Act. Each alternative was reviewed to determine the extent of its impact upon regulatory compliance at the facility. Viable alternatives were also compared to the U.S. Environmental Protection Agency's (EPA) list of 17 high-risk priority chemicals, called the "EPA 17" list. Even alternatives containing ingredients that are heavily regulated under one or more of these laws are still available for use

by facilities, although most facilities wisely restrict their use.

This project focuses on the elimination or reduction of hazardous air pollutants (HAPs) and VOCs identified under the Clean Air Act (CAA), as amended in 1990. In addition, this project focuses on the elimination or reduction of characteristic or listed hazardous waste under the Resource Conservation and Recovery Act (RCRA).

An environmental, safety, and occupational health (ESOH) analysis was performed for ink identification marking operations at LM Missiles and Fire Control and LM Information Systems Companies prior to the demonstration. Some health concerns are constituents that are carcinogens, teratogens, genotoxicants, and neurotoxicants. Similar ESOH concerns are present at NNSY, TYAD, and NADEP JAX. The detailed ESOH analysis was included in Appendix C of the Demonstration Plan for this project, dated February 22, 1999.

1.4 Stakeholder/End-User Issues

As a result of changes in the CAA, defense industry firms are moving to eliminate, replace, or reduce systems within their manufacturing process that result in VOC emissions. Limitations on the level of VOCs emitted require that epoxy-based inks and associated solvents be eliminated or replaced with a suitable substitute. The goal of this project was to identify suitable alternatives and validate them according to the performance requirements of the end-user community (stakeholders). A Joint Test Protocol (JTP), which addresses the stakeholders' performance requirements and was included in Appendix A of the Demonstration Plan, was developed through technical meetings and teleconferences with technical representatives from the affected defense system programs at the LM companies. Additional government and industry stakeholders were also involved with JTP development. A list of stakeholders involved with JTP development was included in Appendix B of the Demonstration Plan. After JTP development, approval authorities endorsed the JTP. A list of endorsers was also included in Appendix B of the Demonstration Plan.

Periodic teleconferences and meetings were held throughout validation testing to inform stakeholders of progress and to screen alternatives that did not meet performance requirements documented in the JTP.

1.5 Previous Testing of the Technology

LM Missiles and Fire Control Company previously tested the Critchley polyester label that was evaluated during validation testing for this project. This material was later implemented on the Target Acquisition and Designation Site/Pilot Night Vision System (TADS/PNVS). Due to the non-critical/low environmental exposure application found on the TADS/PNVS, only very limited testing of adhesion and legibility performance was required to meet program needs. Neither LM nor TADS/PNVS have reported problems with the implemented labels.

During testing under this project, the Navy's Pollution Prevention Equipment Program (PPEP)

had a concurrent project that tested alternative identification marking methods. The project, which was entitled "Improved Stenciling and Marking System" tested labels and printers that were not tested in this project. A summary of the results of the PPEP testing are included in the Joint Test Report (JTR) (refer to Appendix A).

Also, while alternatives were being tested under this project, TACOM-ARDEC initiated a project to evaluate Video Jet Printing. However, this testing evaluated waste minimization techniques, as compared to pollution prevention addressed under this project.

No other DoD-related testing was identified where any of the alternatives tested under this project were evaluated.

2. Technology Description

2.1 Description

The alternatives tested for this project include inks that are cured using ultraviolet (UV)-radiation, inks that are reduced and cleaned using water, and self-adhesive labels. Implementing the water reducible inks will require no additional equipment; however, the UV-cured inks will require hand-held UV lamps. Self-adhesive labels require a printer (InkJet, laser, or thermal transfer) to transfer text or graphics from a computer onto the label. The candidate alternatives were discussed in detail in Appendix C of the Demonstration Plan [Section 4 of the Potential Alternatives Report (PAR)].

The baseline stenciling process consists of three steps, including surface preparation, stencil fabrication and ink application, and stencil apparatus cleaning. The current methods used for applying an identification number to parts such as printed circuit boards and cabinets are stamping, spray stenciling, brush stenciling, and silk screening. All of these applications require cleaning the part surface by either hand wiping or immersion prior to application of the marking. Stencils are fabricated from polyester, acetate, or an equivalent material using a programmed stencil-cutting machine. The cut stencil is placed firmly against the surface of the part and masked with tape to keep it in place. Stenciling inks are then mixed and applied by either brush or spray gun, ensuring that all cut-through areas are covered with ink. In both instances, illegible markings are often produced with a resulting rework rate of about ten percent. Solvent is used to remove unacceptable markings and clean equipment. When stamping methods are used, a precut rubber stamp is selected and charged with ink by pressing the stamp onto an inkpad or rolling the mixed ink onto a rubber roller that is used to spread the material evenly onto the stamp. The stamp is then firmly pressed onto the surface to transfer the ink to the part. During silk-screening, a negative image of the marking is developed on the screen. The screen is placed onto the area of the part where the marking will be applied. The ink is mixed and poured into the screen. A felt covered board is run back and forth across the screen to force the ink through the negative leaving the marking on the part. The current identification marking process and a process flow diagram are discussed in detail in Appendix C of the Demonstration Plan (Section 2 of the PAR). The PAR, JTP, and JTR can all be found on the JG-PP web site at www.jgpp.com.

The specific part applications addressed by this project include circuit boards prior to soldering, components that are exposed to oils and greases in engine rooms, assemblies inside of cabinets that may be wiped with alcohol for cleaning, and parts that are repaired in shops and thus are exposed to flux removers, solvents, and fuels. The surface to be labeled may be bare or may be painted metallic or nonmetallic.

2.2 Strengths, Advantages, and Weaknesses

Refer to Appendix C of the Demonstration Plan (Section 4 of the PAR) for a comparison of the current identification marking process to the alternative identification marking processes. The

technical benefits of implementing the alternative inks include ease of implementation and operator familiarity. The limitations of the alternative inks include use of solvent (although HAPs will be eliminated, and overall solvent use will be reduced) and the use of UV-radiation (for UV-curable inks only). The technical benefits of implementing the self-adhesive labels include a large reduction in the labor requirement, faster process time, and better legibility. The main technical limitation of self-adhesive labeling identified prior to the demonstration was identifying a label that meets the fairly stringent requirements documented in the JTP.

2.3 Factors Influencing Cost and Performance

The largest factor in reducing cost is the amount of labor saved through implementing alternative labeling compared to the current process. A large cost saving results when labels are used in place of silk screening or paint stenciling. However, because all of the labor required to create a stencil, mix paint, spray the stencil, clean the stencil, clean the spray gun, and dispose of solvent waste is still present when ink is used in place of paint, little or no cost saving is seen with this alternative.

3. Site/Facility Description

3.1 Background

Two facilities were selected for the demonstration: NNSY and TYAD. These facilities were selected by Chief of Naval Operations [CNO (N45)] and Headquarters-Army Materiel Command (HQ AMC) JASPPA representatives, based on the results of a JG-PP Cost Benefit Analysis, on previous involvement in the JG-PP project, and on the need for an identification-marking alternative. Formal memorandums from CNO and HQ AMC were sent to NNSY and TYAD, respectively, to ensure their participation in the project. NADEP JAX, Florida was added as a demonstration site based on an identified need for alternative marking capability.

3.1.1 Norfolk Naval Shipyard. NNSY, located in Portsmouth, Virginia, is one of the largest shipyards in the world and the oldest continuously operated shipyard in the Unites States. NNSY specializes in repairing, overhauling, and modernizing ships and submarines. In addition to overhauling and repairing ships, NNSY also performs technical, fabrication, manufacturing, and engineering work. NNSY has 17 production shops located in 69 production shop buildings for a total of 3.6 million square feet. Some production shops include the Forge Shop, Welding Shop, Pipe Shop, and Paint Shop. The Paint Shop was the focus for this project. The Paint Shop, referred to as Shop 71, performs abrasive blasting of ship's hulls and a variety of painting on ships, including identification marking.

NNSY performs a large amount of paint stenciling on a great variety of equipment and applications, including wires, bulkheads, engines, machinery, and electronic equipment. Costs for the current identification marking process consist primarily of labor, followed by waste management and then materials and utilities. Guidance for identification markings focuses on the location, size, and color of marking, as compared to performance requirements. However, many items at the shipyard, including machinery and bulkheads, must withstand heat, cleaning solutions and chemicals, and fire fighting agents. In addition, the alternatives must be non-flammable. Enamels are typically used for identification marking at NNSY. A limited amount of ink stenciling is performed within the torpedo group at the shipyard.

2.0.1 Tobyhanna Army Depot. TYAD, which is located in northeastern Pennsylvania, consists of 1,300 acres of land, 400 of which are currently allocated to the industrial complex. TYAD is the largest full-scale communications-electronics maintenance facility in the DoD and employs approximately 3,000 employees with electronics, engineering, and logistical expertise. Communications-electronics systems supported by TYAD include communications, command and control, surveillance and target acquisition, airborne electronics, intelligence and electronic warfare, electronic support equipment, and powder systems.

Paint and ink stenciling are used for many applications at TYAD; applications targeted by this

project include communication trailers, parts, and enclosures for electronics. Costs for the current identification marking process consist primarily of labor, followed by waste management and then materials and utilities. For identification marking, TYAD uses epoxies for interior applications and polyurethane for exterior applications.

2.0.1 Naval Aviation Depot, Jacksonville, Florida (NADEP JAX). NADEP JAX, located in Jacksonville, Florida, is one of six modern industrial facilities commissioned by the Navy to perform in-depth rework, repair, and modification of aircraft, engines, and aeronautical components. Aircraft such as P-3 (Orion - Antisubmarine patrol plane), T-2 (Buckeye - Basic jet trainer), F/A-18 (Hornet - Strike fighter), and A-7 (Corsair - Light attack carrier-based jet bomber) come to the depot for maintenance, repair, conversion, or modernization. The depot also maintains a state-of-the-art engine facility for rework and repair of aircraft engine components, assemblies, and accessories for the J-52 (A-4 and A-6 aircraft engine), TF-41 (A-7 aircraft engine), and F-404 (F/A-18 aircraft engine). An estimated 1/3 of the workload within the depot consists of large and small electrical or mechanical components that make up an aircraft, engine, or weapon system.

A large portion of the identification marking within the Graphic Arts Shop consists of preparing inspection stickers, equipment labels, and warning signs on vinyl material using a silk screening process. Cost for the current identification marking process consists primarily of labor required to produce these labels.

4. Demonstration Approach

4.1 Performance Objectives

The objective of this demonstration was to identify acceptable alternatives through extensive laboratory testing. Refer to the JTP (Appendix A of the Demonstration Plan) for a description of performance requirements for the alternative identification marking process. The discussion in the JTP includes a description of the test, the reason the test is necessary, test methodologies, substrates being tested, and any unique equipment and instrumentation and data analysis. Test methodology includes the definition of test parameters, test specimens, test trials, and pass/fail criteria. Additional objectives, which were not included in the JTP, include decreased process time and non-flammability (identified by NNSY). After the Demonstration Plan was finalized, TYAD also identified chemical agent resistance (CAR) as a performance requirement and the LM stakeholders identified a requirement of performing gas chromatography/mass spectrometry analysis on one alternative ink (to determine its naphtha content). The JTR (Section 2.2 of Appendix A) discusses the additional tests required.

Verified alternatives were further evaluated through implementation at the selected demonstration sites to assess their performance in real-life application. Alternate inks were utilized in place of paint stenciling at TYAD while label alternatives (Critchley white, clear, yellow, and metallized polyester printed using thermal transfer black and red ribbon) were demonstrated at NADEP JAX. NNSY received computer, monitor, printer, and label material but never demonstrated these alternatives because the shop was investigating multicolor UV-resistant printing options on larger label material.

4.2 Physical Setup and Operation

Verification testing of all candidate alternatives was conducted in 2000 with all testing completed by March 2001. The data was presented in detail in the JTR issued June 26, 2001 (Appendix A). After reviewing the JTR, demonstration sites selected an alternative that best suited the facility's needs. TYAD demonstrated Dell Ink DPI #311 Opaque Black for stenciling. This ink is a drop-in replacement for the current epoxy paint used for numbering parts and identifying the exterior of enclosures. DPI #311 is reduced using water and should be easily cleaned with soapy water.

Equipment requirements for the demonstration at NADEP JAX are computer, monitor, and thermal transfer printer. Since large graphic files may be involved, larger memory options were included. Hardware for storing large files (zip drive and CD recorder) was also provided to prevent loss of files that are created and used frequently for label printing.

4.3 Testing Procedures

The testing procedures required to validate alternatives were described in the JTP (Appendix A of the Demonstration Plan). A description of each validation test, the rationale for the tests, test

methodologies, substrates being tested, and any unique equipment, instrumentation, or data analysis are included in the JTP. Slight modifications to JTP procedures that were required during test execution and additional testing performed are described in the JTR (Appendix A).

Testing was divided into two phases, with Phase I being initial screening of each alternative. Phase I testing included adhesion and legibility of stencil inks on bare substrate and printed ink on label material. Bare labels were evaluated for adhesion to substrate surfaces. After review by the stakeholders, candidate alternatives that did not meet the screening criteria were removed from further consideration. During Phase II, inks and printed label evaluation included adhesion testing to determine the affects of temperature changes and chemical exposure, abrasion, fungus, infrared reflectance and CAR.

For site demonstrations, operators were provided feedback and assessment through a questionnaire.

4.4 Evaluation Procedures

Acceptance criteria for the validation testing were described in the JTP (Appendix A of the Demonstration Plan). In general, the marking should not easily smear (legibility) and must not be easily removed by abrasion (adhesion). Environmental effects should not significantly alter adhesion or legibility. Evaluation methods for the demonstration were described in the Demonstration Plan.

5. Performance Assessment

5.1 Performance Data

Methods for analyzing data were described in the JTP (Appendix A of the Demonstration Plan) and JTR (Appendix A). The results of the analyses are described in the JTR. No conditions or findings that affect the validity of the analytical data are known, except for some adhesion test failures. These failures were believed to result from an unacceptable level of cleanliness on the test panels used to determine the adhesion of labels. This exception is described in more detail in the JTR.

5.2 Data Assessment

All data collected during the testing of identification-marking alternatives were included in the JTR and used to evaluate and validate each alternative. No data gaps, missing values, or other issues were identified. Some ink alternatives were removed from further testing early in the validation process because they failed to meet the screening criteria. The thorough testing of the identification marking alternatives allows for a realistic assessment of the alternatives. The application grades assigned for each alternative can be found in the JTR (Appendix A).

After validation testing was completed, the demonstration facilities selected alternatives to demonstrate within their respective shops. Lockheed Martin implemented label systems within the facilities in Orlando; however, no cost data was collected for this demonstration. TYAD, which uses epoxy and polyurethane coatings of various colors to stencil part numbers and identification numbers onto camouflaged surfaces, chose a low VOC ink alternative, Dell DPI#311, to demonstrate. NADEP Jacksonville selected thermal transfer labeling for equipment inspection stickers, temporary part labeling, and miscellaneous signage within the shop area. Cost data was also provided by NADEP Jacksonville to compare silk screening costs with thermal transfer labeling. NNSY chose a low VOC ink alternative and several thermal transfer label systems to demonstrate. The timing of the demonstration at NNSY conflicted with other shop activities and no demonstration was conducted at NNSY.

5.3 Technology Comparison

Verification testing was conducted to assess the performance of each alternative. The current stenciling ink used to mark circuit boards was tested for all required parameters along with each alternative. The baseline ink is approved for Grade A, B, and C applications. The application grades assigned for alternative inks are shown in Table 1 below. When compared to the baseline ink, only one ink alternative (Dell DPI #311) met Grade A applications on more than one substrate.

Table 1. Alternative Inks and Application Grades

Technology	Alternative	Substrate[1]							
		AL1a	AL2	SS	NR	SR	G/E	C/E	A/E
Baseline Ink	ACMI #6051 Ink	A, B, C	NT	NT	NT	NT	A, B, C	NT	NT
UV-Curable Ink	80 Series UV Curable Ink	C	None	None	None	None	None	C	None
	MSK-Series UV Curable Ink[2]	None	None	None	None	None	None	None	None
	UV3004[2]	None	None	None	None	NT	None	None	None
Waterborne Ink	AERO No. 6565	C	None	None	None	NT	None	None	None
	CS7-56 Water Base Ink	C	None	None	None	NT	None	None	None
	DPI #311	A, B, C	A, B, C	A, B, C	C	NT	None	A, B, C	None
	WB 2040M[2]	None	None	None	None	NT	None	None	None
	WB82[2]	None	None	None	None	NT	None	None	None
	Willmark #44	A, B, C	C	C	C	NT	None	C	C

[1] Only common results are summarized in this table.
[2] Removed from consideration after initial screening tests.
NT – Not tested.

Verification testing was conducted on label alternatives as well. The classification for each label can be found in Table 2 and Table 3 below. Table 2 provides the application grades assigned to aluminum substrates that were primed and painted with common coatings used throughout the DoD. Table 3 provides the application grades for the remaining non-aluminum substrates. Most of the labels met Grade A, B, and C applications on many substrates. One limitation of labels is that exposing them to solder flux followed by terpene-based solvent destroyed the label or caused it to fail adhesion. This limited the use of these type labels to Grade C applications. In situations where solder flux and solvent exposure can be avoided, these labels can be used for Grade A applications.

Table 2. Application Grades for Self-Adhesive Labels on Aluminum-Based Substrates

Name	Printer Technology	Substrate[1,2]					
		AL1a	AL1b	AL1c	AL1d	AL1e	AL2
Brady B-107 Matte White Polyester	Ink Jet	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Brady B-423 Thermal Transfer Printable Glossy White Polyester Label Stock	Thermal Transfer	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Brady B-437 Thermal Transfer Printable Label Stock	Thermal Transfer	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Brady B-652 Printable High Temperature Label Stock	Laser	C	A, B, C	A, B, C	A, B, C	A, B, C	A, B, C
Brady B-747 Lasertab Markers	Laser	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Critchley Clear Polyester (TTP200CL-10)	Thermal Transfer	C	None	A, B, C	A, B, C	A, B, C	C
Critchley Metallized Thermal Transfer (CR-104-MP)	Thermal Transfer	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Critchley White Polyester Film (CR-119-CP2.5)	Thermal Transfer	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Tyton 822	Thermal Transfer	C	A, B, C	A, B, C	A, B, C	A, B, C	C
Tyton 900	Thermal Transfer	None	A, B, C	A, B, C	A, B, C	A, B, C	C

[1] Only common results for blank and printed labels are summarized in this table.
[2] If solder float/terpene-based solvent chemical exposure results are disregarded, all Application Cs in this table change to Application A, B, or C.

Table 3. Application Grades for Self-Adhesive Labels on Non-Aluminum Substrates

Name	Printer Technology	Substrate[1,2]					
		SS	NR	SR	G/E	C/E	A/E
Brady B-107 Matte White Polyester	Ink Jet	C	C	None	C	C	C
Brady B-423 Thermal Transfer Printable Glossy White Polyester Label Stock	Thermal Transfer	C	None	C	C	C	C
Brady B-437 Thermal Transfer Printable Label Stock	Thermal Transfer	C	C	None	C	C	C
Brady B-652 Printable High Temperature Label Stock	Laser	A, B, C	None	None	None	A, B, C	A, B, C
Brady B-747 Lasertab Markers	Laser	C	C	None	C	C	C
Critchley Clear Polyester (TTP200CL-10)	Thermal Transfer	C	None	None	C	C	C
Critchley Metallized Thermal Transfer (CR-104-MP)	Thermal Transfer	C	C	None	C	C	C
Critchley White Polyester Film (CR-119-CP2.5)	Thermal Transfer	C	C	None	C	C	C
Tyton 822	Thermal Transfer	C	C	None	C	C	C
Tyton 900	Thermal Transfer	C	C	None	C	C	C

[1] Only common results for blank and printed labels are summarized in this table.
[2] If solder float/terpene-based solvent chemical exposure results are disregarded, all Application Cs in this table change to Application A, B, or C.

Implementing label options reduces worker exposure to hazardous chemicals and time spent performing rework due to illegible markings. Label-based marking not only is easier to perform than silk screening or stenciling but also reduces the labor involved.

6. Cost Assessment

6.1 Cost Performance

Baseline information and implementation data were collected at NADEP JAX and TYAD for a JG-PP Cost Base Analysis (CBA). The cost analysis follows the *JG-APP CBA Methodology*, which follows the "bottom up" analysis of the Environmental Cost Analysis Methodology (ECAM^{SM}). A summary of the data collected is provided in Table 4, Table 5, and Table 6.

The information in this section provides an assessment of the ***expected operational costs*** for the technology when implemented and not the cost of performing the demonstrations. This data represents two demonstration options where ink was used to replace paint in stenciling operations (TYAD) and labels were used to replace silk screening operations (NADEP JAX).

The alternative demonstrated at TYAD is an ink that can be reduced and cleaned using water. Initially, a cost savings was anticipated due to reduced solvent use for cleaning both stencil material and a spray gun as well as eliminating the solvent used to reduce the paint. However, trials conducted at the Depot revealed that solvent was required to remove the dry ink from the stencil since water did not remove the ink. Solvent was also required for cleaning the spray gun. Consequently, the only cost difference between the paint and ink is the cost variation between the material prices. Table 4 shows an annual paint cost at the depot of approximately $770 per year while the cost for replacing all paint used with ink is approximately $1,500 per year.

Table 4. Material Cost for Paint and Ink Use at TYAD

	Epoxy and Polyurethane paint	Dell DPI #311 Ink
Total annual quantity used	19 gallons	19 gallons
Total annual material cost	$770	$1,500

The alternative demonstrated at NADEP JAX is a thin polyester film (available in white and clear) with adhesive backing and is received on a 100-foot roll. A thermal transfer ribbon, used for TTP onto the polyester film, is black ink on a 900-foot roll. An estimated 50% of the silk screening load can be replaced with TTP using the black ribbon and white or clear polyester film.

A number of printing applications within the Graphic Arts Shop include silk screening with red ink on white material, white ink on red material, black ink on yellow material, and red ink on yellow material. The shop also performs a printing process on metal foil using photographic chemicals, developer, and solvent. The metal foil ranges from thin (0.003-inch thick) to about 1/8-inch thick. The metallized polyester material can be used to replace labeling applications

where the thin metal foil is used. By providing the shop with yellow polyester film, metallized polyester film, and red TTP ribbon, an additional 25% of the workload can be transitioned.

Equipment costs for TTP consist of the purchase of a thermal transfer printer, computer, monitor, and associated software. The vendor, as part of the equipment purchase, will install the equipment; however, start-up labor is required for training the operators. The amount of training will depend upon the operator's familiarity with the graphics software. Additional training may be required for graphics software such as Corel Draw or Adobe Illustrator.

Material costs for silk screening include clear material for preparing a negative image, silk screen film, developer, cleaning solvent, vinyl label stock, and silk screening ink. Material costs for implementing labels compared to using vinyl material include thermal transfer ribbon and polyester label stock. Labor costs for silk screening include preparing chemical solutions, preparing the screen, creating the marking, and cleanup. In addition, a large amount of time is spent handling, transporting, and disposing of waste material. Table 5 shows the cost savings associated with transitioning 50% of the silk screening applications (Scenario 1) with TTP. The cost associated with transitioning 75% of the silk screening applications (Scenario 2) using additional colored label stock and colored ribbon is also provided. The projections indicate that implementing TTP will reduce most of the labor cost associated with the current process.

Table 5. Operating Costs for Current and Alternative Processes at NADEP JAX

Cost Element	Current Operation	Scenario 1 0% Transition	Scenario 2 75% Transition
Capital Costs			
Equipment	$0	$72286	$14,500
Installation	$0	$0	$0
Start-up	$0	$1040	$1040
Total Capital Costs	**$0**	**$15,540**	**$15,540**
Annual Operating Costs			
Silk Screen Film	$900	$450	$225
Misc. (Chemicals, Solvent, cloth)	$2642	$1356	$660
Ink	$286	$185	$72
Vinyl (White and Clear)	$12133	$6067	$3033
Vinyl (Yellow)	$14080	$14080	$3520
Metal Foil	$1123	$1123	$0
Label Material	$0	$4255	$19350
Ribbon Material	$0	$7333	$14400
Total Operating Costs	**$31164**	**$34849**	**$41260**
Annual Labor Costs			
White/Black Decals	$35662	$11822	$11822
Color Decals	$35661	$35308	$23565
Metal Foil Decals	$15438	$15438	$2438
Misc. Labor	$19435	$9718	$4859
Total Labor Costs	**$106196**	**$72286**	**$42684**
Environmental Costs			
Waste Disposal	$3792	$1896	$944
Compliance	$1969	$1125	$303
Total Environmental Costs	**$5761**	**$3021**	**$1247**
Total Cost	**$143121**	**$125696**	**$100731**

Table 6. Capital and Start-up Costs to Implement Alternative Technology

Item	Cost
Capital equipment	$15,540
Expected life of equipment, years	5
Labor for facility assessment, hours	4
Labor for site preparation, hours	4
Labor for equipment installation, hours	4
Training, hours	16

6.2 Cost Comparisons to Conventional and Other Technologies

Table 6 above shows a capital cost of $15,540 for thermal transfer printing equipment that will be purchased during the first year. It is assumed that the equipment will need to be replaced every five years due to wear or outdated software. Since the equipment is general office equipment, no special construction is required. As part of the printer purchase, the vendor provides equipment installation, setup, and training. Minimal labor is required of the operator to assist with installation. Labor for training will depend upon the operator's familiarity with the graphic software used to create the label. Eight hours for each of two operators was assumed to be sufficient for startup training.

6.2.1 Conventional Paint Stenciling Compared to Ink Alternatives. Water reducible ink was demonstrated at TYAD in place of paint stenciling. No cost saving is seen with this type of implementation because the material cost of the ink is about twice that of epoxy and polyurethane paint. The vendor claims that the ink can be cleaned using water, thereby reducing solvent use and recycling costs. During the demonstration, however, the stencil and spray gun required cleaning with solvent. Therefore, solvent purchase and recycling costs will continue at the same level. No reduction of environmental activities is seen because primers, topcoats, and solvents are still used within the shop, and monitoring and reporting will still be required. Minimal reduction in waste disposal is seen as well because waste will still be handled as hazardous paint waste and primers and topcoats are still used. Switching to the ink alternative may not reduce cost for a facility but may be valuable for environmental compliance issues by reducing VOC usage.

6.2.2 Silk Screening Compared to Alternative Labels. Thermal transfer labels were demonstrated in place of silk screening at NADEP JAX. A significant cost saving was seen with this type of implementation. This cost saving is due largely to eliminating the labor cost associated with creating the silk screen and producing the marking.

The capital investment for equipment purchases will be paid back in the first six months after implementation. If this facility transitioned 50 percent of the work to label alternatives, a cost saving of about $17,000 should result in the first year. By transitioning 75 percent, a saving of

about $43,000 should occur. In years 2 through 5, without the capital cost, an annual saving of about $33,000 (for 50 percent transition) and $58,000 (75 percent transition) should result. Although material costs are expected to rise, replacing silk-screening which is a labor-intensive activity, with label alternatives provides a cost saving due to a significant labor reduction.

7. Regulatory Issues

7.1 Approach to Regulatory and End-User Acceptance

Potential regulations that may apply to the demonstration are dependent on the alternatives that meet the validation requirements. Implementing labels will reduce VOC emissions, worker exposure to hazardous chemicals, and environmental reporting and monitoring requirements. Implementing alternate inks, although reducing VOCs, may still contain hazardous chemicals that require reporting and monitoring. Refer to Appendix C of the Demonstration Plan for a description of the affected regulations for the alternatives. Interface with regulators is not expected nor is public participation concerning the environmental issues associated with implementing any of the alternatives.

8. Stakeholder/End-User Issues

End-users of this technology include NNSY, TYAD Paint Shops, NADEP JAX, LM Missiles and Fire Control, LM Information Systems Companies, and other OEMs and sustainment facilities.

8.1 Stakeholder Involvement

The stakeholder group, which included members from all branches of the military, participated in selecting the technologies, developing the test protocol, identifying candidate alternatives, and removing unsuitable products. This helped to ensure that all DoD needs and requirements were fulfilled. The stakeholder group reviewed, accepted, and endorsed the JTP used for testing purposes. This group also reviewed and provided input to the JTR that describes the test data and results.

8.2 Technology Acceptance and Support

The LM companies already had a SPI block change in place for alternative identification marking and were able to begin implementing alternatives on several existing contracts. Technology migration to other acquisition and sustainment facilities is expected to be simple. The main decision-making factor will be whether or not the candidate alternative meets validation requirements, which the stakeholders documented in the JTP.

Technology transfer efforts will continue by JG-PP though their website and interaction with their respective services and organizations. The demonstration will show the validated alternatives in operation, to facilitate implementation at other facilities.

9. Technology Implementation

9.1 DoD Need

Several OEMs exist that are performing activities similar to the LM mission. These include companies such as Raytheon, Boeing, General Dynamics, Northrop Grumman, and United Technologies. These companies also subcontract electronic circuitry manufacturing to other companies for inclusion in larger component systems. Although the cost saving is difficult to assess, each of these companies could reduce operating costs by implementing label alternatives. In addition, numerous maintenance depots and sustainment facilities throughout the DoD perform activities similar to those conducted by NADEP JAX. By implementing label alternatives in place of silk screening, facilities could reduce costs in each shop location.

9.2 Transition

The stakeholder group, assembled from representatives across DoD services, provided input to the JTP. This input was instrumental in developing test procedures that meet the requirements of the various programs. Since the stakeholder group endorsed the JTP, early buy-in was achieved. The JTR with extensive test data is readily available for review by facilities interested in implementing any of the alternatives validated under this project. Computers, monitors, software, and printers required for label creation are commercial off-the-shelf technology and are readily available.

After verification testing was completed, some of the alternatives were immediately implemented at LM Orlando. The technology has also already been transitioned to NADEP JAX where the thermal transfer labels have been used in place of silk-screened material. Transition of these alternatives to other OEMs or sustainment facilities should be easy to accomplish.

In certain instances, conversion to alternatives did not make sense. For example, TYAD maintains and services electronic equipment that is housed in camouflaged trailers and enclosures. Equipment identifications and part numbers are stenciled onto the exterior of these enclosures. Placing a large white or reflective label onto these units did not meet the requirements of the facility or client. In another instance, an Army Ammunition Plant was seeking an alternative for manual marking of ammunition boxes that would allow faster throughput. Providing a label alternative that was manually affixed offered no increase in throughput or reduction of labor cost. This facility investigated high-speed inkjet printing with the potential of utilizing one of the validated ink alternatives. Another facility (USMC) that repairs and maintains ground support vehicles was approached to become a demonstration site. This facility, identifying part numbers and marking camouflaged surfaces, implemented waterborne chemical agent resistant coating for both coating and stenciling vehicles.

10. Lessons Learned

Early involvement of managers, decision makers, and representatives from government maintenance facilities ensured that all requirements were met and led to early acceptance of the technology.

By identifying a facility that has a definite need, the level of effort required to accomplish a demonstration may be reduced. One facility, after one and a half years of effort, never proceeded with a demonstration while another facility in need of an alternative achieved implementation within six months. More participation may be achieved by targeting a facility that has a need or requires a solution rather than designating a facility to perform a demonstration.

11. References

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Appendix A

Joint Test Report

Appendix B

Points of Contact

Points of Contact

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William Loeser	DCMDE-OOW	2301 W. Meadowview Drive Suite 103 Greensboro, NC 27407	336-851-0756	336-854-5782	wloeser@dcmde.dla.mil
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Emil Luft	Javelin	PEO Tactical Missiles Javelin Project Office ATTN: SFAE-MSL-AM-ESP Redstone Arsenal, AL 35898	256-876-5454	256-876-0668	luft.ea@redstone.army.mil
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Joseph Odum	PMS400D41, DDG	Naval Sea Systems Command PMS-400D41 Code 113123 2341 Jefferson Davis Highway Arlington, VA 22202-5165	703-602-3476, x341	703-602-6169	
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Table 2. Representatives Involved with JTP Development (Continued)

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Table 2. Representatives Involved with JTP Development (Continued)

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George Savoca	PMA-241D1, F-14 IRST	PEO (PMA241 D1) Tactical Aircraft Program (PMA 241 D1) 47123 Buse Road Unit #IPT (Room 252) Patuxent River, MD 20670-1547	301-757-7328	301-757-7343	savocagj.ntrprs@ navair.navy.mil
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Table 2. Representatives Involved with JTP Development (Continued)

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Appendix C

Data Archiving and Demonstration Plan(s)

All raw data, documentation, records, test protocols, interpretation of results, correspondence concerning results, and reports will be stored and retained in paper files at NDCEE/*CTC* in Johnstown, Pennsylvania. If any personnel changes occur, all data will remain in the central repository of JG-PP files at NDCEE/*CTC*. All critical summary data to be reported will be stored and reported electronically in the JTR and provided to ESTCP in the final report. Raw data collected will be available to interested parties, on request, in a reasonable time frame.

In instances where data collection was previously deemed by stakeholders to be critical, it is specified in the JTP. The following information was gathered and reported in the Data Reporting Sheets supplied by testing laboratories to NDCEE/*CTC*:

- Test name
- Test method number (reference to JTP Section)
- Project identification name
- Laboratory device identification number
- Operator name
- Date
- General comments and observations about overall test and test set-up, including a description of any variance from the JTP of test procedure performed
- Test results of each coupon, including:
  - Coupon identification number
  - Description of test specimen preparation (e.g., reference to the specimen type described in the JTP)
  - Test results
  - Observations/comments about individual specimens

NDCEE/*CTC* reviewed and compiled all data into the JTR. A summary of the test results was reported in the JTR and a comparison was made to the validation requirements that were listed in the JTP. Where necessary, deviations from the protocol and unanticipated test results were discussed. The PAR, JTP, and JTR are available at the JG-PP website, www.jgpp.com.

Appendix D

Flammablity Information: Vendor Data For Alternatives Tested

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED

	Alte	Flammability Ranking on MSDS(*)	Flammability Data	Comments
UV-Curable Ink	80 Series UV Curable Ink (Nor-Cote International)	1	Prior to application (raw material): "Special Firefighting Procedures: Evacuate area of all non-emergency personnel. Firefighters must wear full emergency equipment with self-contained breathing apparatus. At elevated temperatures, hazardous polymerization may occur causing container rupture and in extreme cases, explosion. Fight fires from upwind and cool intact containers with water spray or stream at maximum range. Flashpoint: > 200°F Method: Open Cup Flammable limits (% in air): Not established Extinguishing method: Water fog, carbon dioxide (CO2), or dry chemical"	MSDS dated 6/7/99
	80-070 Thinner (Nor-Cote International)	1	Same as 80 Series UV Curable Ink	MSDS dated 7/21/99 Less than 10 wt% added to 80 Series UV

				Curable Ink
	800 Initiator	1	Same as 80 Series UV Curable Ink	MSDS dated 6/7/99 0.5-1 wt% added to 80 Series UV Curable Ink

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

Technology	Alternative	Flammability Ranking on MSDS(*)	Flammability Data	Comments
Waterborne Ink	AERO No. 6565 (Specialty Ink Company, Inc.)	0	Flashpoint: 240°F Method: Closed Cup Flammability limits - LEL: 0.9; UEL: 5.9 "Extinguishing data: Water spray Special Fire Procedures: Will not burn unless involved in an intense fire. Water may cause frothing."	MSDS dated 11/18/96
	6565 Thinner	1	Flashpoint: 232°F Method: Closed Cup Flammability limits - LEL: 1.7; UEL: 15.3 "Extinguishing data: Water spray, carbon dioxide, dry chemical, alcohol resistant foam, water in ink will stop fire after flash. Special Fire Procedures: Wear self-contained breathing apparatus; wear protective clothing and equipment; use water spray to cool fire-exposed area; use water spray to protect personnel; water on fire may cause frothing; fire should go out due to water in ink."	MSDS dated 11/18/96
	CS7-56 (Chemsong)	1	Flashpoint: 350°F Method: TCC Flammability limits - LEL: N/A; UEL: N/A Extinguishing data: Water fog, foam, dry chemical, carbon dioxide	MSDS dated 9/1/96

			"Special fire fighting protective equipment: Individual self-contained breathing apparatus required. Protective clothing to prevent contact with skin and eyes recommended. Unusual fire and explosion hazards: Keep container closed. Produces normal products of combustion."	

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Waterborne Ink (con't)	DPI #311 (Dell Marking Systems, Inc.)	1	Flashpoint: None (white); 88°F (black) Flammability limits - LEL: 1.8; UEL: 25 "Extinguishing media: This product contains water and will not burn until dry. Use media suitable for extinguishing fire. Plan fire protection and response strategy through consultation with local fire protection authorities. Special Firefighting Procedures: Clear area of unprotected personnel. Firefighters should wear NISOH-approved, self-contained breathing apparatus. Use water spray to cool fire exposed surfaces. Also, use water to flush spilled material away from the source. Vapors are harmful; stay upwind of a fire to minimize breathing of vapors, gases, fumes or	MSDS for white ink dated 3/17/99 MSDS for black ink dated 3/4/98

			decomposition products being generated. Unusual Fire and Explosion Hazards: Containers exposed to intense hear from fire must be cooled to prevent vapor pressure build-up, which may result in container rupture. Cool containers exposed directly to flames with large quantities of water as needed to prevent weakening of container itself. Empty container warning: "Empty" containers contain residues (liquid, solid, and/or vapor) that can be dangerous. DO NOT pressurize, cut, weld, braze, grind, drill, solder or (con't)	

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Waterborne Ink (con't)	DPI #311 (Dell Marking Systems, Inc.) (con't)	1	exposure containers to heat, sparks, open flame. They may explode and cause injury and/or death. DO NOT attempt to clean drums. Residues are difficult to remove. "EMPTY" drums should be completely drained, properly bunged, and promptly returned to a drum reconditioner. Dispose of all containers in an environmentally safe way and in accordance	

			with governmental regulations. For work on tanks, refer to OSHA regulations ANSI Z49.1 and other governmental and industrial references pertaining to cleaning, repairing, welding or other operations."	
	Willmark #44 (Willard Marking Devices Corporation)	2	Flash point: 134°F Method used: Closed Cup Flammability limits in air, % by volume LEL: 1.7; UEL: 6.7 "Extinguishing Media: Carbon dioxide, dry chemical, alcohol-type foam, universal-type foam, and water spray. Special Firefighting Procedures: Wear self-contained breathing apparatus and protective clothing. Use water spray to cool fire-exposed areas and protect personnel."	MSDS dated 5/3/99
	Willmark Thinner E	2	Flash point: 138°F Method used: TOC Flammability limits in air, % by volume LEL: 1.1; UEL: 10.6 "Special Firefighting Procedures: Use alcohol-type foam for larger fires, air masks self contained air apparatus. Breathing of vapors may be harmful."	MSDS dated 6/29/88

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Self-Adhesive Labels	Brady B-107 Matte White Polyester (W.H. Brady Company) Hewlett-Packard 51629A Cartridge (Hewlett-Packard DeskJet 695C)		**Label - Not available** **Did not obtain**	
	Brady B-423 Thermal Transfer Printable Glossy White Polyester Label Stock (W.H. Brady Company) Brady R6004		**Label - Not available** **Ribbon – Not available**	

	Ribbon (Critchley 170xi Thermal Transfer Printer)			

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Self-Adhesive Labels (con't)	Brady B-437 Thermal Transfer Printable Label Stock (W.H. Brady Company) Brady R4304 Ribbon (Critchley 170xi Thermal Transfer Printer)		Label - ASTM D 1000 ABT = less than 10 seconds; Vendor recommends for applications where self-extinguishing properties are required. **Ribbon – Not available**	Technical Data Sheet dated 12/6/99

	Brady B-652 Printable High Temperature Label Stock (W.H. Brady Company) Hewlett-Packard Toner Cartridge (Hewlett-Packard LaserJet III Printer)		Label - ASTM D 1000 Average Burn Time (ABT) = 5 seconds **Did not obtain**	Technical Data Sheet dated 5/8/98

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

Flammability Information

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Self-Adhesive Labels (con't)	Critchley Clear Polyester Label Coating Polyurethane Coating		**Clear polyester label – Not available** Did not obtain MSDS because during testing, polyurethane flaked off of labels	
	Brady B-747 Lasertab Markers (W.H. Brady Company) Hewlett-Packard Toner Cartridge (Hewlett-Packard LaserJet III Printer)		**Label - Not available** **Did not obtain**	

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Self-Adhesive Labels (con't)	Critchley Clear Polyester (CR-100-CP) (Critchley, Inc.) Critchley RHD TT BLK Ribbon (Critchley 170xi Thermal Transfer Printer)		**Label – Not available** "Product will ignite if exposed to flame. Extinguishing Media: water, foam, dry chemical, or CO2. Special Firefighting Procedures: Positive pressure, self-contained breathing apparatus recommended. Wear full protective clothing."	MSDS dated 5/00
	Critchley Metallized Thermal Transfer		**Label – Not available**	

	(CR-104-MP) (Critchley, Inc.) Critchley RHD TT BLK Ribbon (Critchley 170xi Thermal Transfer Printer)		"Product will ignite if exposed to flame. Extinguishing Media: water, foam, dry chemical, or CO2. Special Firefighting Procedures: Positive pressure, self-contained breathing apparatus recommended. Wear full protective clothing."	MSDS dated 5/00

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Self-Adhesive Labels (con't)	Critchley White Polyester Film (CR-119-WP2.5) (Critchley, Inc.) Critchley RHD TT BLK Ribbon		**Label – Not available** "Product will ignite if exposed to flame. Extinguishing Media: water, foam, dry chemical, or CO2.	MSDS dated

	(Critchley 170xi Thermal Transfer Printer)		Special Firefighting Procedures: Positive pressure, self-contained breathing apparatus recommended. Wear full protective clothing."	5/00
	Tyton 822 (Hellermann Tyton)		"If there was a label material that was non-flammable, then the adhesive would probably burn. Labels are also so small and thin, that even if the label was nonflammable, including adhesive, the wire would still melt or disintegrate the label in less than a second before starting to burn…"	Memo dated 3/24/99 - MSDS not available
	Tyton TT822OUT Ribbon (Critchley Model 170xi Thermal Transfer Printer)	1	Hazardous polymerization will not occur. No other flammability information provided on the MSDS.	MSDS dated 8/28/98

FLAMMABLITY INFORMATION: VENDOR DATA FOR ALTERNATIVES TESTED (Continued)

Flammability Information

	Alte	Flammability Ranking on MSDS (*)	Flammability Data	Comments
Self-Adhesive Labels (con't)	Tyton 900 (Hellermann Tyton)		Same as Tyton 822	Memo dated 3/24/99
	Tyton TT900OUT Ribbon (Critchley Model 170xi Thermal Transfer Printer)	1	Hazardous polymerization will not occur. No other flammability information provided on the MSDS.	MSDS dated 8/28/98

(*) Hazard Rating 0 → 4 is none → extreme.

Appendix E

Joint Test Protocol