ENGINEERING PRACTICE STUDY

TITLE: USING POLYIMIDE OR OTHER TYPE ADHESIVE LABELS FOR ELECTRONIC PARTS MARKING IN MILITARY AND SPACE APPLICATIONS

23 OCTOBER 2007

PROJECT NUMBER 59GP-2007-003

FINAL REPORT

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I. OBJECTIVE

To determine if adhesive label marking of electronic parts is a reliable and prudent choice given the harsh environment presented to military and space components and given the heightened awareness of electronic component counterfeiting.

II. BACKGROUND

In late July 2007, at a NASA Electronic Parts Assurance Group (NEPAG) meeting, the subject of using adhesive labels for electronic parts marking was broached with respect to their use on military and space qualified parts. One of the participants had concerns about the susceptibility of this marking technique to subsequent part processing/handling and wanted to know if DSCC had any established rules on the use of labels. Since the answer to this question is no, DSCC decided the subject warranted a closer look.

An EP study was initiated by DSCC-VAT on August 3, 2007. A search of the internet was done in an attempt to find information on using adhesive labels to mark electronic parts.

Concurrent with a review of the internet, we initiated a government and industry fact finding effort by distributing an electronic (email) request for definitive information on parts marking using adhesive labels. We asked if adhesive label marking of electronic parts is a reliable and wise choice given the harsh environment presented to such parts and given the heightened awareness of electronic parts counterfeiting. Specifically, we wanted to know an adhesive labels' susceptibility to subsequent part processing, handling, and to its application environment. How resistant to solvents are marking labels? Can they be removed easily? Do they present leak testing problems? And, is out gassing an issue with certain label materials?

Our request for information was distributed electronically through both the NEPAG and Government Electronics and Information Association (GEIA) user groups and by using the DSCC military and industrial document distribution lists. Within a 45 day time period DSCC-VAT received 15 replies from approximately 200 recipients of our email request.

III. RESULTS

Label and adhesive materials:

A review of the internet revealed no studies directed specifically at the use of adhesive labels for electronic part marking. The research did however find a number of manufacturers, including the following, who offer label material and adhesives for use in parts marking:

Brady North America: 6555 W. Good Hope Rd, Milwaukee, WI 53223, Ph: 1-414-358-6600, Fax: 1-800-292-2289, http://www.bradyid.com/.

Polyonics, Inc.: 867 Rt 12 Westmoreland, NH 03467 USA, Ph: 1 (603) 352-1415, Fax +1 (603) 352-1936, http://www.polyonics.com/.

Ziptape: 2122 West 5th Place - Tempe, Arizona 85281, Phone 1-800-851-9644 Fax 480-894-6255, http://www.ziptape.com/.

Tyco Electronics: 76 Commercial Way, East Providence, RI 02914. Ph.: (800) 522-6752, http://www.tycoelectronics.com/.

Identco International: 28164 W. Concrete Drive, Ingleside, IL 60041, Ph. (800) 533-2559, Fax: (815) 385-0359, http://www.identco.com

3M Company: Industrial Adhesives and Tapes Division, Converter Markets, 3M Center, Building 21-1W-10, 900 Bush Avenue, St. Paul, MN 55144-1000, Ph. (800) 223-7427, Fax: 615-778-4244 http://www.3m.com/.

These companies are a sample of the many who supply labels for parts marking.

One point that surfaced immediately about the use of labels is to think of the entire application and not merely the label material itself. The properties of the label material and the properties of the adhesives used are both important factors for the given application.

The main concern in selecting a label is deciding what label materials are most appropriate based on part composition, and their exposure conditions. The materials most often used for label face stock are paper, vinyl, polyvinyl fluoride, polyester, acrylic, and polyimide. According to manufacturer's data, paper, vinyl and polyvinyl fluoride are limited to temperatures of 150°F, 176°F and 225°F respectively. Polyester, acrylic and polyimide are usable to temperatures up to 300°F, 350°F, and 500°F, respectively. It should be noted that for long term exposure conditions greater than 300°F, polyimides and fluorocarbons can be used.

Acrylic adhesives seem to be the choice for most electronic part labeling. They are good for long term use up to around 300°F and up to about 400°F for short periods of time.

The information above is a synopsis of what was learned about labels and adhesives in the course of reviewing data available via the internet. Oklahoma City Air Logistics Center at Tinker AFB, OK forwarded a document, *Report on IUID labels and Adhesives*, which contains in-depth information on labels and adhesives. Rather than attempt to extract portions and paraphrase the information, the entire report has been added to this study as an Appendix. It is noted here that permission to publish the report was obtained from Dynamics Research Corporation, with coordination from Rowan Technology Group. Although the report is directed at the U.S. Department of Defense IUID (Item Unique Identification) program, the content is pertinent to this EP study.

DSCC in-house review:

A review of military specifications under the purview of DSCC revealed three manufacturers who are presently using labels to mark their QPL/QML parts:

1. Manufacturer A uses non-woven polyoefin fabric labels that are not fungus nutrient to mark their MIL-PRF-39019 circuit breakers. They have used these labels successfully for about ten years.

2. Manufacturer B uses Brady B-457 polyimide labels to mark their MIL-PRF-38534 hybrid circuits. These labels went through rigorous screening, including temperature cycling to 300°F, burn-in, 1000 hour life test, and resistance to solvent testing. 100 hours of additional temperature cycles were then performed. Fungus and salt atmosphere tests were also performed. It should be noted that these labels can be peeled off with a small amount of effort. However, it should also be noted that this manufacturer has many years of experience with using these labels on printed circuit boards with no issues raised from their customers. Further, it is also noted, that in comparison to direct ink marking of similar type devices, the inking on gold plated surfaces is easily removed by rubbing the printed surface with a standard pencil eraser. Thus, there appears to be little difference, in this case, between direct inking and using adhesive labels where permanency of the marking is concerned.

Presently, there is a second hybrid manufacturer working with the DSCC Sourcing and Qualification Group (DSCC-VQH) to qualify their marking labels. The label material they are using is polyimide.

3. Manufacturer C has been using labels for many years to mark their MIL-S-5595 and MIL-PRF-8805 qualified switches. They have used polyester film labels for the past seven years with no history of reported problems. See Company 4, under External Solicitation Feedback below, for further details.

External Solicitation Feedback:

Of the 16 responders, one activity had no comment. Five indicated they do not use labels for marking their electronic parts. This group of five included two test laboratories that stated they have not come across electronic component testing that included the use of labels.

As noted in the Results section above, Oklahoma City Air Logistics Center at Tinker AFB, OK forwarded a report, *Report on IUID labels and Adhesives,* which gives an excellent review of available label and adhesive materials and their properties. See Appendix for the full report.

Three manufacturers indicated they were not in favor of using marking labels. Two of them stated it would not be cost effective given their small lot sizes and that using labels would be problematic due to the small dimensions of their parts. The third company sees no “up side” to using labels since direct marking is not a problem and adhesive labels can be removed and they can come off or be covered by another label.

Two activities stated they had concerns about the use of labels for space level components. The main concern here is outgassing and in meeting the mission contamination control requirements imposed. Further, even though label material such as polyimide might meet the outgassing requirements, they stated the adhesives and the inks used may not meet the stricter requirements. No specific applications or data was given by these two respondents.

The remaining four respondents stated that they use marking labels and have had much success with their process. No companies mentioned the type of adhesive used, or the printing method (e.g. ink, laser) used. It should also be noted that Company B uses labels on cable and wire and not on electronic parts, per se.

1. Company A did not provide any test data but stated they have used Brady polyimide labels for over ten years in space applications. They stated that the use of the polyimide labels is the standard marking method for their line of crystal oscillators which meet the requirements of MIL-PR-55310E. Further, they say the polyimide labels meet the environmental requirements in MIL-PRF-55310 and the labels hold firm when subjected to standard cleaning solvents and they have no documented failures for permanency or legibility with these polyimide labels.

2. Company B uses Brady labels to mark cable and wire. They use two types of Brady labels; a Brady polyimide label that has a clear wrap-around overlay which protects the print area and one that, when it doesn’t have the wrap-around (Tedlar; a polyvinyl fluoride), is protected by applying Kapton tape (polyimide) over the label to protect the print area. Again, this company does not have any test data. They look at their non-conformance history to establish the reliability history of a system. They have had no performance issues with this system of marking.

3. Company C uses Brady polyimide labels (B-457, B-652 and B-497 material) to mark both PROMs and to mark serialization on circuit boards. They also use these labels to serialize subassemblies and to mark top level units until metal nameplates are applied. Evaluation of the labels was done through qualification testing by placing the labels on applicable metal coupons and running them through a batch cleaner and water wash for several cycles and then recording the print legibility. Further, resistance to solvents was evaluated by hand scrubbing sample coupons with a multi-alcohol-blend cleanser. In terms of permanency, they tested the labels per method 215 of MIL-STD-202 requirements. Further, adhesion tests per ASTM D 1000 were performed to ensure compliance with the Technical Data Sheets provided by Brady. This company has been using these labels for approximately ten years and has had very good success with this marking method.

4. Company D (QPL Manufacturer C, from DSCC in-house review above) has used labels for many years to mark their military qualified products. The current label material in use is a polyester film and has been in use for at least seven years. They stated that these labels and marking are resistant to household cleaners, mild acid, oil, water, isopropyl alcohol, mineral spirits, and toluene. They have held up to verification testing and qualification retention testing per MIL-PRF-8805 and MIL-S-5595. They stated that these labels, once applied, cannot be removed without damage to the label and are therefore considered permanent.

IV. CONCLUSIONS

There are many companies that supply labels suitable for electronic part marking. This is evidenced through a simple search of the internet. Finding manufacturers who utilize this method of marking military qualified parts, and finding research or data on the permanency and susceptibility of labels to subsequent part processing, handling, and to their application environment is problematic. However, in polling the QPL/QML manufacturers who supply to our military specifications, and with the help from the NEPAG and the GEIA in distributing our questions, we have gathered useful information to help make an informed decision on the use of adhesive labels for marking our military qualified parts.

There was nothing found to indicate that marking of parts, with adhesive labels is a process problem or a serious issue for high reliability military applications. There is concern, however, within the space community on the use of adhesive marking labels for space applications. Therefore, the use of adhesive labels appears to be a viable means of marking military qualified parts as long as they conform to the requirements as defined by the specifications to which they are qualified. For space qualified parts, marking with the use of adhesive labels is questionable and not recommended unless research and data can show otherwise.

Little feedback was received concerning adhesive labels being an issue with respect to the counterfeiting of parts. Therefore, it seems that attempts at counterfeiting would not be aided by or because of the use of adhesive labels.

V. RECOMMENDATIONS

In general, high reliability military component specifications do not require special language on the use of adhesive labels for marking. Specifying the information required to be marked on the part and citing MIL-STD-1285 is sufficient. However, for those components with applications deemed problematic and for space applications, DSCC should work with the manufacturer to define adequate verification tests or define an acceptable alternate marking method.

APPENDIX

to

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23 OCTOBER 2007

REPORT ON IUID LABELS AND ADHESIVES

by

Rowan Technology Group

LINKING GLOBAL TECHNOLOGIES WITH MARKETS

REPORT ON IUID LABELS AND ADHESIVES

Report to:

Terry Reneau

DRC

Project: DRC IUID Labels

Report: Topical

Date: May 23, 2007

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1. Introduction

Rowan Technology is assisting Dynamics Research Corporation with the "Option" portion of their SKITT IUID Project (Terry Reneau Project Manager).

The U.S. Department of Defense MIL-STD-130 requires unique identification (UID) of parts for property identification and tracking. It covers all items costing $5,000 or more, items that are assigned a serial number, items that are considered mission-critical, items that are part of a controlled inventory, and even consumables where deemed necessary by the DoD. The specification covers both new and in-use or on-hand items. Meeting this requirement is a daunting task considering the vast number of items meeting one or more of the above descriptions. Widely varying item exposure conditions further complicate the task.

The codes that have been selected for UID are 2D data matrix codes. They may be applied to the items by direct marking, with tags or nameplates, or with adhesive labels.

Direct marking is usually done with lasers or by dot peening. Tags and nameplates are usually metallic and may be attached with adhesives, screws, or rivets. Labels may be either metallic or plastic and are attached to the items with adhesives.

Since many of the items in need of UID identification are one of a kind, the DoD needs to be able to prepare the data matrix codes themselves. They have access to the software necessary to design the UID codes, to lasers to create the codes, and to scanners to read the codes. A major concern, however, is deciding what UID materials (labels, etc.) are most appropriate for the items based on their composition, and their exposure conditions.

2. Objective

2.1. Overall

The objective of this phase of the project is to gather information on UID label suppliers and their products so that the DoD facilities can make the most informed selection of labels for each application. Focus is to be placed on labels that are amenable to laser encoding by the DoD. Properties and performance data are to be obtained wherever possible.

2.2. Specific Objectives

Specific objectives are as follows.

- Identify UID label suppliers focusing on laser markable labels.
- Obtain samples and property and performance data on these UID labels including testimonials from users if available
- Pass the most important results on to DRC staff as they are found.
- Identify testing laboratories that could help evaluate label performance.
- Summarize the results in this report

3. Summary

Companies that provide labels suitable to meet MIL-STD-130 were surveyed. Emphasis was placed on laser markable labels with adhesive backing. There are many companies that supply labels that could be used for UID applications, but a lesser number, including the following, offer labels that are suitable for laser marking by the DoD itself.

- Tesa (distributed by CodeSource)
- Horizons (distributed by Camcode)
- 3M
- Metalcraft (distributed by Camcode)
- Metalphoto (distributed by Camcode)
- Tyco Electronics

These company's products are distributed by a variety of other companies sometimes making it difficult to tell who actually manufactured a label.

The properties of the label face stock materials and the properties of the adhesives used on the labels limit their utility especially at elevated temperatures. Under otherwise mild physical and chemical exposure conditions, acrylic adhesive backed labels may be used for applications up to approximately 300°F. Brief excursions up to 400°F can be tolerated provided they are not exposed to solvents, or rubbing action while hot.

The most commonly used face stock materials for adhesively backed labels are acrylics, polyesters, and anodized aluminum. Other face stock materials used to a lesser degree include polyimide, polyolefins, fluorocarbons, PVC, steel, copper and brass.

For long term exposure conditions greater than 300°F, metal based labels and nameplates as well as high temperature plastics such as polyimides and fluorocarbons may be used. At present, they must be physically attached to the item rather than adhesively bound. Polyimide labels with silicone adhesive backing are available for temperatures up to 500°F but are questionable for UID applications because of cost, adhesion and life expectancy concerns. Currently, the main option for high temperatures is direct part marking.

Acrylic adhesives are used on currently available UID labels. They are suitable for long term use up to about 300°F and short time use to near 400°F. Label suppliers Tesa and 3M make their own adhesives and in the US most other label suppliers use 3M's adhesive transfer tapes. Although the Tesa and 3M labels should have generally similar properties, there are differences. For example, 3M labels have shown higher temperature stability in DRC oven tests.

Metalphoto's anodized aluminum labels are a good option for harsh environment applications provided they will not be exposed to strong caustics.

The types of available UID labels and their physical and performance properties are described in the following text and are summarized in a table for quick reference. Data sheets for several important laser engravable labels are provided in the appendix.

Results of this study have been shared with DRC staff during the study in order to provide information as rapidly as possible. Examples include the 3M's line of labels and Metalcraft's photo-anodized aluminum labels which are presently on test at DRC.

Table 3 and Table 4 give the properties of label materials and adhesives respectively.

4. Label Selection Criteria

Selection of the appropriate label for any specific item depends on the conditions to which the item/label will be exposed. The following exposure conditions must be considered.

Temperature (long term and/or intermittent exposure)

Abrasion (including cleaning method)

Oils & Solvents

Chemicals (acids, bases, salts, etc.)

Surface condition (roughness, flatness, low or high energy, etc.)

Combinations of the above

4.1. Temperature Limitations

In general, adhesive backed labels are appropriate for application to items exposed to temperatures of 300°F or less. If abrasion and solvent/chemical exposure conditions are mild, plastic labels such as those supplied by Tesa (Codesource), 3M, Tyco, Horizons (Comcode), and Metlcraft should be stable. Some label suppliers claim their labels will stand up long term to 400°F but oven tests should be done by the user to confirm stability.

4.1.1. Face Stock Temperature Limitations

Common face stock materials used for UID labels and their approximate temperature limitations are listed in Table 1 below. Full details on label materials are provided in Table 3.

Table 1. Use Temperatures - Label Materials.

	Use Temperature Range			
	Min	Max	Min	Max
Material	°F	°F	°C	°C
Acrylic	-40	375	-40	190
Polyester	-100	350	-73	177
Polyimide	-100	500	-73	260
Aluminum	-100	550	-73	288
Fluorocarbon (FEP)	-100	400	-73	204
Fluorocarbon (PTFE)	-100	500	-73	260
Polypropylene	-100	250	-73	120
Polyethylene (UHMW)	-100	200	-73	93
Vinyl (PVC)	-40	176	-40	80

The minimum temperatures listed above are from suppliers and manufacturers data sheets and probably just mean they did not test at any lower temperatures.

4.1.2. Adhesive Temperature Limitations

Acrylics are the most commonly used adhesives for UID labels. Silicone adhesives offer higher thermal stability as shown by the comparison in Table 2 below, but have a shorter shelf life than acrylics. There are suppliers of polyimide labels with silicone adhesives but none were found that were laser markable. Full details on label adhesives are provided in Table 4.

Table 2. Use Temperatures - Adhesives.

	Use Temperature Range			
	Min	Max	Min	Max
Material	°F	°F	°C	°C
Acrylic	-40	375	-40	190
Silicones	-100	500	-73	260

Adhesives may be applied to label face stocks using adhesive transfer tapes. Acrylic adhesive transfer tapes are available from 3M and Tesa

and others. The properties of many of the commercially available adhesive transfer tapes, including those from 3M and Tesa, may be found at http://tapeinfo.com/TapeInfo/AdhesiveTransferTape.aspx .

Silicone adhesive transfer tapes are available from companies such as Saint-Gobain, Trebnick, and Stockwell Elastomerics, Inc. but do not appear to have been applied to UID labels - probably for the following reasons. Silicone based pressure sensitive adhesives generally are more expensive than acrylics, have shorter shelf lives, have shorter use lifetimes, and have lower adhesion levels on most substrates (silicone polymers being the exception). They often are supported by a polyimide film or a woven glass matrix. Brady and YS America sell high temperature labels with silicone adhesives.

Epoxy adhesives generally are intermediate between acrylics and silicones in thermal stability but are not well suited for use as pressure sensitive adhesives.

Tesa and 3M make their own adhesives. Most other label suppliers in the US use 3M's adhesive transfer tapes on their labels. Properties of several of these adhesives are listed in Table 4. Other adhesive manufacturer's products were not identified on UID labels but there is no apparent reason why they could not be used.

4.1.3. Exposure temperatures of 150°F or less:

For labels exposed to temperatures below 150°F, the choice of plastics and adhesives used in the labels is wide.

Most adhesive-backed labels can be used. This applies to plastic, foil, and solid metal labels, tags, and nameplates. Therefore, lower cost labels can be used for the lower temperature applications.

Although many different plastics and adhesives can be used for these lower temperature applications, acrylics and polyesters are the most widely used plastics and acrylics are the preferred adhesives. Further, there is an advantage to using the same labels for all applications below 300°F to avoid stocking different materials and needing to change marking parameters.

4.1.4. Temperatures of 300°F or less:

Labels exposed to temperatures up to 300°F for extended periods of time require "high performance" or "high temperature" adhesive backed labels. The following laser-markable labels are suitable for this type of temperature exposure:

- Tesa Labels (supplied by Codesource) - *tesa Secure 6973 PV3*, *tesa Secure 6973 PV6 Black Matte*, and *tesa Secure 6973 PV6 AF48 Glossy footprint*. All three are double layered acrylic foil polymerized by electron beam with a modified "high-performance"

acrylic adhesive. These labels mark nicely with either CO_2 or Nd:YAG lasers. The PV6 labels are said to perform somewhat better than the PV3 labels at high temperature. These labels have short time (minutes to hours) stability to 400°F.

- 3M Labels - #7846, #7847, #7848, and #7652. They are "modified acrylic" facestock with "modified" acrylic adhesive. Their data sheets indicate that they are very similar to the above Tesa labels and can be used for the same applications. 3M does offer a wider range of adhesives and therefore may provide better options. In fact, 400°F oven tests by Richard Schroeder at DRC show 3M's 7847 laser-markable label material is significantly superior to Tesa's 6973 PV6 and Metalcraft's anodized aluminum. The differences presumably are entirely due to the choice of adhesive.
- Metalphoto Labels (supplied by Camcode Division of Horizons, Inc.) - These labels are available with 3M's 200 series adhesive backing (see Table 4). They are anodized aluminum and although they can be laser marked on site, they are more efficiently made using Metalphoto's process equipment. These labels would be recommended for applications subject to significant abrasion.
- Metalcraft Labels (supplied by Camcode Division of Horizons, Inc.) - These labels are available with 3M's 200 series adhesive backing. They are anodized aluminum and their use temperature will be determined by the adhesive used. Note that 3M's 200 series adhesives have lower temperature stability than their 100 series or their 350 adhesives (See Table 4)
- Tyco Labels - #ACR-400 Poly (Poly-Acrylic Tamper evident with acrylic adhesive). It is listed as good up to 200°C (392°F) with short term stability to 270°C (518°F). #AL-AN – Anodized Aluminum (Color anodized aluminum with high-performance aerospace grade adhesive). Tyco recommends their Nd: YAG laser #LMS6000 for marking these labels, but they almost certainly can be marked with CO_2 lasers.

4.1.5. Intermittent Exposure to 400°F

Data sheets for the labels described above for use at or below 300°F say they can be used at temperatures up to 392 or 400°F. Tests done at DRC indicate that they might be suitable when they are exposed to temperatures between 300°F and 400°F for short periods of times ranging from minutes to hours at most. The DRC oven tests find that Tesa's *tesa Secure 6973 PV6* labels become loose after 1 hour at 400°F while the 3M 7847 withstood significantly longer times at 400°F.

The efficacy of using silicone adhesives on UID labels does not appear to have been sufficiently evaluated.

4.1.6. Long Term Exposure to

Temperatures of 300°F and Above

For long term exposure conditions greater than 300°F metal based labels and nameplates as well as high temperature plastics such as polyimides and fluorocarbons may be used. Generally, they must be physically attached to the item rather than adhesively bound. The upper continuous use temperature for 3M's 7847 has not been established but preliminary tests indicate it may work well for temperatures between 300 and 400°F.

Higher temperature adhesives such as epoxies and silicones do not appear to be currently available on laser markable labels. Plain polyimide and Teflon film tapes with silicone adhesives are available from Saint-Gobain, Trebnick, Stockwell Elastomerics, Inc., YS America, and others. These tapes are stable to temperatures between 500 and 600°F. No supplier was found that makes a double layer, laser markable tape, but some offer silicone adhesive transfer tapes which could be applied to thermally stable, laser markable facestocks including anodized aluminum foil. Alternatively, there is a process where they can apply their adhesive directly to the label material provided it is stable to the 350°F application process. The above companies specialize in custom tapes and labels.

4.2. Abrasion Effects

Plastic face stock labels have limited abrasion resistance. Abrasion resistance can be improved by overcoating, but the coating must not impair code readability. ID Integration recommends the use of an overcoat (e.g. Akzo Nobel polyurethane) over Tesa and other labels to provide UV and abrasion resistance.

Major label suppliers generally list some abrasion resistance test data in their product data sheets. Data sheets for the Tesa and 3M labels listed above indicate essentially identical Tabor Abraser abrasion resistance.

The Metalphoto anodized aluminum labels have excellent abrasion resistance since the marking is sealed under a clear aluminum oxide (sapphire) surface. Tyco's anodized aluminum labels would be expected to have very good abrasion resistance although not as good as the Metalphoto product.

Labels that are printed on the under side are protected from abrasion of the printing but not from scratching that can occur on the outer surface.

If the items are subject to periodic cleaning, the cleaning method is important. If plastic labels are wiped with a solvent, the surface could be damaged. This effect has been observed by users of Tesa labels and no doubt would be similar for 3M labels. Thus, tests should be done by the user in conjunction with the supplier to insure lasting performance in the field.

The greatest abrasion resistance is for direct marked metal items.

4.3. Oils & Solvents

Most suppliers provide oil and solvent resistance data in their product data sheets. These data are a good starting point, but tests with the actual oil or solvent, if known, to which the item is exposed should be done to insure the best choice. Most data sheets include test results with JP-4 or JP-8 jet fuel.

P-D 680 solvents, classified as mineral spirits, are widely used for maintenance cleaning and degreasing of parts for DoD ground vehicles, aircraft, and equipment. Although it is undergoing replacement with more environmentally friendly solvents, either it or its replacements are logical choices for testing. Both the label facestock (and/or coating) and the adhesive must be stable in the presence of the oil or solvent to which the labels will be exposed.

A clear, solvent-resistant polymer coating such as a polyurethane may be applied after the label is attached to protect it form oil and solvent attack.

Anodized aluminum labels should be especially stable to oils and solvents, but the adhesive could be vulnerable to attack if not protected by a solvent resistant sealant.

4.4. Chemicals (acids, bases, salts, etc.)

As stated in the previous section for oils and solvents, the label supplier's data sheets are a good starting point. However, specific tests may be appropriate. These might include weatherometer tests, salt spray, corrosion (especially for aluminum labels) and chemical-specific tests where the exposure chemicals are known.

As with oils and solvents, anodized aluminum labels are especially resistant to chemicals other than strong alkali.

4.5. Surface Condition (roughness, curvature, low or high energy, etc.)

The surface condition has an effect on the label choice. If the surface is rough, a thicker adhesive layer is appropriate. Most label suppliers offer labels with at least two different adhesive thicknesses. If the surface is not flat (curved), the label must be flexible enough to conform.

Different materials have different surface energies. Adhesives generally work best on high surface energy (HSE) materials such as metals, wood

and polar polymers. Not all adhesives work well on low surface energy (LSE) substrates such as polyolefins like polyethylene and polypropylene, and fluoropolymers. The label suppliers data sheets generally give information on adhesion to a variety of HSE and LSE substrates. Adhesion is usually given as a peel strength in Newtons per cm or lb/in of width and may be reported for 90° or 180° pulls.

Finally, of course, the surface should be clean and dry when the label is applied.

4.6. Product Selector Guides

3M has a product selector guide where performance requirements may be input and the selector lists the 3M labels that meet the requirements. It can be found at:

http://selector.3m.com/selector/us/en/manufacturing_industry/converter_markets/cm_p/ss.asp?FAM=Labels&LL=en

For example, if the input requirements are laser etch for print requirement and a temperature range from -40 to 390^oF, it will select Label Material 7847 and list its composition and other performance properties.

Zebra's product selector guide is informative but it is for thermal transfer labels with emphasis of bar codes rather than 2D data matrix codes. It can be found at

www.**zebra**.com/id/**zebra**/na/en/documentlibrary/misc/uid_brochure.html .

These guides are helpful but don't allow comparison of products from one company to another.

5. Laser Markable Label Property Comparisons

The properties of laser markable UID labels from several suppliers are compared in Table 3. Properties of a variety of acrylic adhesives commonly used on UID labels are included given in the Table 4. The information in the Tables came from the supplier's data sheets which are provided in the appendix. These data sheets contain additional valuable information.

Table 3 compares the labels in terms of composition, use temperature range, qualitative abrasion resistance, adhesion on stainless steel, chemical and solvent resistance, and surface condition requirements. The table provides a quick comparison of properties and is recommended as a starting point in selecting a label for a particular application.

Table 4 is a lists of some commercial adhesives available in the form of adhesive transfer tapes. These are or can be used to transfer the adhesive to the label. Properties were taken from the supplier's data sheets. All but one of these adhesives are acrylic. The other is silicone which has a much higher use temperature of 500 to 600°F. Although no laser markable labels with this adhesive were found they could be made.

Caution is recommended to avoid missing the best option. For example, the adhesive used on the Metalcraft photoanodized aluminum label limits its upper use temperature. However, there is no apparent reason why they could not use a higher temperature 3M adhesive if requested to do so by the user.

5.1. UID Supplier Information

Name, address, phone and fax numbers, web sites, and contact personnel of suppliers of laser markable labels are given below followed in each case by brief descriptions and discussions of their products. More detailed property and performance data are given in the data sheets in the appendix.

Tesa Tape, Inc.

Address: 5825 Carnegie Blvd., Charlotte, NC 28209

Contact: Dave Adams, Marketing Manager, Office: 704-553-4686, Cell: 704-957-9905, Fax: 704-553-5632

Email: dadams@tesatape.com

Tesa is one of the most well known suppliers of UID labels. The DoD is familiar with their labels which are distributed by CodeSource.

CodeSource

Address: 4115 Mesa Drive, Denton, TX 76207

Contact: Bob Hatley, National Sales Manager, Phone: 940-891-1281, Fax: 940-484-7234

Email: bhatley@codesourceinc.com

Their three main UID products are *tesa Secure 6973 PV3*, *tesa Secure 6973 PV6 Black Matte, and tesa Secure 6973 PV6 AF48 Glossy footprint.*

All three are double layered acrylic foil polymerized by electron beam with a modified "high-performance" acrylic adhesive. These labels mark nicely with either CO_2 or Nd:YAG lasers. They should work quite well for environments that are not too harsh in terms of temperature, oils, solvents and chemicals.

Tesa/CodeSource define thermal stability of these labels in several ways as follows.

General: -50°C to 200°C / -58°F to 392°F

Long term: to 250°C / 482°F (48 hours without visible changes)

Short term: to 270°C / 518°F (15 minutes - no visible changes)

The last two definitions are almost meaningless since visible change says nothing about adhesion, chemical exposure resistance, abrasion resistance, or what happens upon repeated temperature excursions. Tests such as those conducted by Richard Schroeder at DRC show that the Teas labels do not hold up well to 392 °F despite what their data sheets indicate.

Ordinary acrylics do not stand up well to solvents. The degree to which the Tesa labels are crosslinked by using divinyl ether in their acrylic formulation will determine solvent resistance. Tesa says their labels have good solvent resistance. Others have said that if you wipe a Tesa label with on oily rag it will ruin it. ID Integration recommends the use of an overcoat (e.g. Akzo Nobel polyurethane) over Tesa and other labels to provide UV and abrasion resistance.

Camcode (Division of **Horizons Incorporated**)

Address: 18531 South Miles Road, Cleveland, OH 44128

Contact: Jon Keserich, Vice President, or Dawn Roberts, Inside Sales Phone: 800-627-3917 or 216-714-0053, Fax: 216-587-4719

Email: JonKes@camcod.com Website : www.camcod.com

Camcode is working with Tinker and is a major supplier to ID integration along with Tesa and Metalcraft. Camcode manufactures their own labels. They offer labels made of aluminum, stainless steel, polyester, polyimide, paper, vinyl, and other specialty materials. They claim to have 30 different adhesives available but use 3M's 200MP type adhesive transfer tapes such as MP467 and MP468 on most of their label line. They use 3M's #9469 adhesive for higher temperature applications. This adhesive is rated as resistant to 500°F for minutes to hours and to 300°F for days to weeks.

Camcode's polymer labels (polyester, polyimide, etc.) come preprinted by Camcode. Their polyimide labels have a higher temperature adhesive than the Tesa labels and Camcode's standard labels. The adhesive comes with the polyimide label stock which they obtain from someone else. They are getting increasing numbers of requests for information on the polyimide labels, apparently from people looking for higher temperature labels. They are commonly used as soldering masks on circuit boards.

They sell laser markable aluminum foil sheets called AlumaMark. They are available in 5mil and 20mil thicknesses. They come in either black or gray metallic and can be marked by either CO_2 or Nd:YAG lasers. Unfortunately, however, they use 3M's 9675 adhesive which has a long term use temperature limit of 250°F.

Metalphoto (Division of **Horizons Incorporated**)

Address: 18531 South Miles Road, Cleveland, OH 44128

Contact: Dan Tuleta, 800-482-7758 ext. 0059

Although they are made from anodized aluminum, Metalphoto's UID labels are unique. Their labels may be applied either mechanically for harsh or hot environments or with an adhesive for less severe conditions. When mechanically attached, they tout their product as resistant to the following harsh conditions:

- Extreme ultraviolet exposure,
- Temperatures exceeding 700°F,
- Salt spray,
- Abrasion,
- Gasoline, Jet fuels, Hydraulic fluids, Chemicals and Solvents.

In their process, the anodization is done with oxalic acid rather than the usual sulfuric acid. This gives a fairly deep honeycomb anodized surface layer (not blackened). They then fill the pores with a silver salt leaving a metallic appearing aluminum blank. Marking is done photographically. The desired artwork (pattern) is created and printed onto transparent plastic film or a recently developed paper which works as a negative. The anodized aluminum blank is exposed to uv light through the film. The silver salt is converted to black silver metal in a developer (fixed) wherever exposed to the uv light. The sample is then sealed by converting the surface to a clear, hard, protective aluminum oxide (sapphire).

Metalphoto supplies all the components needed to create the labels and nameplates. They say their users include the Army, Navy, Boeing and Sikorsky among others. Their labels undoubtedly cost more than tapes like Tesa's and 3M's but a cost performance study would need to be done to decide if and where they should be used.

They use 3M adhesives of the 200MP series such as MP467 and

MP468 but say any of 3M's adhesives could be used as appropriate. This would include 3M's 9469, 100MP series adhesive which has short term stability to 500°F.

If they blacken the entire surface, it can then be laser marked. A YAG laser (probably Nd:YAG) is preferred over a CO_2 laser since the latter would have to be of about 100 watts to work. The YAG lasers are considerably more expensive than CO_2 lasers.

Since Metalphoto and Camcode are both part of Horizons, Inc., Camcode handles the Metalphoto line.

3M Company, Converter Markets

Address: 1030 Lake Road, Medina, OH 44258

Contact: Erin L. Johnson, Application Development Specialist, Performance Label Materials. Office: 800-422-8116 or 330-764-8866, Cellular: 330-321-1691, Fax: 877-722-5072

Email: ejohnson@mmm.com Website: www.3M.com/converter

3M makes adhesive transfer tapes which are used by many label suppliers. They also make laser engravable labels but do not seem to be well known for this product line. Little appears to be known about 3M's labels by the UID user community. Information should be pursued and labels engraved and tested to evaluate performance and to see how cost effective they are relative to other label supplier's products. DRC is actively involved in evaluating the 3M labels

Data sheets describing laser markable label stock materials #7847 and #7848 are provided in the appendix. They list #7847 as stable to 200°C (392°F) with 1-hour stability at 225°C (440°F).

Property and performance data sheets for several of their adhesive transfer tapes are included in the appendix.

Metalcraft ID Plates and Labels

Address: 149 4th Street SW, P.O. Box 1468, Mason City, IA 50401-1468

Contact: #1 Jodi Torkelson Phone 800-437-5283 or 641-423-9460

#2 Julia Deets, Marketing Director,

Email: JuliaD@idplate.com Website: www.idplate.com

Metalcraft services the UID market and is said to be a major competitor to Tesa. Metalcraft, however, does not offer labels of the same type as Tesa. In addition to their nameplates and foil bar code labels which are metal (photo anodized aluminum and stainless steel), they offer "PREMIUM" and"CRAFTMARK" polyester labels, and "STYLMARK" polycarbonate labels. These labels are preprinted by Metalcraft. They utilize both UID and RFID. Their only laser markable labels are discussed below.

Metalcraft makes photo-anodized aluminum labels that are laser markable. For example, they can be marked using a 45-watt Epilog Mini CO2 laser operating at a speed of 70 and a resolution of 600 dpi. The result is a gray (metallic) pattern on a black background. They offer label stock with 3M adhesive as well as for mechanical attachment.

Data sheets for some of the adhesives they use on these labels are enclosed. Adhesive #MC53FL is for use on low surface energy substrates like polypropylene but has a service temperature limit of 200°F. Adhesives #MC60, MC69, and MC73 VHB have service temperatures of 300°F and can tolerate short term exposure to 500°F.

Tyco Electronics, Identification Products

Address: 76 Commercial Way, East Providence, RI 02914

General Contact: 800-522-6752 or William J. Duffy 717-592-4445

Illinois Contact: Oscar Espita 847-910-5780

Tyco appears to be relatively new in the UID market. They offer the following three types of laser markable labels.

- Poly-A200 – Laser Etch Polyester (Polyester with laser markable acrylic top coat)
- ACR-400 Poly (Poly-Acrylic Tamper evident with acrylic adhesive)
- AL-AN – Anodized Aluminum (Color anodized aluminum with high performance aerospace grade adhesive)

Property and performance data sheets for all three types are included in the appendix. They need some updating since they are self-contradicting. The Poly-A200 lists a service temperature up to 125°C (257°F) on page 1 but on page 2 they say no change after 168 hours at 150°C (302°F). The AL-AN data sheet says the service temperature is up to "120°C (302°F)". They probably mean 150°C instead of 120°C. The ACR-400 Poly has the highest service temperature of the three products. It is listed as good up to 200°C (392°F) with short term stability to 270°C (518°F). It I not clear whether Tyco makes these labels themselves or if they are simply supplying other company's products. For instance, the data sheets for the ACR-400 Poly give properties that are essentially identical to those of Tesa Secure 6973 PV6. Also, their AL-AN may be Metalcraft's photoanodized aluminum.

Tyco recommends their Nd: YAG laser #LMS6000 for marking these labels. The Poly-A200 and ACR-400 Poly should be markable with CO2 lasers. Whether or not a CO2 laser can be used on the AL-AN labels depends on how deep the anodizing goes.

Express, Inc

Address: Box 537, La Jolla, CA 92038 or 9235-A Trade Place, San Diego CA 92136

Contact: Jack Leaming, Assistant Sales Manager, Phone: 1-858-549-9828, Fax: 1-858-549-8708

Email : JackL@ExpressCorp.com Website : www.ExpressCorp.com

They have been in the UID label business for two years and can supply a variety of labels including anodized aluminum but not Kapton. They do not make laser engravable labels. Express manufactures "long lasting, harsh environment labels and tags" made of aluminum, steel, polycarbonate, and polyester. The images on their anodized aluminum labels are sub-surface and are made photographically. This gives them good abrasion resistance. The data sheet (Durability Profile) in the appendix is for the label or tag itself without adhesive. They look similar to Metalcraft's product. They come in different sizes and thicknesses. Teflon and ceramic coatings are available. Express is on the U.S. GSA list for labels.

5.2. Companies Supplying UID Services and/or Distributing Labels

There are a great many companies that supply or distribute labels or provide other services to UID solutions. Some of the more active of these are listed below.

Zebra Technologies International, LLC

Address: 333 Corporate Woods Parkway, Vernon Hills, IL 60061-3109

Contact: Carroline Harrington, Government Account Management

Representative 847-793-5793, Fax 847-573-0873

Email: charrington@zebra.com

Zebra makes thermal transfer labels which are especially useful in high volume for mild condition applications. In addition to the label materials, they sell complete thermal transfer kits for making UID labels including ribbons, printers, encoders, design software, and verifiers. Their products are supplied by over fifty other companies.

They supply labels made from paper, polyimides, polypropylene, polyolefin, acrylic, and polyesters. Acrylic adhesives are used predominantly. Thermal transfer labels have poor scuffing resistance which might be improved by overcoating, but they didn't recommend it. Service temperatures for these labels generally are 300°F or less. They have a GSA Advantage Supply Schedule contract.

Roemer Industries

Address: 155 Masury Rd., P.O. Box 217, Masury, OH 44438

Contact: Guy Gugliotti, Account Manager Ph: 330-448-2000, Fax: 330-448-8161

Email: Guy@RomerInd.com Website: www.RoemerInd.com

They say they customize complete solutions for their customers. They offer a wide variety of labels ranging from paper to metal foil to several different plastics including acrylic, polyester, polycarbonate, polyethylene, polypropylene, polyurethane, phenolic, and fiberglass. Most, if not all, of the labels are made by other companies such as MetalCraft. This may account for comments about their slow turnaround times. They specialize in imaging processes such as etching, screen printing, thermal transfer printing, flexology, and photoengraving.

Technigraphics

Address: 350 Clubhouse Rd., Hunt Valley, MD 21031-1321

Contact: Trey Hooper, President Ph: 410-584-9500, Fax: 410-584-9687 Email: thooper@technigraphics.com

Website: www.technigraphics.com

They offer labels and nameplates in polyester, vinyl, polycarbonate, Kapton, and Metalphoto's anodized aluminum as well as overlaminates for chemical and UV resistance. It is not clear how many, if any, of the labels are actually manufactured by Technigraphics rather than purchased, printed and then sold. They utilize 3M adhesives. They have a complete Metalphoto facility.

A2B Tracking Solutions, Inc.

Address: 207 Highpoint Ave., Portsmouth, RI 02871

Contact: Marc Corriveau UID Sales Manager Ph: 401-683-5215 ext120 or 800-733-7592

Website: www.uidsolutions.com

A2B offers several options to meet UID compliance ranging "from a turn key, end to end UID compliance solution to UID consulting services along with a fully outsourced UID service". They are GSA approved and their contract for UID kits and service offerings is listed under Schedule 81 IB, Special Item Number(SIN) #617-13. They outsource labels and a variety of equipment. Some of their products include *UID Comply! Software Suite, UID Comply Validator, and UID On Demand Service Offerings*.

JETEC Corporation

Address: 2817 McGaw, Irvine, CA 92614

Contact: Derrick Ford, President Ph: 949-477-6161, Fax: 949-477-6167

Email: info@jetec.com Website: www.jetec.com

They claim to handle all labeling needs. They don't make labels but have access to all types of label materials. They ask customers for their specs and then select the most appropriate label materials. They appear to focus on thermal transfer labels.

Integrated Labeling Systems, Inc.

Address: 22 Cotton Rd., Nashua, NH 03063-1242

Contact: Greg S. Goodwin, Area Sales Manager Ph: 877-995-0155 ext 4057

Email:ggoodwin@integratedlabeling.com, sales@ilsinc.com

Web: www.integratedlabeling.com

Their focus is on thermal transfer printed labels and RFID labels. They distribute Zebra, Brady, Intermec, and Printronix smart labels and tags. They provide software and other UID services. They pointed out that Yushi-Seihin Co., LTD in Japan (see below) has very high temperature labels.

Yushi-Seihin Co., LTD (YS America - Canada)

Address: 30 Duke St West, Suite 509, Kitchener, ON. N2H 3W5

Contact: Paul Porter Ph: 1-519-489-4950, Fax: 1-519-489-4953 Toll Free : 1-866-616-8482

Email :ppporter@ysamerica.com

A Japanese company with offices in Phoenix and Toronto. They offer a series of "Heatproof" high temperature labels, http://www.yushi.co.jp/eng/jisya/jisya_sub_04.html. Their polyimide labels with silicone adhesive are said to have heat resistance to 572°F (300°C) with excellent chemical resistance, high pliability and high adhesiveness to a variety of materials. They are printable but not laser engravable and no data was given on use life expectancy.

Brady North America

Address: 6555 W. Good Hope Rd, Milwaukee, WI 53223

Contact: Ph: 1-414-358-6600, Fax: 1-800-292-2289

Brady offers a wide variety of labels including polyester and polyimide.

A catalog can be obtained by calling 1-877-995-0155. Many of their labels are printable, usually thermal transfer, but none are laser engravable.

6. Independent Testing Laboratories

The following independent testing laboratories were identified as sources for performance and comparative testing of UID labels.

Chemir Analytical Services

2672 Metro Blvd., Maryland Heights, MO 63043

General: Phone: 314-291-6620, Fax: 314-291-6630

Web: www.chemir.com

Contact: Ila Sharma 314-291-6620 ext 122

Bodycote Testing (Detroit Laboratory)

15350 Mercantile Drive, Dearborn, MI 48120

General Phone: 888-263-9268

Email: info@bodycoteusa.com

Contact: Michelle St James, 313-271-8490, Fax: 313-271-4007, mstjames@bodycoteusa.com

Intertek Consumer Goods, NA

70 Diamond Road, Springfield, NJ 07081

Contact: Sanjeev Gandhi, Technical Director, Ph: 973-924-2561, Fax: 973-379-5232

Email: sanjeev.gandhi@intertek.com

Table 3 Properties of Laser Markable Labels*

Trade Name	Mater-ial	Mark	Temperature (F)	Abrasion Resist-ance	Adhes-ion on steel	Safe Chemicals	Safe Solvents	Surface: OK Conditions	Notes
Tesa Secure 6973 PV6	Acrylic foil	CO2 NdY	-58 to +392	Fair ** (with no topcoat)	(peel) 17 lb/in	30% H_2SO_4, 10% Caustic, Detergent Hot engine oil	60/95 test petrol Gasoline splash Toluene Antifreeze	Slightly rough Curved	A polyurethane topcoat would improve abrasion resistance
Adhesive	*Acrylic*								*Tesa Adhesive*
Tesa Secure 6973 PV3	Acrylic foil	CO2 NdY	-58 to +392	Fair **	(peel) 17 lb/in	30% H_2SO_4 10% Caustic, Detergent Hot engine oil	60/95 test petrol Gasoline splash Toluene Antifreeze	Slightly rough Curved	
Adhesive	*Acrylic*								*Tesa Adhesive*
3M #7846	Acrylic	CO2 NdY	-76 to +392	Fair **	180° pull 6.75 lb/in	30% H_2SO_4 10% Caustic, Detergent Salt spray	Gasoline, SAE20 Xylene, IPA, MEK	Slightly rough Curved	
Adhesive	*Acrylic*								*3M #350 Adhesive*
MetalPhoto	Anodiz-ed Al	NdY CO2	-67 to 1000	High	NA	3% HNO_3, alkaline cleaners, salt spray	JP-4, gasoline, jet & turbine fuel	Depends on thickness	Sensitive to caustic
Adhesive	*None*								*3M Adhesive*
MetalPhoto	Anodiz-ed Al	NdY CO2	-67 to +392	High	180° pull 6.25 lb/in	30% H_2SO_4 Salt spray, Detergent	JP-4, gasoline, jet & turbine fuel	Slightly rough Curved	Sensitive to caustic
Adhesive	*Acrylic*								*3M 300 Series adhesive*
Metalcraft	Photoa nodized Al	CO2 NdY	-67 to +300	Good	180° pull 6.25 lb/in	10% H_2SO_4 Salt spray, Detergent	JP-4, Skydrol, Kerosine, MEK	Slightly rough Curved	Sensitive to caustic. OK with ammonia cleaners
Adhesive	*Acrylic*								*3M Adhesive*
Tyco Poly-A200	Poly-ester	NdY CO2	-40 to +275	Fair **	5.8 lb/in	Water, Salt water Hydraulic fluid	Skydrol 500B, Ethylene glycol	Slightly rough Curved	For lower temperature applications
Adhesive	*Acrylic*								*Source unknown*
Tyco ACR-400Poly	Acrylic	NdY CO2	-58 to +392	Fair **	17 lb/in	30% H_2SO_4, Salt spray, 10% NaOH	Petrol, Transformer oil, SAE 20,	Slightly rough Curved	This appears to be a Tesa product
Adhesive	*Acrylic*								*Tesa adhesive?*
Tyco AL-AN	Anodiz-ed Al	NdY CO2	-40 to +302	Should be good	No data given	Salt water	Gasoline, Skydrol 500B, Hydraulic fluid, Anti-icing	Should be flat and smooth	
Adhesive	*Acrylic*								*Probably 3M adhesive*

NdY = Nd:YAG laser, CO2 = CO_2 laser

** None of these labels have a topcoat. Application of polyurethane topcoat should improve abrasion resistance and seal the adhesive

Table 4. Properties of Label Adhesives*.

		Max. Use Temperature (F)		Adhesion ASTM D-3330		
Adhesive	Type	Short Term	Continuous	In lb/in	Safe Chemicals and Solvents	Surface Conditions
3M 300	Acrylic	250	180	4.7 on ss	Plasticizers Call 3M for more information	Different grades for HSE and LSE surfaces
3M 200MP	Acrylic	400 (min/hrs)	300	4.8 on Al	Splashes of gas, oil, weak acids and bases	Good on HSE but not on LSE surfaces
3M 100HT	Acrylic	540 (min/hrs)	350	5.0 on Al	No data Call 3M for information	Good for under-hood applications
3M 350	Acrylic	450 (hours)	300	3.1 on Al	Gasoline, oil, mild acids and bases, $NaCl_{aq}$	Good on LSE and HSE surfaces
Perma595 B	Acrylic	390 (minutes)	300	1.3 on ss	Call Permacel for information	Call Permacel
Tesa68105	Acrylic	446 (minutes)	302	3.8 on ss	Plasticizers Call Tesa for more information	Call Tesa or Codesource
Tyco 065	Acrylic	395 (min/hrs)	~300	1.4 on ss	Call Tyco for information	Good on irregular surfaces
Saint-Gobain	Silicon e	600	500	3.7 on ss	"Good chemical resistance"	Could use on Al & polyimide Poor adhesion

* Although the data in these tables were taken from the supplier's data sheets, they are not complete and it is highly recommended that they be used only as a starting point. The actual data sheets are attached to this report and should be examined for further information. The label suppliers should be contacted for specific application information. The properties in the table are for the labels as supplied with their adhesive backings. Adhesive properties are from the supplier's adhesive transfer tape data sheets. Each adhesive group, such as 3M 300 series, contains several different variations of thickness, surface compatibility, chemical and solvent stability.