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An Investigation into Hand Sanitizers and Hand Lotions and Potential Risks to High Performance Electronics

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Abstract
As people become more concerned about the global outbreaks of various strains of influenza, more precautions are being taken with respect to personal hygiene. A common precaution involves the use of hand sanitizer solutions or similar germicidal agents. For manufacturers of electronic assemblies, this may mean a potential transfer of these solutions/agents to the surface of the assemblies as a contaminant material. Similarly, many production employees in the electronics industry deal with harsh chemicals, which often remove hand oils resulting in chapped or dry skin. The use of hand lotions may or may not be allowed, depending on the manufacturer, with a similar concern regarding transfer of unknown chemicals to the assembly surface. This paper is an examination of some typical hand sanitizers and hand lotions and their impact on high reliability electronic hardware.

Introduction
With yearly announcements of pandemic flu outbreaks comes a concern for minimizing personal exposure to germs. Consequently, the use of ethanol-based hand sanitizers has grown dramatically over the last few years. While some of these sanitizers evaporate completely, some of the more recent additions to the market contain persistent fragrances and/or dyes for color. As many of these sanitizers are now being used instead of soap and water before employees return to the manufacturing floor, it raises the question of whether hand sanitizers leave deleterious residues on electronic assemblies. Similarly, those who handle electronics on a daily basis may use hand creams or hand lotions to address dry skin resulting from the use of harsh chemicals. These hand lotions contain heavier oils, fragrances and emollients, which have a greater potential for detrimental impacts than sanitizer residues as they are more persistent than the faster evaporating sanitizer materials.

Rockwell Collins is a manufacturer of high performance (IPC Class 3) avionics equipment for both military and commercial applications. Many of the products produced have long design lives (20+ years) and are mission critical or safety critical, with loss of life implications for hardware failure. The presence of unknown or variable residues on an assembly surface can and does impact the reliability of the manufactured hardware. With increasing inquiries from production personnel for sanitizers and lotions that "smelled better" than the already-qualified lotion, the study outlined in this paper was initiated.

Materials Investigated
For this study, four hand sanitizer solutions and three hand lotions were chosen for evaluation. These materials were by no means an exhaustive coverage, considering there were thousands of variations in the market, but they were considered to be representative. Hand sanitizers, in general, are gel forms of ethanol (ethyl alcohol), with some additives, which kill germs and bacteria on contact, but which then rapidly evaporate, leaving little or minimal residue. Hand lotions contain a variety of ingredients, such as skin moisturizers and emollients (wax like, lubricating, thickening agents) which impede water loss and have a softening and soothing effect on the skin. Lanolin is one example of an emollient. These longer lasting chemical agents have a greater potential for transferring to an assembly surface.

<u>Hand Sanitizers:</u>

- Purell Hand Sanitizer with Moisturizers and Vitamins. This sanitizer was already in some of the facility restrooms; purchased by the facilities maintenance department. The Purell sanitizer was predominantly ethyl alcohol based, with no added fragrances or colored dyes.
- Sam's Club Hand Sanitizer. This sanitizer was chosen as a very low cost, easily obtainable material. This material was also predominantly ethyl alcohol based, with no fragrances or dyes, but without moisturizer additives.
- Germ-X Gnarly Green Sanitizer. This ethyl alcohol sanitizer was chosen for a number of reasons. This sanitizer contained a faint green color, indicating the presence of a dye, as well as a mild apple smell, indicating the presence of a fragrance. There are other such sanitizers on the market, but this was in the conference room when the team designed the study. The true reason for its inclusion was that the authors deeply desired to have a situation where they could legitimately use the word "gnarly" in a technical paper.

- X3 Clean Foaming Hand Sanitizer by X3 Labs, Inc. This sanitizer was chosen as a non-alcohol-based material and was a popular choice at area medical facilities. When applied, the X3 had no noticeable smell and appeared to dry very quickly. This sanitizer was chosen after most of the study was completed and initial results available. Consequently, only certain tests were run on this sanitizer.

Hand Lotions:

- Chemtronics Static Free Hand Guard Lotion. This lotion had been previously qualified as an acceptable hand lotion for the production floor, and had been in use successfully for over 10 years, with no reported problems from this coating. However, a number of operators had indicated that they did not like the "industrial" smell of the lotion, and preferred other lotions they used outside of work.
- Jergens Ultra Healing® Extra Dry Skin Moisturizer with Vitamin E: This lotion was a very popular hand lotion and contained aloe vera. Most operators found the this lotion to be preferable to the Chemtronics lotion from a fragrance standpoint.
- Bath and Body Works (B&BW) Midnight Pomegranate Hand Cream. This hand cream lotion was selected as a material that had a significant moisturizer content as well as a strong fragrance, but with no aloe vera constituent. The lotion was the choice of the sales associate at B&BW, a retired industrial engineer from one of the Cedar Rapids chemical plants, who was very interested in the design of experiments. Seriously, when was the last time YOU heard a discussion of replicates, design of experiments and sample error margins in YOUR local Bath and Body Works. We love Cedar Rapids.

Experimental Design

To understand the test metrics chosen and the experimental procedures, it is necessary to understand certain central points about the in-house manufacturing process.

- During manufacturing processing, the printed wiring assemblies are handled with unprotected hands.
- Assemblies are cleaned multiple times during the assembly process.
- Gloves or finger cots are not deemed necessary because the final process step prior to conformal coating is an in-line saponified aqueous water wash process, which removes all finger salts and handling oils. After aqueous cleaning, assemblies are handled only with gloved hands until after conformal coating cure. Consequently, any sanitizers or lotions which may be on the assembly surface would be removed before coating and so would not be in fielded hardware.
- Consequently, the tests were chosen on potential impacts from sanitizer and lotions on the intermediate manufacturing operations.

Focus Areas

A. Chemical Analysis. Many of the chemicals listed in the Material Safety Data Sheets (MSDSs) were not typically found in an electronics manufacturing area, chemical analytical tests were performed.

   a. Ion chromatography was used to determine if there were ionic materials, especially halide materials, in the sanitizers and lotions. Ionic materials, especially halides, can initiate electrochemical failure mechanisms, such as electrolytic corrosion, leakage currents in humid conditions, or electrochemical migration.

   b. Fourier Transform Infrared Spectroscopy (FTIR) was used to examine the non-ionic content of the sanitizers and lotions chosen. FTIR analysis generates a characteristic spectra for a material based on the absorption of infrared energy by different chemical bonds (e.g. carbon-hydrogen). Rockwell Collins has an extensive library of chemical signatures in its FTIR library, which is desirable in failure analysis scenarios. Non-ionic materials may not directly cause electrochemical failures, but such residues are often hydrophilic (water attracting) which initiates other kinds of failure mechanisms.

B. Residue Transfer. Was all this concern about residues from sanitizers and lotions much ado about nothing? If the suspected residues do not transfer from the hands of the operator to the electronic assembly surface, then there would be little or no impact on assembly reliability, especially considering the final aqueous cleaning step. However, with no-clean assembly processes anticipated in the future, this final cleaning step would not be present. The residue transfer study incorporated both ion chromatography and FTIR analyses.

C. Impacts on Electrical Parameters. One of the intermediate process steps of concern was in-circuit testing (ICT). If a surface residue degraded the inherent insulation resistance of an assembly surface, then a functional electrical test, potentially at high voltage / current, could result in hazardous electrical discharges. The impact of residues on electrical insulation resistance was examined using dielectric withstanding voltage (DWV) tests for ambient humidity conditions (August, Iowa) and surface insulation resistance (SIR) testing for elevated humidity conditions (August, Iowa).

D. Impacts on Adhesion. If an operator with hands wet with a lotion or sanitizer were to handle a portion of an assembly which later received an adhesive, as was often done for staking high mass components for vibration resistance, would the residues degrade the adhesion between substrate and the adhesive material? If an assembly somehow missed the final cleaning process, would the adhesion of conformal coating to the substrate be detrimentally impacted by the residues? To answer these questions, lap shear testing was done for a common part staking adhesive to see if lap shear strength was degraded by the residues.

E. Impacts on Solderability. Rockwell Collins assemblies contain a combination of machine placed and hand placed components. Soldering operations occur at numerous places during the build process. Could the presence of hand lotions or sanitizer residues impact the solderability of assembly surface finishes, resulting in solder defects? To answer this question, solder spread testing was done on four common surface finishes: hot air solder leveled (HASL) tin-lead; electroless nickel immersion gold (ENIG); copper with organic solderability preservative (OSP); and immersion silver (ImAg).

Chemical Analysis

The sanitizers and lotions were analyzed chemically using a variety of techniques. Samples of the pure materials were placed in a Perkin Elmer Fourier Transform Infrared (FTIR) spectrometer, using a diamond ATR (Attenuated Total Reflectance) attachment (see Figure 1). Reference spectra were generated for each material in the study. These reference spectra were used in the later residue transfer studies.

Figure 1 Diamond ATR

Sanitizers

The ethanol-based sanitizer materials all had nearly identical infrared fingerprints, correlating strongly to alcohol. The X3 sanitizer, which was not alcohol based, had a different IR fingerprint. Figure 2 shows the composite FTIR scan.

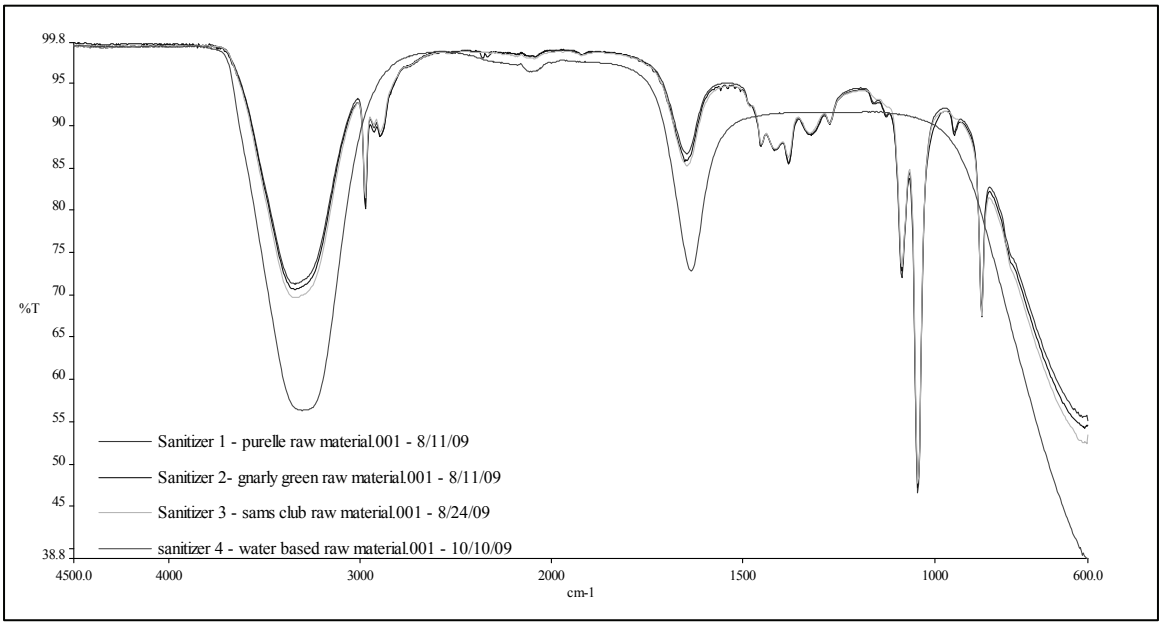


Figure 2. FTIR Spectra of Alcohol Based Sanitizers

Lotions

Figure 3 shows the scans for the different lotions tested. All have dominant broad peaks typical of water in the ranges of 3300 and 1600cm^{-1}.

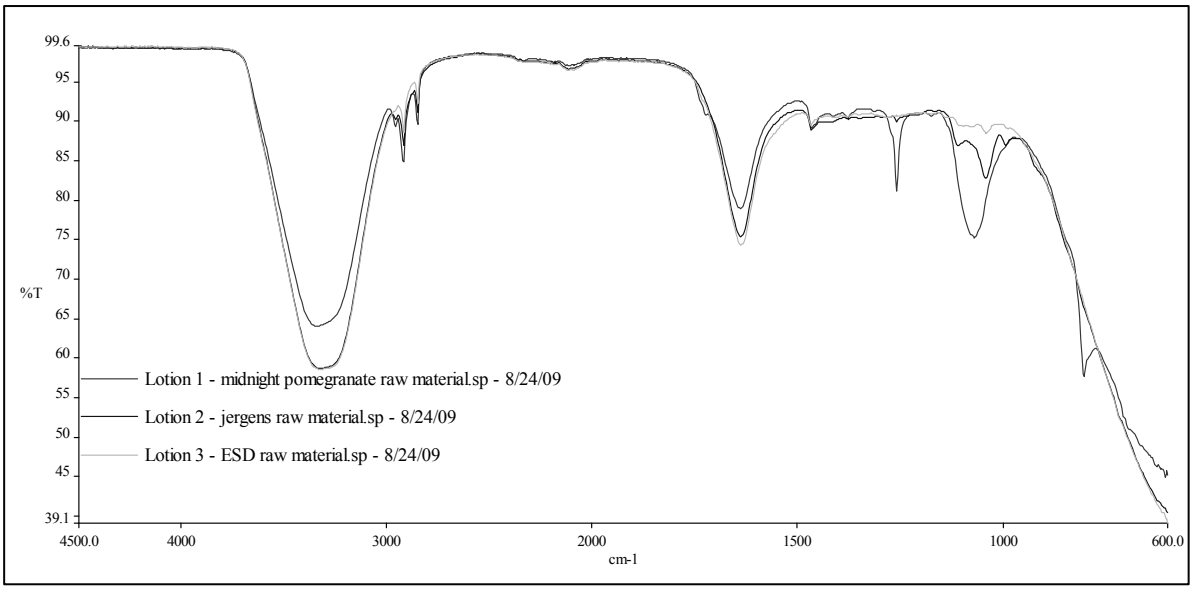


Figure 3. FTIR Scans of Lotions

As part of the residue transfer study (see below), sanitizer and lotion residues were extracted using acetonitrile solvents. A sample of the extract solution was placed on the Diamond ATR and allowed to evaporate, with the chamber closed to keep out dust. Figure 4 shows the FTIR scans from the residue transfer study.

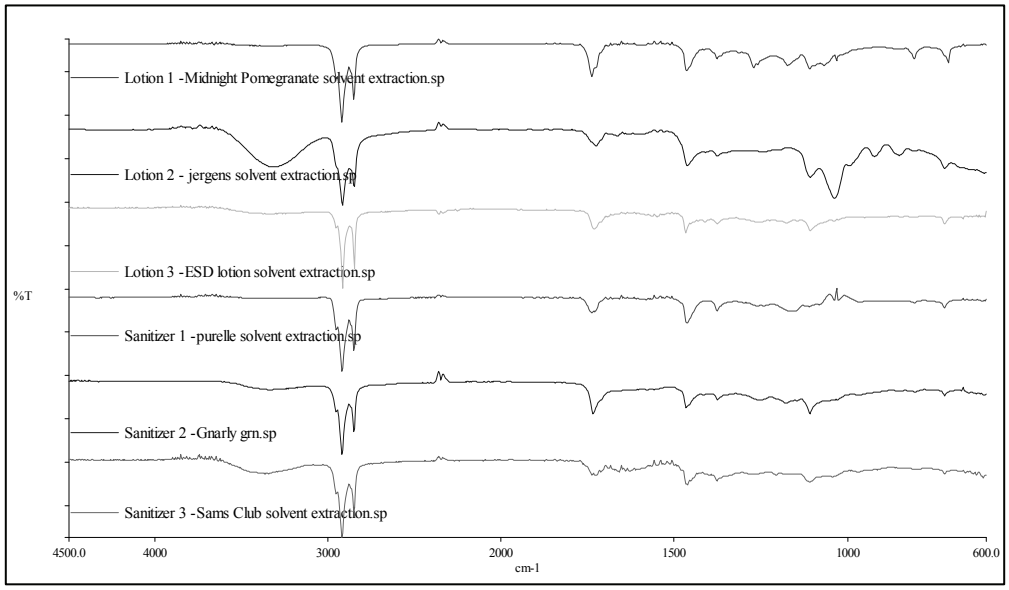


Figure 4. FTIR Scan of Acetonitrile Extracts

Blanks were used in all cases to ensure that there were no external residue contributions. No external residues were found in this study, so there was no need for any baseline subtractions.

Conclusions – Chemical Study

1. All of the sanitizer materials, with the exception of the X3 material, had a dominant alcohol signature. The X3 material showed the presence of the water carrier solvent. All of the sanitizer materials show similar non-alcohol constituents, which are the remainder residues after the alcohol evaporation.
2. The three lotions all had dominant peaks in the 300-360 nanometer range, indicative of the water in the lotions. The Midnight Pomegranate had two peaks in the 100-140 nanometer range, which would be the presence of the heavier oils

and fragrances of that lotion. The Jergens lotions, which had a milder fragrance, had a noticeable peak in the 100-120 nanometer range, also traced to the fragrance material. The Chemtronics lotion, with no added fragrance, had no significant response in this same range.

3. No additional work was done to correlate the specific peaks in the spectra to the individual constituent materials listed on the MSDS.

Residue Transfer Study

In the residue transfer studies, the methods outlined below were chosen to be representative of typical use of a sanitizer or a lotion. It could be argued that a worst case scenario would be direct application of the material to circuit assemblies. The team decided that this possibility was very remote and so was not pursued. The methods outlined below show how the candidate materials were applied to the investigator's hands and then to the test substrate.

Procedures – Residue Transfer Study

1. Hands were thoroughly washed and dried with soap and water. This was done to remove the majority of finger salts and oils.
2. The candidate material was then applied to the hands and lathered for roughly 15 seconds.
3. The test samples for this evaluation were 2.5 inch square ceramic plates, shown in Figure 5.
4. The ceramic plates were handled for 30 seconds. The entire ceramic plate was touched by various parts of the hands.
5. Hands were cleaned with soap and water between candidate materials.
6. For the samples slated for ion chromatography evaluation, the handled ceramic plates were placed in clean, contamination free, extraction bags. A 30 mL volume of 10% isopropanol (IPA) and 90% deionized (DI) water was introduced into each test bag. The bag was then placed in an 80°C water bath for one hour.
7. Following the 1 hour extraction period, the bag was removed from the water bath and the bag and extract solution were allowed to cool to room temperature.
8. A sample of the solution was then placed in clean sample polypropylene vials and analyzed.
9. For samples slated for FTIR analysis, the ceramic plates were extracted using acetonitrile. A sample of the extract solution was placed on the Diamond ATR and allowed to evaporate, with the chamber closed to keep out dust.
10. The candidate material was then applied to the hands and lathered for roughly 15 seconds.
11. The test samples for this evaluation were 2.5 inch square ceramic plates, shown in Figure 8.
12. The ceramic plates were handled for 30 seconds. The entire ceramic plate was touched by various parts of the hands.
13. Hands were cleaned with soap and water between candidate materials.
14. For the samples slated for ion chromatography evaluation, the handled ceramic plates were placed in clean, contamination free, extraction bags. A 30 mL volume of 10% isopropanol (IPA) and 90% deionized (DI) water was introduced into each test bag. The bag was then placed in an 80°C water bath for one hour.
15. Following the 1 hour extraction period, the bag was removed from the water bath and the bag and extract solution were allowed to cool to room temperature.
16. A sample of the solution was then placed in clean sample polypropylene vials and analyzed.
17. For samples slated for FTIR analysis, the ceramic plates were extracted using acetonitrile. A sample of the extract solution was placed on the Diamond ATR and allowed to evaporate, with the chamber closed to keep out dust.

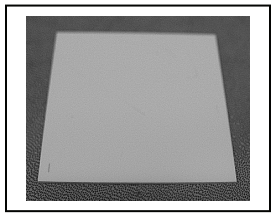


Figure 5: Ceramic Substrate

Procedures – Ion Chromatography

1. The specifics of the RC ion chromatography system are shown below.

Cations

- Metrohm 761 Compact Ion Chromatograph with a Metrohm 766 Autosampler
- Method: Non-Suppressed Cation
- Eluent: 8.0 mmol/L d-tartaric acid , 0.75 mmol/L dipicolinic acid (DPCA), 1 ml/min flow rate
- Metrohm Cation2 column with guard column
- Sample loop: 20 µL
- Run time: 18 minutes per run
- Control cations: sodium, ammonium, potassium, magnesium, calcium

Anions

- Metrohm 761 Compact Ion Chromatograph with a Metrohm 766 Autosampler
- Method: Suppressed Anions
- Eluent: 2.8 mmol/L sodium bicarbonate / 1.4 mmol/L sodium carbonate with a 0.7 ml/min flow rate
- Metrohm ASUPP5-250 column with guard column
- Suppressor: Metrohm MSM
- Regenerant: 100mM sulfuric acid
- Sample loop: 20 uL
- Run time: 34 minutes per run
- Control anions: fluoride, chloride, bromide, nitrate, nitrite, phosphate, sulfate

2. Prior to any analytical runs, the IC system was allowed to warm up and eluent run through the system until a stable baseline was attained.
3. A four-point calibration method was run and covered the range of 0.2 – 20 parts per million (PPM) concentration for all anions and cations in the control groups. The integration parameters were reviewed.
4. All test samples were run using the parameters shown above. Approximately 3 ml of sample solution was used in each run.
5. The generated chromatograms were reviewed. If any chromatograms showed unstable baselines, the sample was re-run.
6. The sample information, extract information, and resultant PPM values were entered into an Excel spreadsheet and converted to a normalized figure of micrograms per square centimeter.

Test Results – Residue Transfer Study

Ion Chromatography Results

1. Table 1 shows the extractable anions (negatively charged ions) from the ceramic card substrates. All values have been converted from parts per million (ppm) to a normalized microgram of the candidate ion per square centimeter of extracted surface.
2. The values noted can be considered as acceptably low. In past evaluations Rockwell Collins cleaning programs, the authors have determined that chlorides and sulfates are the primary anions of concern. The authors consider any substrate with less than 0.75 micrograms of chloride per square centimeter to be acceptably clean. The values shown below are all well below this metric. Sulfate levels are desired to be less than 1.0 micrograms per square centimeter and all of the measured values are well below this threshold.

Table 1. Ion Chromatography Results - Anions

Description	Fluoride	Chloride	Nitrite	Bromide	Nitrate	Phosphate	Sulfate
Blank - Hands Only	0.10	0.23	0.10	0.00	0.00	0.00	0.34
After Purell	0.23	0.37	0.12	0.00	0.00	0.00	0.21
After Sam's Club	0.03	0.10	0.00	0.00	0.00	0.00	0.00
After Mid. Pom	0.06	0.14	0.00	0.00	0.00	0.00	0.00
After Jergens	0.05	0.14	0.00	0.00	0.00	0.00	0.00
After ESD Lotion	0.00	0.10	0.00	0.00	0.00	0.00	0.00
After Gnarly Green	0.06	0.10	0.00	0.00	0.00	0.00	0.00
After X3	0.00	0.18	0.00	0.00	0.00	0.00	0.00

3. Table 2 shows the levels of cation (positively charged) ionic residues extractable from the coupons after handling. As with the anions, all values are reported as a normalized micrograms per square centimeter. Cation residues are considered as process indicators, rather than undesirable materials, as are anions. None of the cation residues give reason for concern. The measurable cation residues from the Purell material are believed to be part of the chemistry of the vitamins incorporated into that material.

Table 2. Ion Chromatography Results – Cation Residues

Description	Lithium	Sodium	Ammonium	Potassium	Calcium	Magnesium
Blank - Hands Only	0.00	0.32	0.00	0.00	0.00	0.00
After Purell	0.00	0.51	0.00	0.34	0.48	0.00
After Sam's Club	0.00	0.00	0.00	0.00	0.00	0.00
After Mid. Pom.	0.00	0.25	0.00	0.00	0.00	0.00
After Jergens	0.00	0.32	0.00	0.00	0.00	0.00
After ESD Lotion	0.00	0.00	0.00	0.00	0.00	0.00
After Gnarly Green	0.00	0.00	0.00	0.00	0.00	0.00
After X3	0.00	0.00	0.00	0.00	0.00	0.00

FTIR Results

1. A sample of the acetonitrile blanks, used to determine the presence of any background organic contamination, is shown in Figure 6.

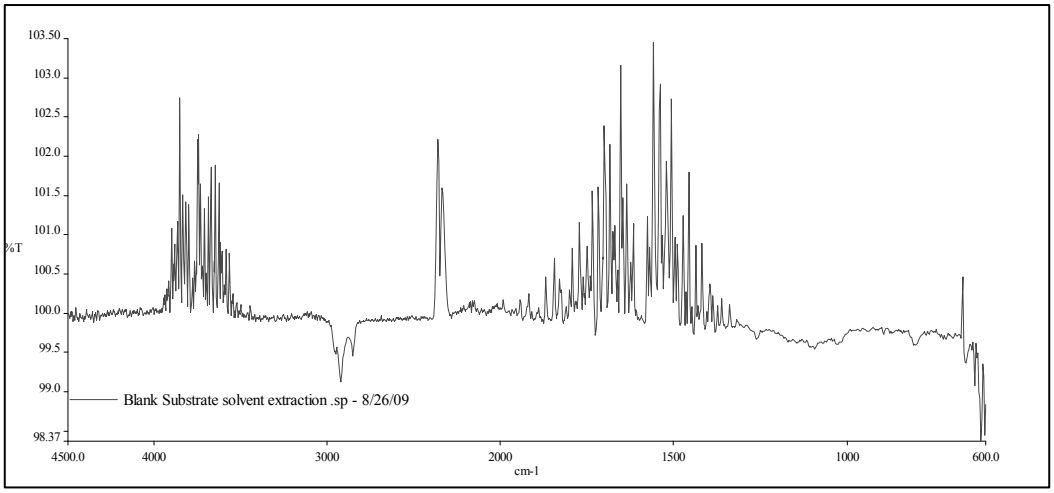


Figure 6: Acetonitrile Blank

2. The control showed very little signal which means that the data collected was usable with no "baseline subtraction" to correct for background contaminants. The minor variations noted were believed to be due to slightly different ambient conditions (nitrogen and humidity levels).

3. Figure 7 shows a composite FTIR scan for the residues detected for all of the candidate runs for the three candidate lotions and three of the sanitizers.

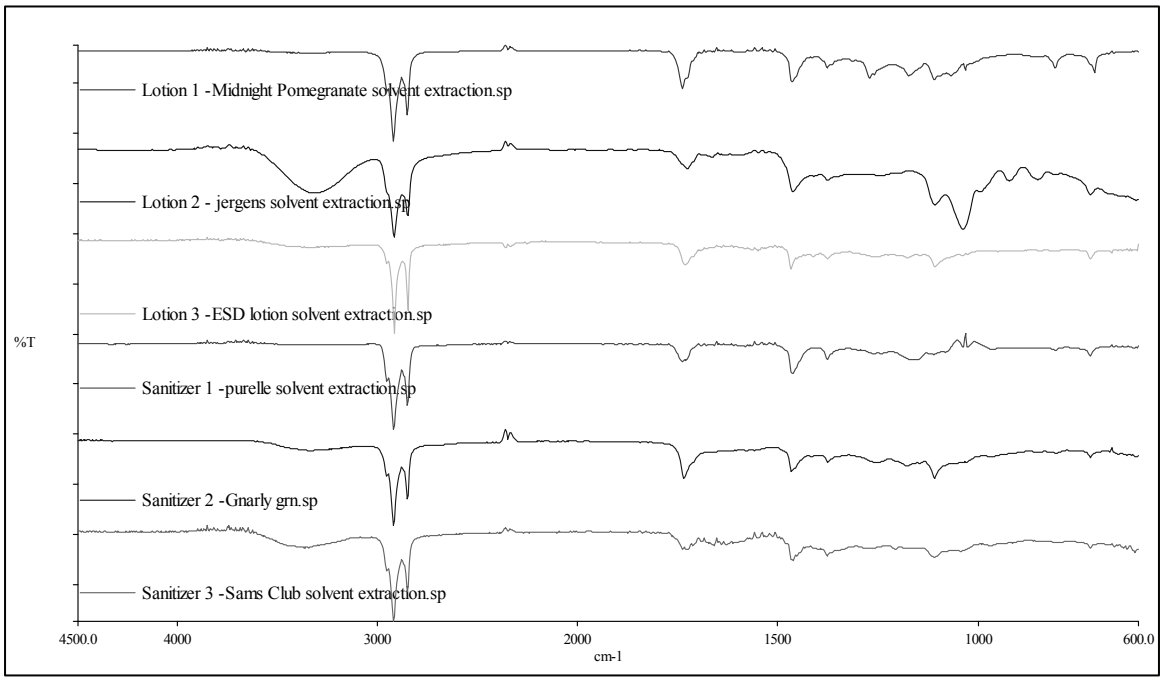


Figure 7: Composite Scans After Solvent Extraction

4. The X3 sanitizer was added later in the study. The composite FTIR scan of the four sanitizer materials is shown in Figure 8.

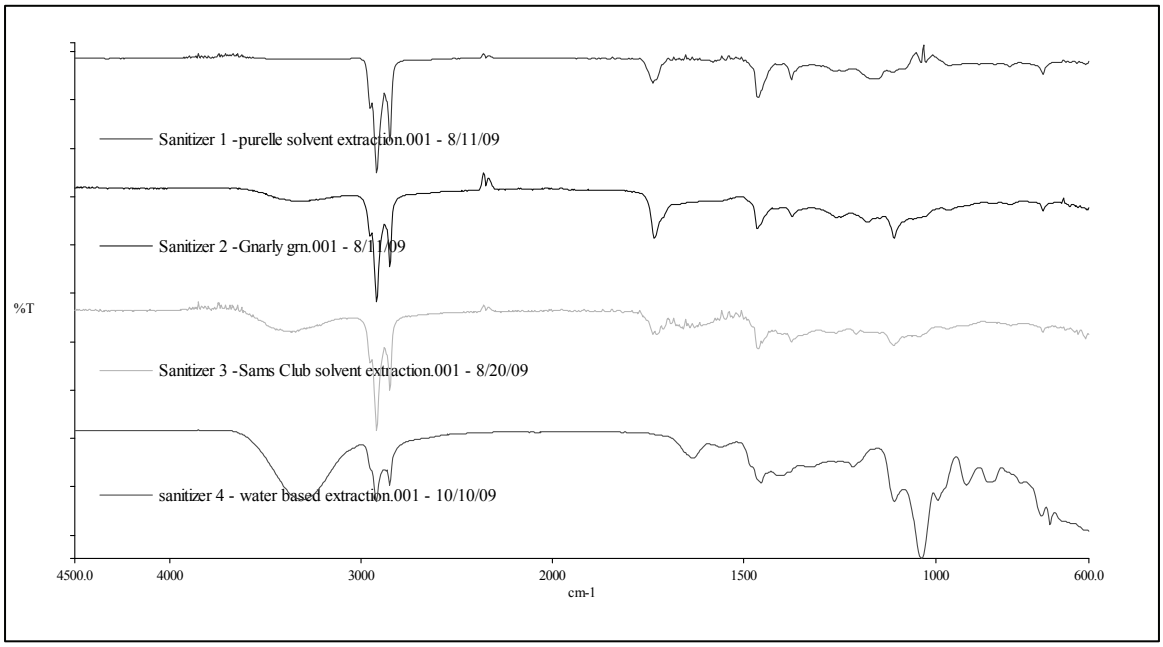


Figure 8: Composite FTIR for Sanitizers After Extract

Conclusions – Residue Transfer Study

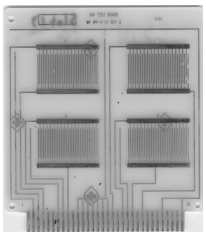
1. The ceramic plates were chosen as a substrate which would contribute no additional organic residues and which would not be chemically attacked by the harsh extraction solvents used in this study.
2. The FTIR scans showed that in all cases, there was some organic material transferred to the ceramic plates. It should be stressed that this FTIR technique is qualitative, not quantitative, so we can conclude that some material was transferred, but not how much.
3. The ion chromatography data shows that the amounts of ionic residues, primarily chloride, are relatively low and do not represent a contamination risk. Considering the variable nature of the handling of the ceramic plates, the amount of variation between the different candidate materials was expected. The differences between the lotions and sanitizers, and that of bare hands alone are not considered to be significant.
4. The overall conclusion was that some amount of the sanitizer and lotion residues transfers to the substrate, but the nature of the residue was not quantifiable with the methods used, but was not ionic in nature.

Impacts on Electrical Parameters

In-Circuit Testing (ICT) or functional/operational testing, often done at high voltages or currents, require that conductive paths conduct and insulating materials insulate. The presence of ionic residues, when mixed with the normal humidity of the workplace, can result in weak electrolytic solutions that may conduct electricity, resulting in undesired leakage currents. In high voltage applications, these leakage currents may be sufficient to cause arcing or coronal discharges. Non-ionic residues, which may be hydrophilic, or water attracting, may enhance or exacerbate the ionic leakage currents. Two tests were chosen examine the impact of sanitizer and lotion residues on electrical insulation: (1) dielectric withstanding voltage, or hi-pot testing; and (2) surface insulation resistance (SIR) testing.

Dielectric Withstanding Voltage

Dielectric Withstanding Voltage (DWV) involves applying an electrical potential across an adjacent electrode configuration. The substrate for this test was the IPC-B-24 standard test board, shown in the photo to the right. This test board had four identical interdigitated comb patterns, each with 0.4 mm wide lines and 0.5 mm line spacing, labeled A, B, C, or D. The surface finish was bare copper over FR-4 multifunctional epoxy glass laminate with no applied solder mask. Short wire segments (pigtails) were soldered (Kester 245) to the board contact fingers to better interface with the test equipment. Following the soldering operation, the test boards were cleaned in the saponified aqueous water wash process to remove all soils. A total of 24 test boards (six conditions, three replicates each) were prepared.



IPC-B-24 Board

Each of the test boards were handled in a manner similar to that described in the Residue Transfer Study. The team did consider applying the sanitizers and lotion materials directly to the comb patterns, but after a review of the chemical constituents, it was felt that the materials would be electrically conductive in their liquid form, resulting in immediate test failures. The team desired to test a more practical scenario of a hand transferring trace amounts of a material to the substrate. Therefore, for each of the test boards were handled as in the Residue Transfer Study. Comb D of each board was not handled to serve as an unprocessed control. Comb patterns A-C were handled for a period of approximately one minute and allowed to air dry for 24 hours prior to the start of DWV testing.

In a DWV test, a potential is placed across the two sides of each comb pattern. The potential is increased linearly until breakdown occurs. When breakdown occurs, current begins to increase in a non-linear rate and a visible electrical arc is often observed. The hi-pot testers record the voltage at which this breakdown occurs.

The results for the DWV are shown in Table 3.

Table 3. DWV Test Results

Material	Ave. Breakdown Voltage Controls (kV)	Ave. Breakdown Voltage Treated (kV)
Purell	1.7	1.40
Sam's Club	1.8	1.11
Germ-X Gnarly Green	1.8	1.08
Jergens Ultra Healing	1.6	1.35
Midnight Pomegranate	1.5	1.30
Chemtronics Lotion	1.6	1.12
X3 Clean	1.4	1.40

Conclusions – Dielectric Withstanding Voltage

1. The average values, relative to the unprocessed control, was slightly lower for all of the treated patterns. It is apparent that some small amount of material was transferred to the test patterns, however, all of the test patterns maintained values above 1100 volts for a 20 mil (0.020 inch) space pattern.
2. Consequently, the decrease is not considered as significant.
3. If this test were to be run again, we would include handling with untreated hands to determine what the effect of handling would be from normal skin salts and oils.

Surface Insulation Resistance (SIR) Testing

In SIR testing, a set test voltage was applied to an electrode configuration and the resulting current measured. The insulation resistance was a ratio of the test voltage to the test current (Ohms Law). The test measurements were repeated frequently as the test substrate was subjected to elevated temperature and humidity conditions. A hydrophilic residue would be expected to perform poorly in such a test. As with the DWV test, the IPC-B-24 standard test board was used as the substrate. With the exception of the soldering of test leads, which were not needed for this test, the processing was performed the same as for the DWV test. Comb D served at the unprocessed control, with Combs A-C as the treated patterns. SIR testing generates a large volume of individual data points and so is impractical to reproduce in table format. All of the SIR charts are shown in LogOhms; the base 10 logarithm of the measured resistance (1 megohm = 1 x 10^6 ohms = 6.0 LogOhms). The horizontal axis of each graph represents the hours in test at 40°C / 90% relative humidity.

It should be noted that there are no nationally accepted pass-fail criteria for SIR testing for this kind of material, however, many IPC test labs, as well as Rockwell Collins, have found that 100 megohms (8.0 LogOhms) represents a reasonable pass-fail criteria for most residue-related SIR tests. This metric was considered as the overall discriminator between acceptable and unacceptable for this test.

Results for Purell

1. Figures 9 through 12 show the results for the Purell material.

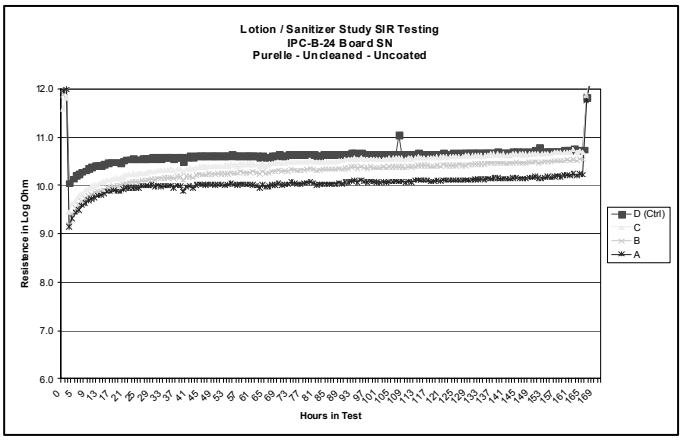


Figure 9

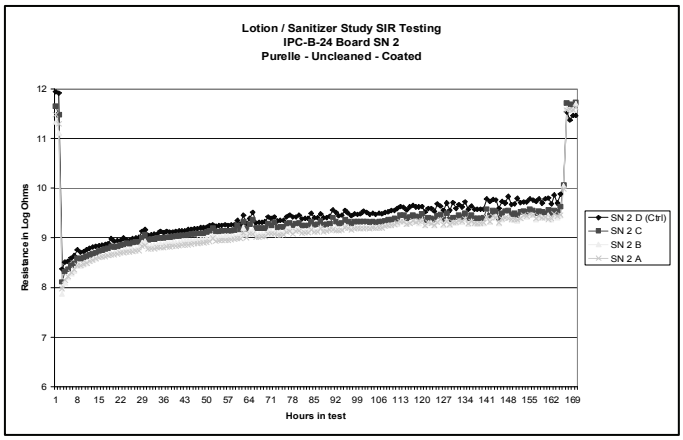


Figure 10

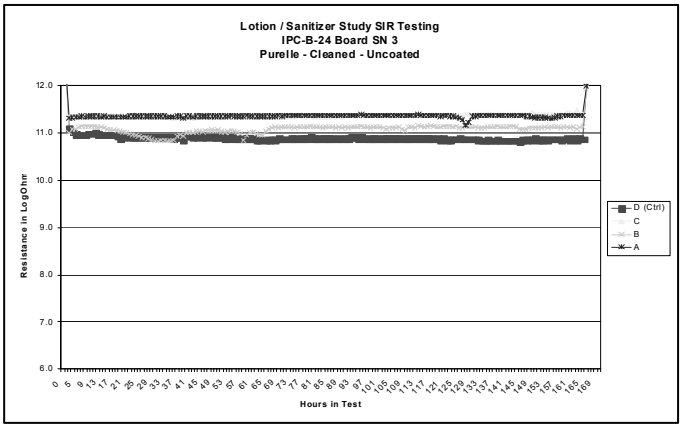


Figure 11

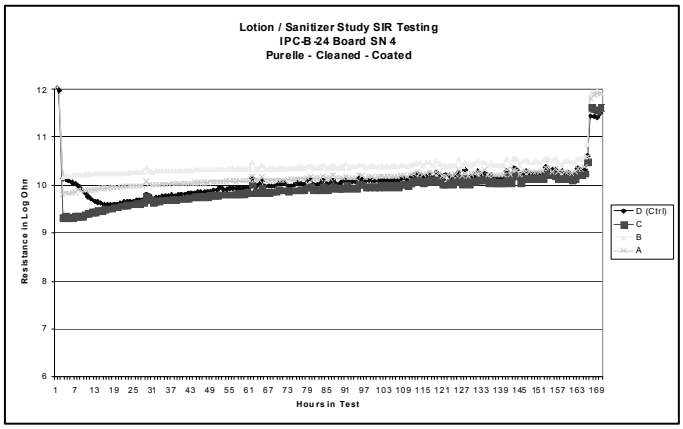


Figure 12

2. For the samples handled with Purell treated hands, all of the measured results were above the 8.0 LogOhm criteria.
3. For all of the Purell combinations, there was not a great deal of variation between the control pattern (D) and the handled patterns. In most cases, the uncoated control pattern was higher in SIR level than for the handled patterns, but not dramatically so. While all of the SIR values were above the 8.0 LogOhm level, it is clear that handling the patterns has some degradation on SIR performance, though minor in this case. The two best SIR performances came from the cleaned boards and the two poorest (though still acceptable) came from the uncleaned boards.
4. The cleaned samples would be most representative of cleaned hardware, where as the uncleaned cases would be of more concern to a reduced clean or no-clean assembly process.
5. In the post-SIR visual examination, performed at 4-10X magnification, no indication of corrosion or electrochemical migration (dendritic growth) was found.

SIR Results for Sam's Club

1. Figures 13 through 16 show the results for the Sam's Club material.

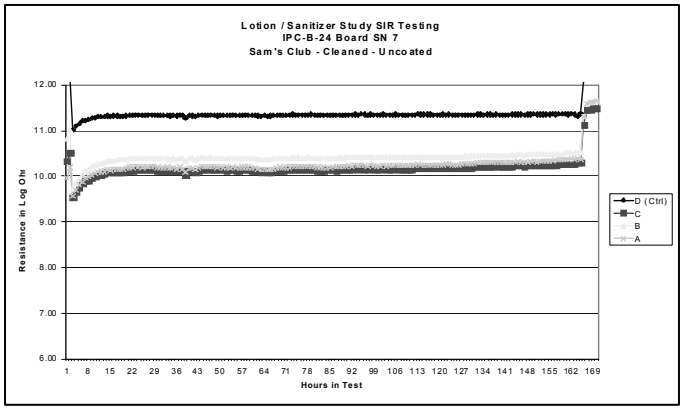


Figure 13

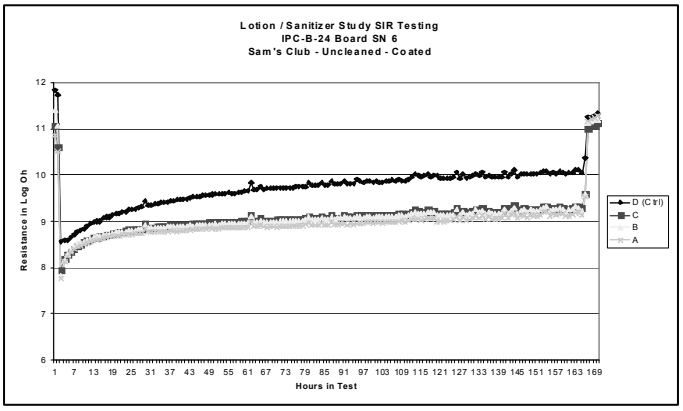


Figure 14

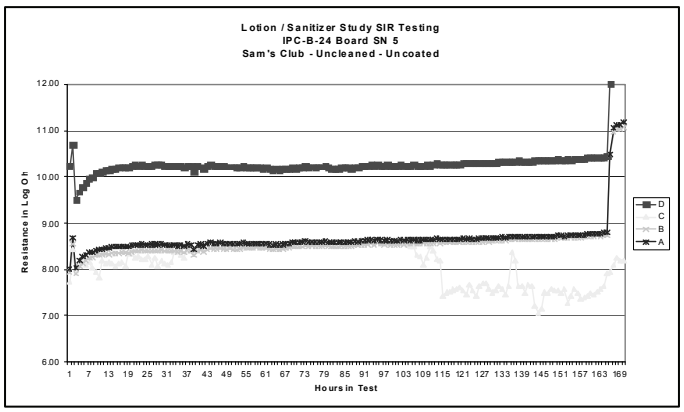


Figure 15

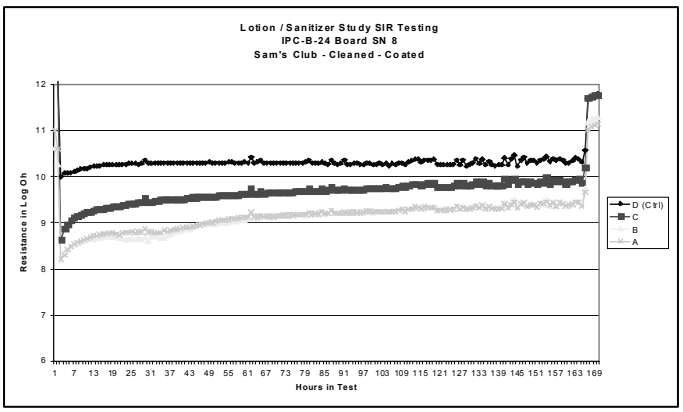


Figure 16

2. For the samples handled with Sam's Club treated hands, not all of the measured results were above the 8.0 LogOhm criteria. The uncleaned and uncoated samples had one pattern (C) which had poor performance in the latter portion of the SIR test.
3. For all of the Sam's Club samples, there was a more noticeable variation between the control pattern (D) and the handled patterns, in some cases as much as two decades. During the processing of the test samples, Mr. Vosatka noted that the Sam's Club sanitizer had a much more noticeable residue or "feel" after applying it to the hands and rubbing, compared to the other hand sanitizers. The SIR performance bears out this observation. The residues remaining after SIR testing have a much greater effect, although, using the 8.0 LogOhm metric, still acceptable for most cases.
4. This shows that the Sam's Club sanitizer does leave a form of residue that can still impact SIR performance, even after exposure to an optimized aqueous wash process.
5. In the post SIR visual examination, there was no evidence of corrosion or metal migration, even for comb pattern C in Figure 15.
6. This sanitizer would not be our first choice for use.

SIR Results for Germ-X Gnarly Green

1. Figures 17 through 20 show the results for the Germ-X Gnarly Green material.

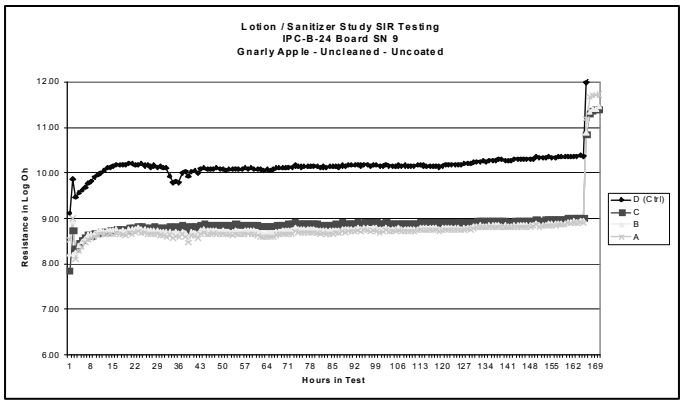


Figure 17

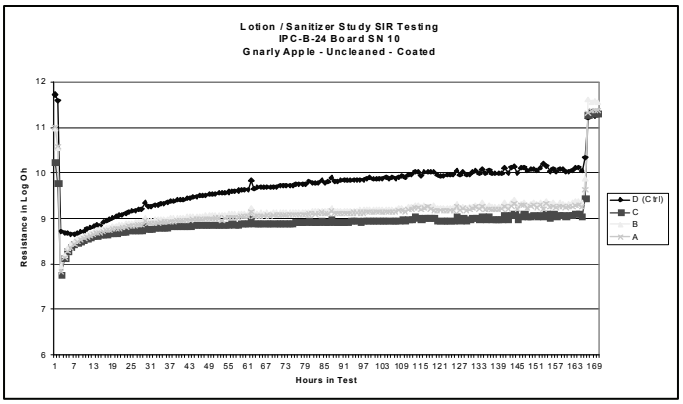


Figure 18

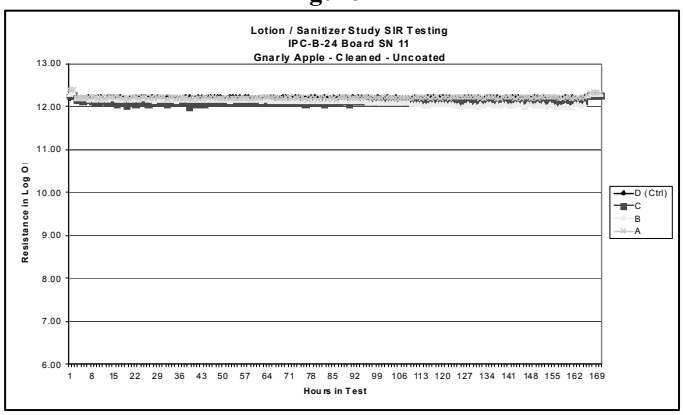


Figure 19

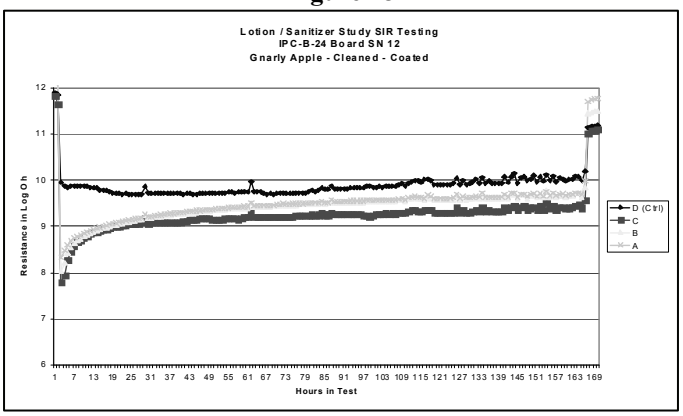


Figure 20

2. For the samples handled with Gnarly Green treated hands, the SIR levels were above the 8.0 LogOhm level, with the possible exception of the first initial measurements at the hot and humid test conditions.
3. In general, most SIR test methods do not consider the first data points taken at elevated conditions to be valid, as the system is still coming to equilibrium. The SIR testing in this evaluation was also done with a more frequent measurement interval than most SIR test methods, so the first initial data points were not given much weight.
4. The data shown in Figure 19 was suspicious. Normally, SIR levels at 40°C/90% RH for a B-24 board, even when scrupulously clean, is around the 11 LogOhm level, as can be seen for the uncleaned / uncoated Comb D in Figure 17. It is likely that the test board was not receiving an adequate bias voltage during the test and the data from Figure 17 should not be considered.
5. Using the remaining data for analysis, there was a noticeable difference between the control patterns (D) and the treated patterns (A-C), though not as great as noted for the Sam's Club material. As with the Sam's Club sanitizer, the data suggests that the Gnarly Green material does leave a form of residue that can still impact SIR performance, even after exposure to an optimized aqueous wash process. However, as the values were above the 8.0 LogOhm level, the impact would not be considered as harmful.
6. The post-SIR visual examination showed no signs of corrosion or metal migration.

SIR Results for Midnight Pomegranate

1. Figures 21 through 24 show the results for the Midnight Pomegranate material.

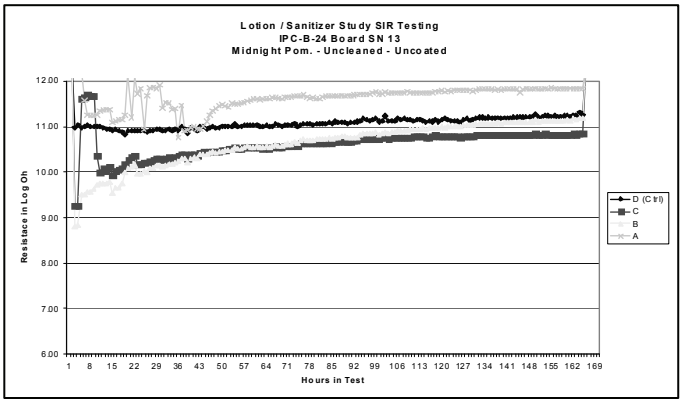


Figure 21

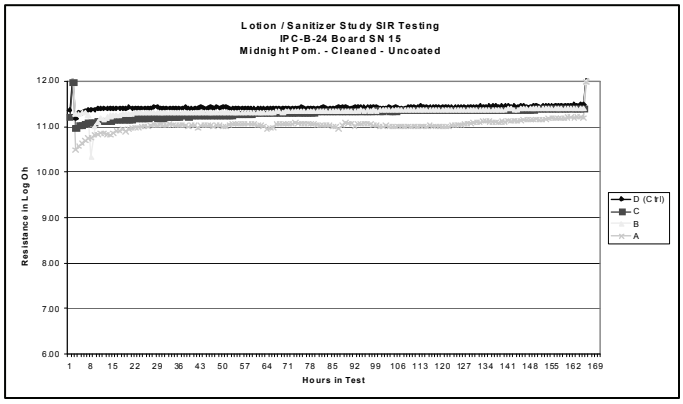


Figure 22

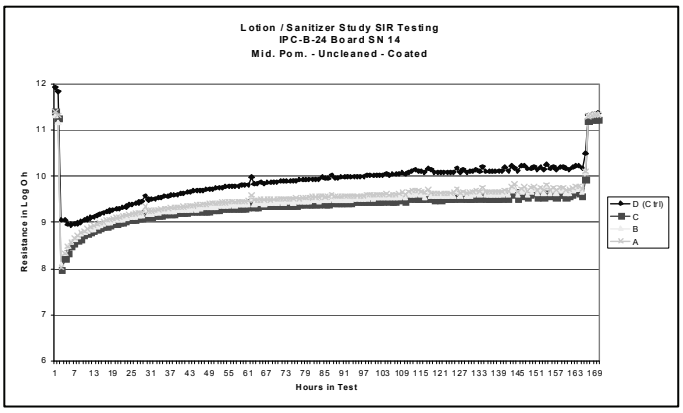


Figure 23

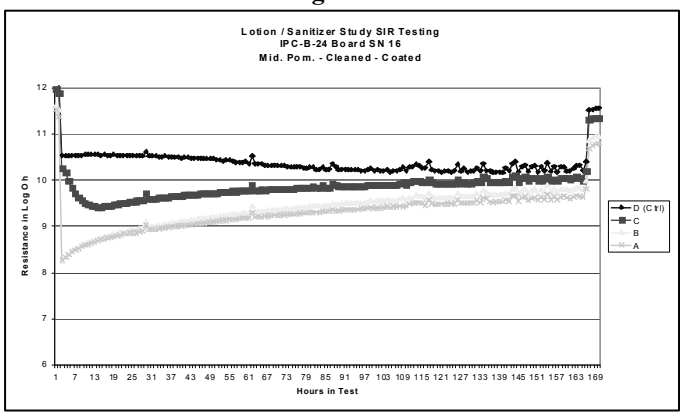


Figure 24

2. For the samples handled with Midnight Pomegranate treated hands, all of the measured results were above the 8.0 LogOhm criteria.
3. The data for Figure 21 suggests that for the uncleaned and uncoated boards, there was an interaction between the lotion residues and humidity, taking several days to come to an equilibrium condition. The data in Figure 22 (cleaned/uncoated) shows that the cleaning process removed the residues.
4. The variability in the SIR performance in Figure 24 (cleaned / coated) is unexplained. The most likely cause is variability in the applied coating, which was applied by hand.
5. The post-SIR visual examination showed no signs of corrosion or metal migration.

SIR Results for Jergens

1. Figures 25 through 28 show the results for the Jergens material.

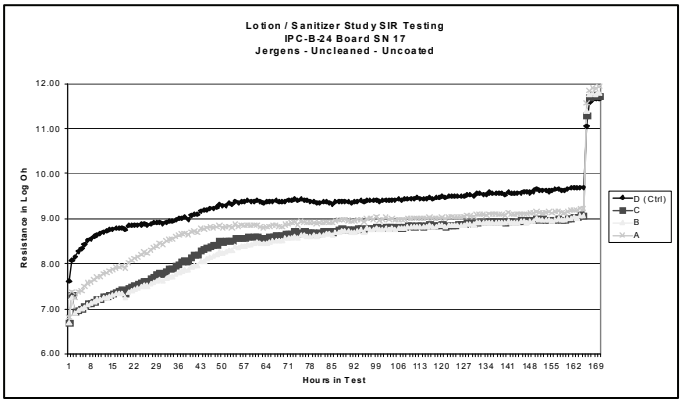


Figure 25

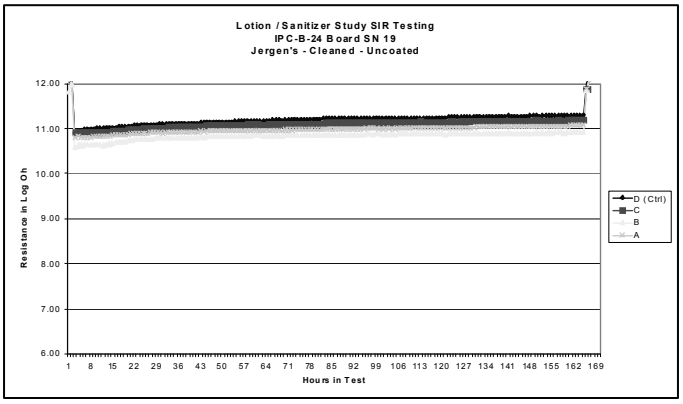


Figure 26

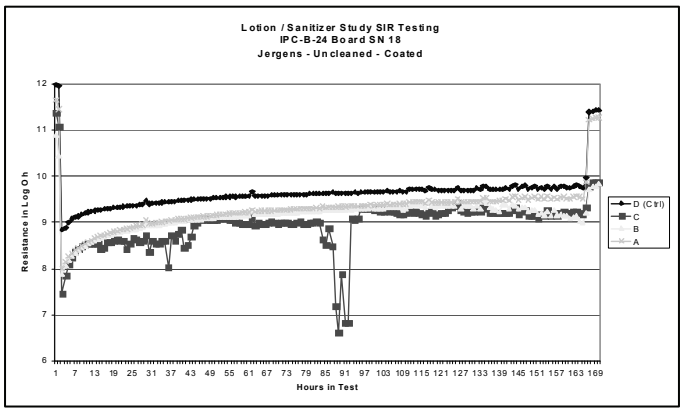


Figure 27

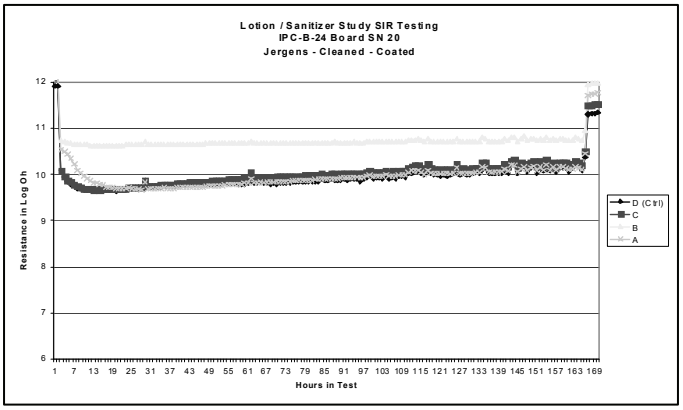


Figure 28

2. The SIR performance for the Jergens' material was significantly poor than for the other lotions or sanitizers examined. The values for the first two days of testing in Figure 25 were consistently below the 8.0 LogOhm criteria. This suggests that the residues from the Jergens lotion was more persistent and hydrophilic (water attracting). The poor performance of the control pattern suggests that the residues may be mobile. It may also be that this test board had lotion residues inadvertently applied to the control pattern.
3. The data in Figure 27 suggests that the lotion residue, even when coated over with conformal coating, can combine with moisture to degrade insulation resistance. The difference in performance between the different treated patterns (A-C) suggests that there may be some threshold value for the residues, where enough residue was present on pattern C to show poor performance, whereas patterns A and B did not exhibit the same performance.
4. The data for Figures 26 and 28 showed desirable SIR performance, well above the 8.0 LogOhm criteria, with consistent performance from all patterns. This indicates that whatever the residue was that caused the poor performance, it was fully removed by the aqueous wash process.
5. As with the other materials, there was no evidence of corrosion or metal migration on any of the test patterns.

SIR Results for Chemtronics

1. Figures 29 through 32 show the results for the Chemtronics material.

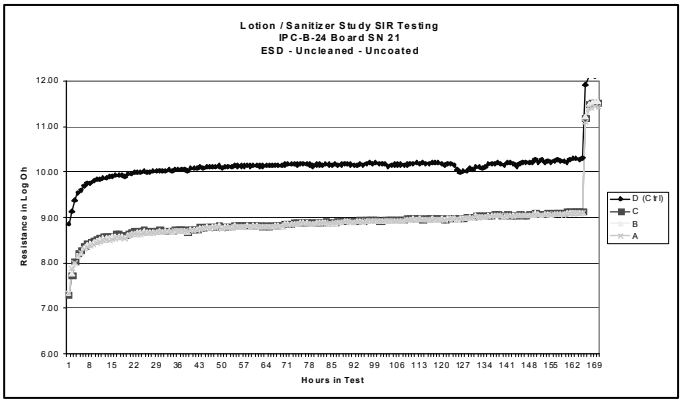


Figure 29

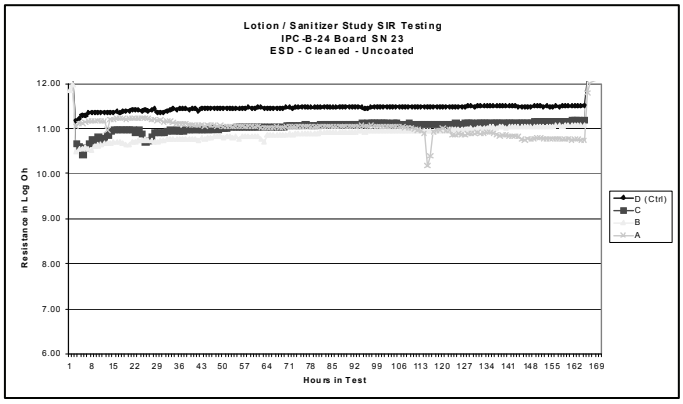


Figure 30

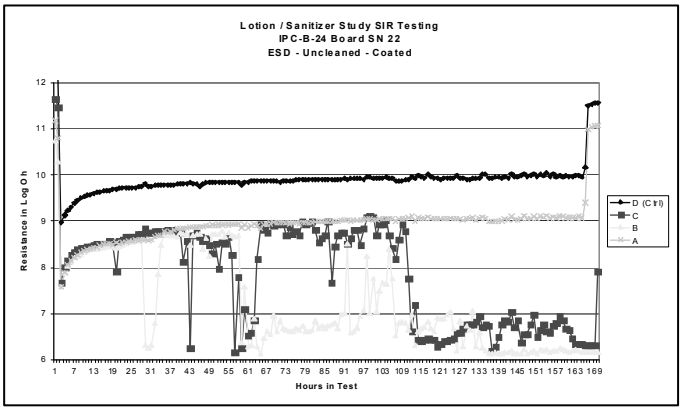


Figure 31

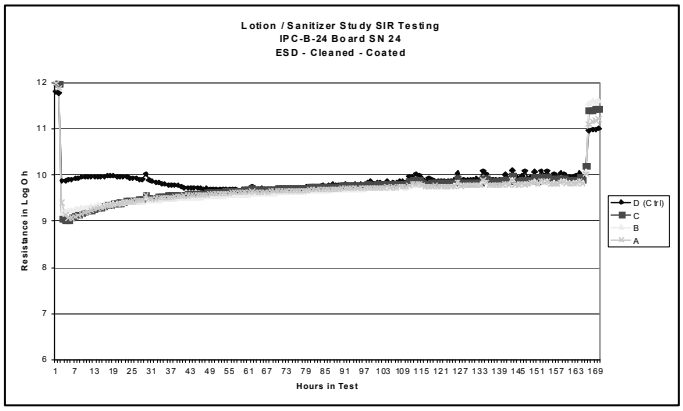


Figure 32

2. As with the other lotion materials, the SIR performance dipped below the 8.0 LogOhm metric initially, recovering to higher levels later in the test.
3. The data for the two uncleaned cases (Figures 29, 31) showed a decade of difference between the untreated control pattern (D) and the treated patterns (A-C). Figure 29 shows that the samples that were uncleaned and uncoated had consistent performance throughout the test. Figure 31 shows highly variable results for the uncleaned but coated condition. The two affected patterns (B and C) had some level of coating delamination noted in the post-SIR visual examination, indicating that the residues could interfere or interact negatively with conformal coating, leading to poor SIR performance. No corrosion or metal migration was noted for these affected patterns.
4. The data from Figures 30 and 32 shows that whatever residue remained was removed by the aqueous cleaning process.
5. No corrosion or metal migration was noted for any of the other test patterns.
6. It is unlikely that these lotion residues have any harmful effects on SIR performance in the cleaned condition. This lotion has been in use at Rockwell Collins for over 10 years and had the lotions resulted in a contaminated condition, our product acceptance tests would have indicated a problem long ago.

Overall SIR Conclusions

1. Sanitizer and lotion residues do have an effect on SIR in the uncleaned condition, though the impact will depend on the chemical nature of the residue and the amount of residue left on the assembly surface.
2. The performance of the cleaned samples shows that the standard Rockwell Collins aqueous cleaning process adequately removes the sanitizer and lotion residues to acceptable levels, even though some of the sanitizer and lotion residues have an impact even after cleaning and conformal coating.
3. None of the test samples showed any corrosion or electrochemical migration (dendritic growth). This indicates that the residues were not ionic in nature and the effects were due to the attraction of water vapor by the hydrophilic nature of the residues.

Impact on Adhesion

One of the potential failure mechanisms considered was the presence of a sanitizer or lotion residue that would interfere with the bonding of an adhesive to the assembly surface. Consequently, the effect of substrates coated with these candidate materials was examined using lap shear testing on several different kinds of adhesives. While not exhaustive, the adhesives chosen represent the major adhesive technologies presently used at Rockwell Collins. Four adhesives were chosen for this study:

- Dow Corning 3145: a one-part Room Temperature Vulcanizing (RTV) silicone adhesive
- Dow Corning SE-1700: a two-part, thermal cure, silicone adhesive
- Huntsman Araldite 2040: a two-part, thermal cure, urethane adhesive
- Loctite 382 Tak Pak: a one-part, cyanoacrylate adhesive

Procedures – Coating Adhesion Study

1. The Rockwell Collins fabrication department prepared strips of standard multifunctional FR-4 epoxy glass laminate, each measuring approximately 1 inch x 4 inches.
2. Each strip was cleaned with isopropanol to remove any background contaminants and then baked for one hour at 100°C to dry the samples.
3. An illustration of the lap shear fixture is shown in Figure 33. This allowed two strips of laminate to overlap each other by a standard 1" overlap. Spacer material was placed under one strip to give a consistent standoff height, or bondline, between the strips. Two bondlines were chosen for this evaluation. The thinner Tak Pak cyanoacrylate adhesive was applied in a 0.002 inch (2 mil) bondline and the remaining, thicker adhesives were applied in a 0.045 inch (45 mil) bondline.

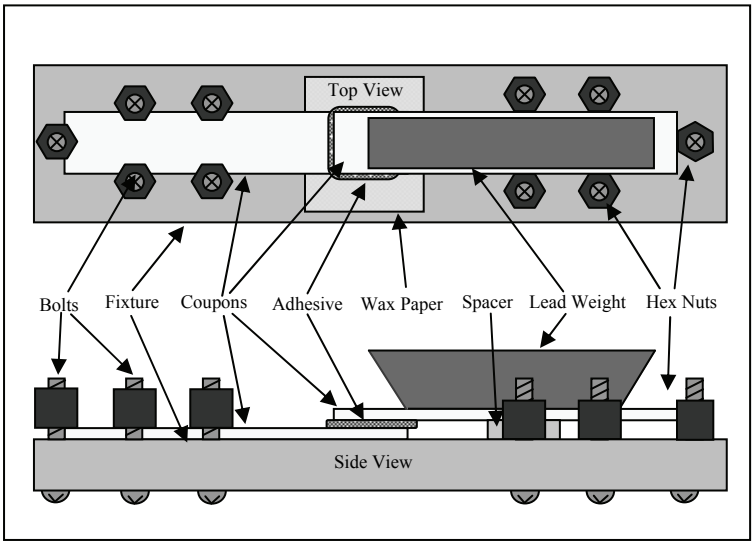


Figure 33: Lap Shear Fixture

4. One of each pair of strips was handled using hands prepared with the candidate material as outlined in the other sections of this study. The remaining strip was not handled with conditioned hands.
5. The candidate adhesive was applied to the end of the unhandled strip and the two strips mated together as shown in Figure 33. Each adhesive as cured per the appropriate Rockwell Collins process specification.
6. After the adhesives were cured, each test pair was pulled to breaking with a MTS Sintech 10G/Tall Tensile Tester, using 10,000 pound load cell and a 0.2 inches/min cross head speed.
7. The maximum yield strength and mode of failure was recorded for each test pair.
8. The samples for Dow Corning 3145, as a slow curing adhesive, was found to be incompletely cured in the first test run. A second set of test samples was generated and the adhesive allowed to completely cure before testing.

Test Results – Coating Adhesion Study

1. Figure 34 shows a typical output from the tensile test machine. Lines 1, 2, and 3 represent three test coupons per test condition.

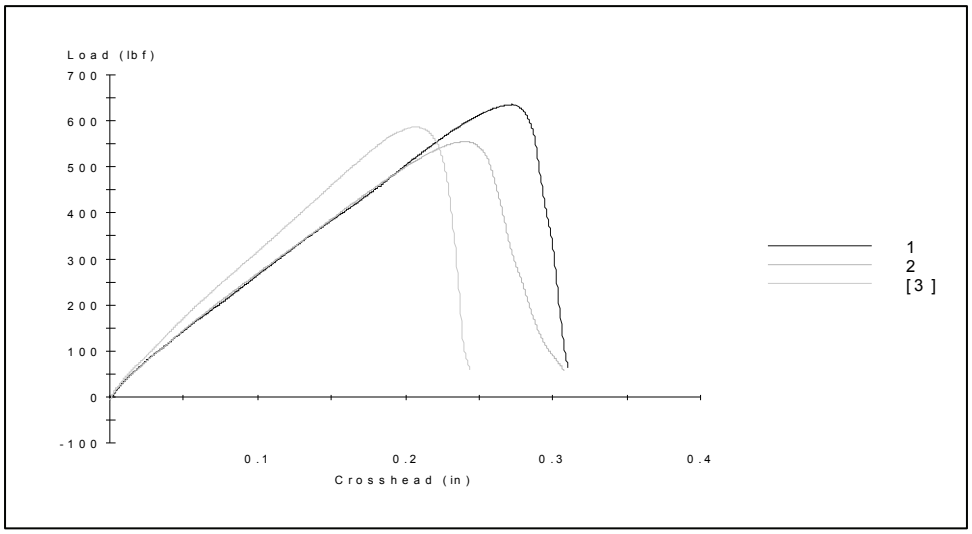


Figure 34: Typical Tensile Plot

2. Tables 4 and 5 show the mean lap shear strength of the three test samples in each test group. A high degree of variability was noted for most data sets due the amount of adhesive "squeeze out" in the test samples.

Table 4. Mean Lap Shear Strength – DC3145

Test Group	DC 3145 Run 1	Std. Dev.	DC 3145 Run 2	Std. Dev.
Control	114.2	3.37	50.8	10.25
Purell	117.7	50.4		
Sam's Club	118.7	21.06		
Germ-X Gnarly Green	102.5	38.31		
Jergens Ultra Healing	104.9	25.01	83.2	11.72
Midnight Pomegranate	37.7[1]	2.10	117.8	12.66
Chemtronics lotion	37.5[1]	3.27	102.1	10.09

1 = insufficient cure of adhesive

Table 5. Mean Lap Shear Strength – Other Adhesives

	Araldite 2040	Std. Dev.	DC SE-1700	Std. Dev.	Tak Pak	Std. Dev.
Control	360.0	49.80	172.5	23.01	479.4	26.38
Purell	598.5	60.25	36.6	5.21	561.6	70.58
Sam's Club	476.4	12.78	144.3	33.69	518.8	89.68
Germ-X Gnarly Green	535.0	66.54	100.6	33.81	526.2	27.14
Jergens Ultra Healing	590.4	72.71	158.6	15.04	472.7	17.21
Midnight Pomegranate	693.7	51.38	190.9	20.20	612.9	83.72
Chemtronics Lotion	592.2	40.82	110.1	32.88	606.3	93.36

3. Figures 35 through 39 are graphical representations of the data.

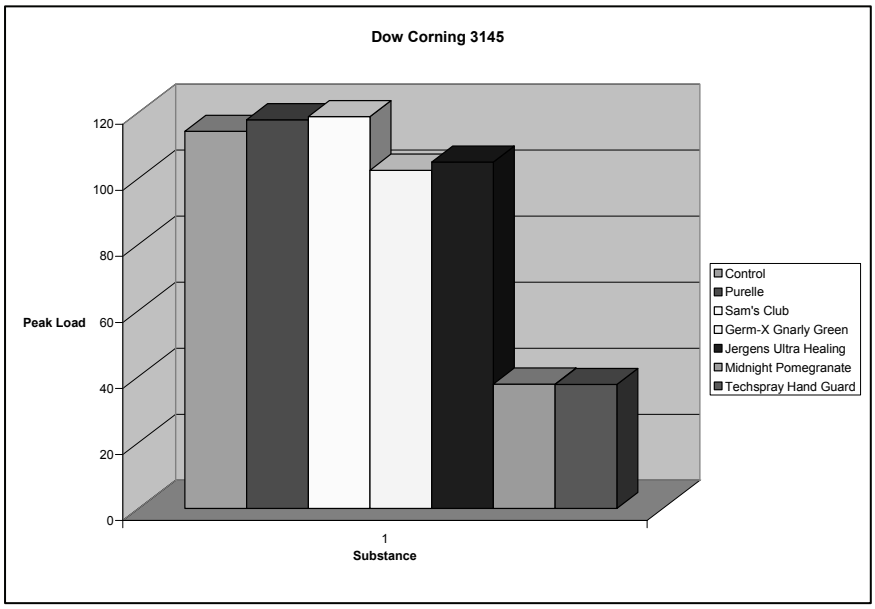


Figure 35: DC3145 Lap Shear Strength (incomplete cure) (45 mil bondline)

4. The data in Figure 35 is somewhat misleading. Moisture cure room temperature vulcanizing (RTV) adhesives take an extremely long time to cure in this kind of lap shear test specimen. RTV adhesives require moisture to cure. As the outer surface cures, it limits diffusion of moisture to the uncured inner portions of the adhesive. In essence, the lap shear specimen is equivalent to an adhesive mass that is one inch thick, which requires weeks or months to fully cure. Therefore, none of the values shown in Figure 16 should be considered as "full cure" and this variable cure led to variability in the overall lap shear strengths determined. The two samples for the Midnight Pomegranate and the Chemtronics had 3 days less cure time than the other samples, leading to the lesser values for those two material. The lower values were not due to the residues themselves but due to differences in cure.

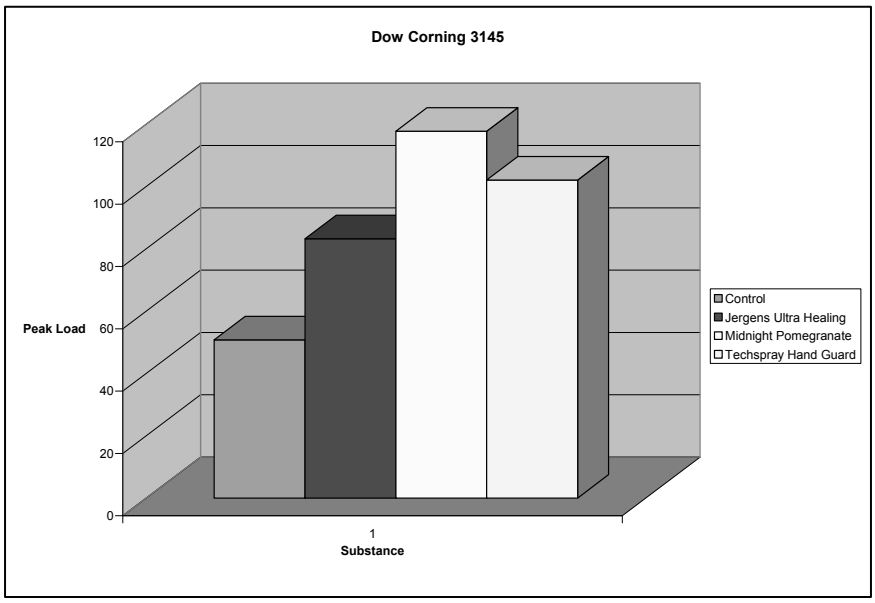


Figure 36: DC3145 Lap Shear Strength (second run) (45 mil bondline)

5. Figure 36 also shows variability in the data, again due to difficulties in curing the RTV adhesive. Rockwell Collins has had some success in the past with accelerated curing of RTV adhesives using humidity chambers set at elevated temperature and humidity conditions. While this approach often works, the use of too high a temperature and humidity can lead to the evolution of bubbles in the mass of the adhesive. An examination of the lap shear specimens after testing showed a high degree of bubbles in the control samples. All of the samples for this group had been processed at the same time and under the same conditions, but the control samples bubbled much more than the other samples, leading to the overall decrease in strength shown in Figure 36. It is unknown why the control samples bubbled more than the other samples.

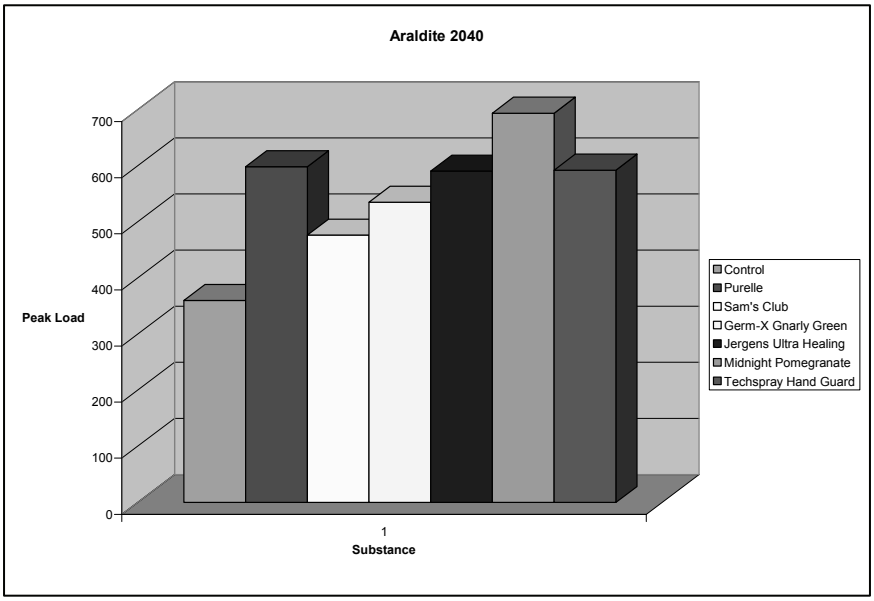


Figure 37: Araldite 2040 Lap Shear Strength (45 mil bondline)

6. The data in Figure 37 is for the Araldite 2040 urethane adhesive. All of the test cases showed no loss of adhesion due to handling residues. The variability for this adhesive is due more to the amount of adhesive that extends past the sides of the lap shear specimens than to any other differences.

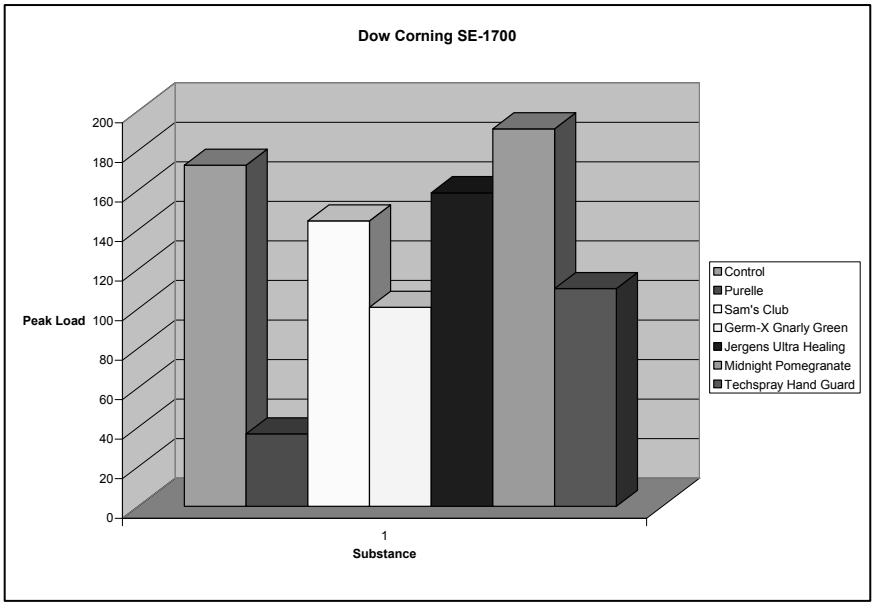


Figure 38: Dow Corning SE-1700 Lap Shear Strength (45 mil bondline)

7. The data in Figure 38 is for the thermally cured Dow Corning SE-1700. As with the other adhesives, some of the variability in the data can be traced to variations in the amount of excess adhesive on the specimens. One of the observations made during the post-test visual examination was that all of the SE-1700 samples felt slightly tacky, and not

the firm material representative of a fully cured SE-1700 adhesive mass. Past experience with this adhesive has shown that the cure mechanism can be poisoned or inhibited by trace amounts of contaminants. Both the processed samples and the control samples had this tacky/gummy condition.

8. It is unknown why the Purell samples were so much lower than the other samples. The combinations of Purell residues and the SE-1700 adhesive were the first samples to be run, so experimental error is a distinct possibility.

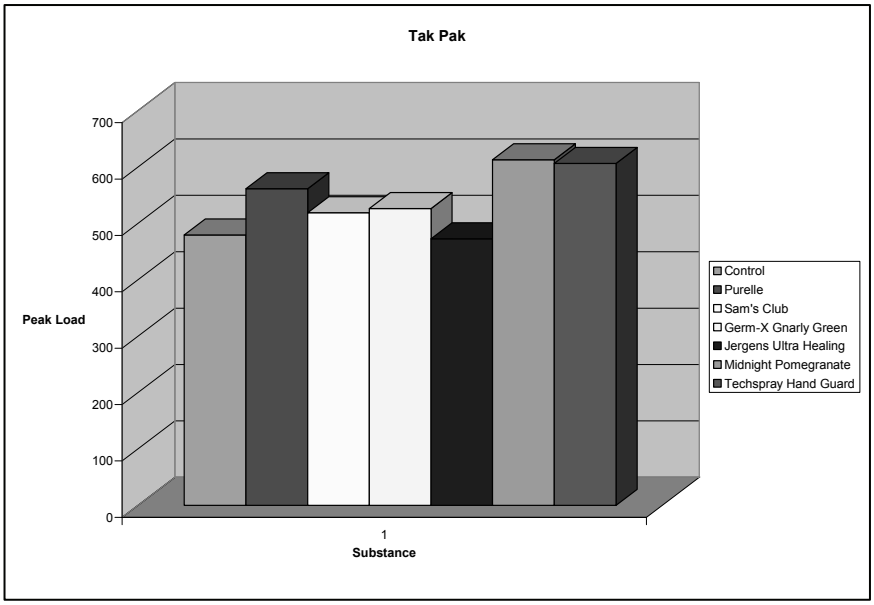


Figure 39: Tak Pak Lap Shear Strength (2 mil bondline)

9. Figure 39 shows the data for the Loctite 382 Tak Pak cyanoacrylate adhesive. This type of adhesive was less susceptible to variations in the amount of material, as only a 2 mil bond line was used. Consequently, the data was much more consistent for this material. None of the candidate residues appeared to result in degradation of adhesive strength for this adhesive.
10. Table 6 is a listing of the observed failure modes for the test samples. An adhesive failure (1) is a failure where the adhesive did not adhere to one or more faces of the test sample. A cohesive failure (2) is a failure where adhesive remains on both surfaces of the test sample. For the first run of the Dow Corning 3145 samples, the primary failure mode (3) was inadequately cured adhesive and tacky adhesive was found at the inner portion of the adhesive mass.

Table 6. Adhesive Failure Modes

	DC 3145	DC 3145-2	Araldite 2040	DC SE-1700	Tak Pak
Control 1	3	1	2	2	1
Control 2	3	1	1	1	1
Control 3	3	2	2	2	1
Purell 1/2/3	3	n/a	1	1	1
Sam's Club 1/2/3	3	n/a	1	1	1
Germ-X Gnarly Green 1/2/3	3	n/a	1	1	1
Jergens Ultra Healing 1/2/3	3	1	1	1	1
Midnight Pomegranate 1	3	1	1	1	1
Midnight Pomegranate 2	3	1	1	1	1
Midnight Pomegranate 3	3	1	Lost sample	1	1
Chemtronics Lotion 1/2/3	3	1	1	1	1

11. In all cases, with one exception, the loss of adhesion was on the side of the test sample handled with the candidate material. The one exception as for sample #15, Dow Corning SE-1700 and Jergens lotion. The failure mode in that case was a loss of adhesion on the side of the test sample that was not handled. The fact that almost all the samples lost adhesion on the handled side, rather than the non-handled side, indicates that the residues were at fault and not the surface conditions of the laminate material.

Conclusions – Coating Adhesion Study

1. It is difficult to come to an overall conclusion on the effects of the residues on adhesive strength. The data from the failure mode show that almost all the samples failed on the surface that had been handled. This showed that there was some deleterious effect from the handling; however, there were no controls run that would have represented normal handling with only simple finger salts and oils being present. Based on testing that has been done in the past, we might expect similar failure mechanisms from normal handling.
2. Alternatively, some of the samples did show unexplained degradation in adhesive strength, all other factors being equal.
3. This portion of the study should be re-run for the silicone adhesives, allowing longer cure times and incorporation of additional controls, with a more consistent application of adhesives.
4. The question remains as to whether these residues constitute a reliability risk for adhesives on assembled hardware. The risk of failure should be considered to be low for a number of reasons:
    a. In most manufacturing cells, operators wear gloves during the adhesive application process. Consequently, any sanitizer or lotion residues would be prevented from transfer to the assembly surface by the gloves.
    b. Most assemblies go through the water wash process prior to adhesive application, which would handle most transferred residues, if any.
    c. Having observed operator handling for a number of years, most operators do not grasp assemblies in areas where the adhesive would make the critical bond to either the solder mask surface or the component surface for the bond. Most grasp the boards by the edges or on the tops of components where adhesive is seldom applied.
    d. The Chemtronics lotion has been used for many years at Rockwell Collins. If hand lotion residues were a significant risk, we would have seen evidence of this by now.
    e. For most of the adhesives studied, the yield strength is still sufficiently high for most parts staking applications.
5. Consequently, it is not recommended that any sort of "ban" on hand lotions or sanitizers be pursued, nor should the use be encouraged either. Operators should be counseled that hand lotion and sanitizer residues can transfer to assembly surfaces and the use of such lotions should be minimized while at work.

Impacts on Solderability

If a hand lotion or sanitizer reside was present on a metallic surface, the potential exists for that residue to degrade solderability of that surface, impeding the ability of a molten solder alloy from flowing out, or wetting, across the contaminated surface. One method of determining the degradation of solderability is to do a solder spread test.

Procedures – Solderability Study

1. An illustration of the solder spread test coupon is shown in Figure 40. The base metal was copper, with different test samples coated with one of four surface finishes: tin lead hot air solder leveled (HASL); electroless nickel immersion gold (ENIG); organic solder preservative (OSP); or immersion silver (ImAg).
2. Each test coupon was cleaned with isopropyl alcohol and a lab tissue wipe (e.g. Kimwipe), and allowed to dry.
3. Each initial coupon weight was weighed to the nearest milligram and recorded.
4. One set of coupons was separated out as the unprocessed controls.
5. A small amount (typical use) of lotion was applied to hands that had been previously cleaned with soap and water and dried with paper towels.
6. Each coupon was then rubbed with the fingers and palms of the conditioned hands, transferring lotion or sanitizer to the surface of the coupon.
7. Each coupon was again weighed to the nearest milligram and the weight recorded as the conditioned mass.
8. Using a standard application apparatus, a uniform amount of solder paste (Indium SMQ-92J) was applied to each test coupon.
9. Each coupon was then subjected to a standard tin-lead reflow profile in a nitrogen inert atmosphere, followed by cleaning in a standard in-line aqueous water wash process (Coralville Common Process Center), to remove all flux residues. The in-line blowers of the wash process dried all test coupons. An example of a processed solder spread coupon is shown in Figure 41.
10. Each coupon was again weighed to the nearest milligram and the weight recorded as final mass.
11. Using a digital caliper, the thickness of the coupon was measured in an area free of solder to determine the base thickness, and again over the maximum solder thickness. The difference represented the solder height (H).
12. The mass of the remaining solder (M) was determined by subtracting the final mass from the conditioned mass.
13. The diameter (D) of the reflowed solder was determined by this formula:
    $D = 1.24 \times (M/8.42)^{\wedge 0.333}$
14. The spread factor (SF) was determined by this formula:
    $SF = ((D-H)/D) \times 100$

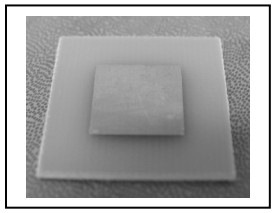


Figure 40: Solder Spread Coupon

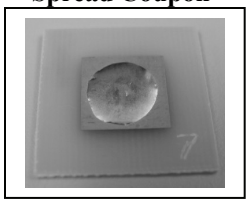


Figure 41: Solder Spread Sample

Test Results – Solderability Study

1. The results of the solder spread tests are shown in Tables 7 through 10. The values in the table represent the calculated spread factor for each test group.

Table 7. Solder Spread Factors – HASL Finish

Material	Uncleaned	Cleaned	Combined
Purell	95.8	94.7	95.3
Sam's Club	95.4	94.8	95.1
Germ-X Gnarly Green	95.6	94.9	95.2
Jergens Ultra Healing	96.0	94.9	95.5
Midnight Pomegranate	95.8	95.3	95.5
Chemtronics Lotion	95.9	95.6	95.7
Unprocessed Control	95.5		

Table 8. Solder Spread Factors – ENIG Finish

Material	Uncleaned	Cleaned	Combined
Purell	94.5	94.3	94.4
Sam's Club	94.2	94.5	94.4
Germ-X Gnarly Green	94.5	94.5	94.5
Jergens Ultra Healing	94.4	94.2	94.3
Midnight Pomegranate	94.7	94.4	94.5
Chemtronics Lotion	94.6	94.1	94.3
Unprocessed Control	94.9		

Table 9. Solder Spread Factors – Copper OSP Finish

Material	Uncleaned	Cleaned	Combined
Purell	95.4	95.7	95.6
Sam's Club	94.3	95.8	95.0
Germ-X Gnarly Green	94.5	95.7	95.1
Jergens Ultra Healing	95.7	95.7	95.7
Midnight Pomegranate	95.5	95.6	95.6
Chemtronics Lotion	95.4	95.6	95.5
Unprocessed Control	95.8		

Table 10. Solder Spread Factors – ImAg Finish

Material	Uncleaned	Cleaned	Combined
Purell	93.8	93.8	93.8
Sam's Club	93.5	93.6	93.6
Germ-X Gnarly Green	93.9	94.0	94.0
Jergens Ultra Healing	93.8	93.8	93.8
Midnight Pomegranate	93.1	92.9	93.0
Chemtronics Lotion	94.1	93.3	93.7
Unprocessed Control	94.1		

Conclusions – Solderability Study

Rockwell Collins internal specifications, based on References [1] – [3], required an 85% minimum solder spread factor. Reference [1] relates a measurement of contact wetting angle of reflowed solder paste for various surface finishes. Wetting angle is equal to 1 minus the solder spread factor (1-SF). Reference [1] gives a scale for determination of the acceptability of the wetting angle and is shown in Table 11.

Table 11. Contact Wetting Angle Criteria

$0° < \theta < 10°$	Perfect
$10° < \theta < 20°$	Excellent
$20° < \theta < 30°$	Very Good
$30° < \theta < 40°$	Good
$40° < \theta < 55°$	Adequate
$55° < \theta < 70°$	Poor to Fair
$70° < \theta$	Very Poor

Using the criteria of Table 11, we see that all of the solder spread factors, converted to contact wetting angle, fit in the "Perfect" category. Consequently, we conclude that the sanitizer and lotion residues do not adversely impact solderability.

Study Conclusions

Chemical Study

1. All of the sanitizer materials, with the exception of the X3 material, had a dominant alcohol signature. The X3 material showed the presence of the water carrier solvent. All of the sanitizer materials show similar non-alcohol constituents, which are the remainder residues after the alcohol evaporation.
2. The three lotions all had dominant peaks in the 300-360 nanometer range, indicative of the water in the lotions. The Midnight Pomegranate had two peaks in the 100-140 nanometer range, which would be the presence of the heavier oils and fragrances of that lotion. The Jergens lotions, which had a milder fragrance, had a noticeable peak in the 100-120 nanometer range, also traced to the fragrance material. The Chemtronics lotion, with no added fragrance, had no significant response in this same range.

Residue Transfer Study

3. The FTIR scans showed that in all cases, there was some organic material transferred to the ceramic plates. It should be stressed that this FTIR technique is qualitative, not quantitative, so we can conclude that some material was transferred, but not how much.
4. The ion chromatography data shows that the amounts of ionic residues, primarily chloride, are relatively low and do not represent a contamination risk. Considering the variable nature of the handling of the ceramic plates, the amount of variation between the different candidate materials was expected. The differences between the lotions and sanitizers, and that of bare hands alone are not considered to be significant.
5. The overall conclusion was that some amount of the sanitizer and lotion residues transfers to the substrate, but the nature of the residue was not quantifiable with the methods used, but was not ionic in nature.

Dielectric Withstanding Voltage

6. The average values, relative to the unprocessed control, was slightly lower for all of the treated patterns. It is apparent that some small amount of material was transferred to the test patterns, however, all of the test patterns maintained values above 1100 volts for a 20 mil (0.020 inch) space pattern.
7. Consequently, the decrease is not considered as significant.
8. If this test were to be run again, we would include handling with untreated hands to determine what the effect of handling would be from normal skin salts and oils.

Surface Insulation Resistance

9. Sanitizer and lotion residues do have an effect on SIR in the uncleaned condition, though the impact will depend on the chemical nature of the residue and the amount of residue left on the assembly surface.
10. The performance of the cleaned samples shows that the standard Rockwell Collins aqueous cleaning process adequately removes the sanitizer and lotion residues to acceptable levels, even though some of the sanitizer and lotion residues have an impact even after cleaning and conformal coating.
11. None of the test samples showed any corrosion or electrochemical migration (dendritic growth). This indicates that the residues were not ionic in nature and the effects were due to the attraction of water vapor by the hydrophilic nature of the residues.

Adhesion Study

12. With one exception, all of the adhesion failures occurred on the interface that had been handled with treated hands. This indicates that the candidate materials had some effect on adhesion.
13. The data for the cyanoacrylate Tak Pak and Araldite 2040 urethane materials showed no decrease in adhesion strength compared to control samples. The conclusion is that the candidate residues do not significantly impact the adhesion of these two adhesives.
14. There was a high degree of variability in the data for the moisture cure RTV, which was very difficult to cure consistently for the parameters used in this study. The accelerating effect of high humidity resulted in excessive bubbles in the adhesives, degrading lap shear strength. The incomplete curing found in first study rendered that data questionable. While the overall data suggests that there was not a significant decrease in lap shear strength for the Dow Corning 3145 RTV silicone, we do not place a great deal of confidence in this conclusion.
15. The data for the silicone Dow Corning SE-1700 adhesive showed no significant decrease in lap shear strength for the residues studied, with the exception of the Purell sanitizer residues. This two-part, thermally-cured adhesive can have the cure mechanism poisoned by a number of residues. It is equally possible that the difference was due to experimental error as this test condition was the first material run in the study.
16. This portion of the study should be re-run before firm conclusions are reached.

Solderability Study

17. None of the sanitizer or lotion residues had any adverse impacts on solderability.

Recommendations

1. The best method for cleaning hands is with soap and hot water, which removes residues from the hands. Hand sanitizer solutions, which do not remove residues, should not be considered as a replacement for washing hands with soap and water.
2. It is recommended that the hand sanitizers remain in rest room areas for the following reasons:
    a. It is a general best industry practice to keep non-essential liquids (e.g. drinks) out of a manufacturing area due to the potential for contamination.
    b. If kept to the rest rooms, there is additional time for any volatile materials to evaporate, minimizing any potential transfer of residues to the assemblies.
    c. Most of the sanitizer materials were contained inside plastic containers, which may represent an ESD hazard.
3. In the event that hand sanitizers are placed in assembly areas, the following actions should be taken:
    a. The plastic containers should be considered as an ESD hazard and must be kept a minimum of 12” away from any ESD sensitive assembly, per ESD Association guidelines. Alternatively, the plastic containers can be treated with an approved staticide chemical.
    b. When (not if) the sanitizer material is spilled onto electronic assemblies, they should be run through a suitable (aqueous) wash process as soon as practical. This would remove the majority of residue material and reduce the risk of failures.
    c. The message given to floor personnel should consistently be that hand sanitizing is not an acceptable alternative to washing hands with soap and water.
    d. To clean up sanitizer spilled on work surfaces, wipe up the excess with paper towels and dispose of as flammable waste. Clean the area with alcohol and allow to dry.
4. The data does show some minor degradation due to residues from the heavier hand lotions, primarily with respect to the impact on adhesion of applied adhesives. It is recommended that operators wear gloves during the application of adhesives, both to limit contact with the adhesive and to limit transfer of lotion/sanitizer residues to the assembly surface.
5. Consequently, it is not recommended that any sort of “ban” on hand lotions be pursued, nor should the use be encouraged either. Operators should be counseled that hand lotion residues can transfer to assembly surfaces and the use of such lotions should be minimized while at work.

References

[1] A. Mayhew and G. Wicks, “Solderability and Contact Angle”, INTERNEPCON UK Proceedings, Brighton, 1971, pages 45-55

[2] W. Johnson, et al, “Thermosonic Gold Wire Bonding to Palladium Finishes on Laminate Substrates”, International Conference on Multichip Modules and High Density Packaging Proceedings, 1998, pages 291-299

[3] D. Hillman, et al, “Wirebondability and Solderability of Various Metallic Surface Finishes For Use In Printed Circuit Assembly”, SMI Proceedings, 1996, pages 687-701