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REWORK METHOD FOR CONFORMAL COATING

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TIIVISTELMÄ

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Tutkimus toteutettiin ABB Distribution Solutions -yksikköön. Suojareletuotantoon on tullut moduulikortteja, joihin on lisätty lakan tapainen, yhtenäinen suojapinnoite estämään ei-toivottuja hälytyksiä ja laukauksia sähköasemilla. Opinnäytetyössä tutkitaan lakattujen korttien korjaus- ja testausmahdollisuutta. Tarkoituksena on löytää paras mahdollinen työmenetelmä, jolla voidaan poistaa lakka kortilta, jotta kortit voidaan uudelleen testata. Selvitetään myös, onko rikkinäisiä kortteja mahdollista korjata ja kuinka uudelleen lakkaus onnistuu.

Tutkimuksessa käytettiin apuna muutamia eri IPC standardeja suojalakoista ja piirikorttien korjauksesta, sekä niiden pohjalta tehtyä käsikirjaa, myös lakka toimittajien omia artikkeleita lakkojen käyttämisestä ja niiden eri ominaisuuksista tutkittiin. Tutkittiin tarkasti myös läpi toimittajien ehdottamat tyylit lakan poistamiseen. Käytännön osuus lakan poistosta painottuu pitkälti tarvittavien testi pisteiden löytämiseen, sekä itse lakan poistamiseen korteilta. Komponenttien vaihtamiseen käytettiin apuna IPC -standardien ohjeistuksia, sekä tuotannon laatutiimin kokemuksia komponenttien vaihtamisesta.

Tutkimuksessa saatiin selville paras mahdollinen lakan poisto menetelmä, käytettyistä lakan poisto menetelmistä, sekä arvio lakan poistamiseen kuluva ajasta. Työn aikana havaittiin myös lakan poiston vaikeudet ja työturvallisuuden tärkeys. Komponenttien vaihtamiseen sujui odotettua paremmin ja lakka komponenttien jaloissa irtosi helpommin kuin kortista itsestään. Mahdollisia kehitys kohteita lakan poisto menetelmiin löydettiin. Tutkimuksessa myös todettiin mahdollisuudet laajentaa lakattujen korttien korjausmenetelmää, myös muihin Relion -perheen tuotteisiin.

ABSTRACT

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The research was implemented for the ABB Distribution Solutions -division. The protection relay production has received a module of cards with the addition of a varnish-like, protective conformal coating layer to prevent unwanted alarms and trips at substations. The thesis investigates the possibility of repairing and testing the conformal-coated cards. The aim is to find the best possible working method to remove the conformal coating from the card so that the cards can be retested. It will also be investigated whether broken cards can be repaired and how recoating is successful.

The study was aided by a few different IPC standards for the conformal coating and circuit board repairs, as well as a manual based on them, including conformal coating suppliers' own articles on the use of conformal coating and their various properties. The methods proposed by the suppliers for removing the conformal coating were also carefully examined. The practical part of removing the conformal coating is largely focused on finding the necessary test points, as well as removing the conformal coating itself from the cards. The guidelines of the IPC standards were used to replace the components, as well as the experiences of the production quality team in replacing the components.

The best possible conformal coating removal method among the conformal coating removal methods used was found in the research, as well as an estimate of the time taken to remove the conformal coating. Difficulties in removing the conformal coating and the importance of occupational safety were also observed during the work. The replacement of the components went better than expected and the conformal coating on the feet of the components came off more easily than on the card itself. Potential developments for conformal coating removal methods were found, as well. The study also identified opportunities to extend the varnished card repair method to other products in the Relion family.

Keywords	Conformal coating, printed circuit board, rework method and removal method
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LIST OF ABBREVIATIONS

PCB – Printed Circuit Board

UV – Ultraviolet

ESD – Electrostatic Discharge

CAD – Computer-Aided Design

IEC - International Electrotechnical Commission

ANSI - American National Standards Institute

PCBA - Printed Circuit Board Assembly

PUA - Polyurethane Acrylate

1 INTRODUCTION

The purpose of this thesis was to become familiar with the conformal coating of circuit boards in relay production and to develop an existing card repair process for these conformal-coated circuit boards. The thesis was done for the ABB Oy Distribution Solutions unit and the practical part of the thesis was done on the premises of Distribution Solutions Vaasa production quality team.

The thesis begins with a discussion of why circuit boards are conformal coated and what conformal coating is on a general level in Chapter 2. The methods for choosing right conformal coating and using it are introduced in Chapter 2. There are many different suppliers for conformal coating and each of them has a slightly different way to rework the conformal coating, but all suppliers follow the IPC-7711/7721 standard and this is covered in more detail in the theoretical part, which are introduced in Chapter 3.

After getting to know the ways to rework conformal coating, the thesis moves to the removal of the conformal coating from the circuit boards. It is explained in more detail why removing the conformal coating from the circuit board is important and what are the ways are to do it. Then the areas where it is necessary to remove the conformal coating and why are explained in more detail. Finally, the risks involved and the removal of conformal coating in practice are look at in Chapter 3.

The testing of conformal-coated circuit boards is introduced in Chapter 4, this was used to determine the condition of the cards and any erroneous test point findings. The possibilities of replacing any defective components are investigated in Chapter 5 and the recoating method for the reworked conformal coating circuit boards is introduce in Chapter 6, as well the risks involved. In Chapter 7 the recoated cards are put in the climate test cabinet, where the durability of the recoating is examined.

2 GENERAL ABOUT CONFORMAL COATING

Conformal coating is a polymer film or protective coating, which is thinly applied to a printed circuit board (PCB) to protect the board and its components from corrosion and environment. The coating is a breathable protective layer, allowing trapped moisture to escape from electronic boards while keeping protection from environmental contaminants. Typically, the coating is applied at 12 μm to 250 μm and conforms to the shape of the PCB and its components, protecting and covering the leads of electronic components, soldering joints, exposed traces, and other metallized areas from corrosion, eventually improving components durability on the PCB. The standards for conformal coating are MIL-I-46058C, IPC-CC-830 and IPC A610. These standards list good and bad coverage and describe various failure mechanisms for conformal coating. /1-3, 6/

A recently manufactured PCB will usually perform well, but the performance may deteriorate rapidly due to external factors in its operating environment. Conformal coating can be utilized in a variety of environments to protect PCBs from chemicals, temperature extremes, salt spray and moisture to prevent unwanted things such as electrical failures, mold growth and corrosion on a PCB. The protection provided by conformal coating, offers the possibility for higher voltage gradients and closer track spacing, which enables designers to meet the requirements of miniaturization and reliability better. It also protects the PCB's components from arcing, shorts, static discharges, and thermal shocks. The idea for electronics to be conformal coated was initially proposed and developed through research to meet the challenging requirements of military decades earlier. /1-3, 6/

The use of conformal coating on PCBs has skyrocketed and come particularly important also in automotive, marine, aerospace, lighting, industrial and rapidly expanding green energy applications. Due to the growth of electronics industry, conformal coatings are finding their way into the domestic and mobile electronics industries, providing the needed combination of reliability and high performance within a vast array of electronic devices. Because in all these industries device failures might have huge consequences, the quality of coating material application is

critical. This is speeding the processes for smooth transition to automated precision conformal coating, which needs a good analysis of the product being coated and the wanted result, the coating material used, the process selected, and financial cost over a period. /1-3, 6/

Normal lacquer raw materials are very much the same products as the paint as well. Lacquer is basically a paint that only lacks pigments and often some fillers /4/. Choosing the right coating type is very crucial because they have many different features. Conformal coatings can be divided into two liquid, organic and silicone. The primary traditional classifications are acrylic (AR), epoxy (ER), silicone (SR), urethane (UR) and Parylene (XY). Appendix 1 provides a comparison of various product types of conformal coating; this appendix is from IPC-HDBK-830A. In many of these types of conformal coating can be visual inspection with UV Light (Figure 1). /1-3, 6/

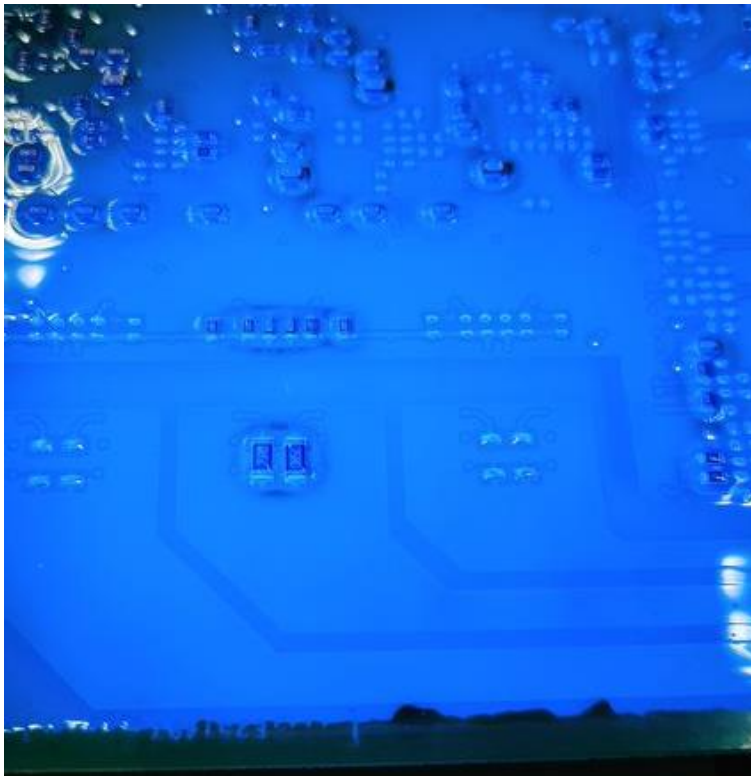


Figure 1. Visual inspection.

The second necessary thing to choose is the application of conformal coating and there are variety different methods to apply the conformal coating successfully. The

most successful and popular techniques are brushing, spraying, dipping, selective coating, and vacuum deposition coating. All these application methods have disadvantages and advantages, as well as considerations for coating dilution, layering, shadowing, and material utilization. Considering the intended method of application will help to avoid inconsistencies in reliability data between production conditions and test. /1-3, 6/

The third thing to choose is the curing method but it is not a primary criterion when choosing a conformal coating and it mostly depends on the chemistry of the conformal coating. There are four main curing mechanisms, which are evaporative cure, moisture cure, heat cure and UV cure mechanism. The evaporative cure mechanism is a very slow process and can usually be very sensitive to ambient humidity. The moisture cure mechanism is primarily used with silicone and urethane systems. In this mechanism, the materials will react with ambient moisture to form coating for the PCB. Often this curing mechanism is coupled with evaporative cure and the curing process can also be accelerated by a mild elevation of temperature and humidity. Heat cure mechanisms are often used as a secondary cure mechanism in all other curing method, but it can be used as a main cure mechanism. However, thermal sensitivity of PCB and components must be taken into attention when curing with heat. The UV cure mechanism offers very fast production throughputs. This cure mechanism is line-of-site, so it needs secondary curing mechanism to cure coating under components and shadow areas. /1-3, 6/

3 REMOVAL OF CONFORMAL COATING

On occasion, it is necessary to remove or rework a conformal coating on the PCB. There are many different suppliers for conformal coating and all of them are using the principle of IPC-7711/7721 to remove and rework the conformal coating on the PCB. The supplier who Distribution Solutions has chosen to supply the conformal coating to the PCBs, has given some guidelines for removal and rework of the used UV cure conformal coating. The rework or removal of unwanted conformal coating from the PCB can be a relatively simple process or a very messy and difficult job. The different methods and materials used to remove conformal coatings are determined by the conformal coating resins as well as the size of the removable or the reworkable area and can impact the time required. Furthermore, all the removal and rework methods can be damaging to the PCB in any time if the wrong method is used. There are four common removal method for cured conformal coating, and they are chemical stripping, thermal removal, mechanical removal, and abrasive blasting. All the methods are explained in more detail in section 3.2. Before any of these removal or rework methods are used, it is necessary to identify the conformal coating that is in use. This can be done by identifying method found on IPC-HDBK-830A, Figure 2 and Table 1 show a few of the overall characteristics of conformal coatings that can help in the identification of the conformal coating type. Table 2 shows suggestions for rework methods for different conformal coating types. /6/.

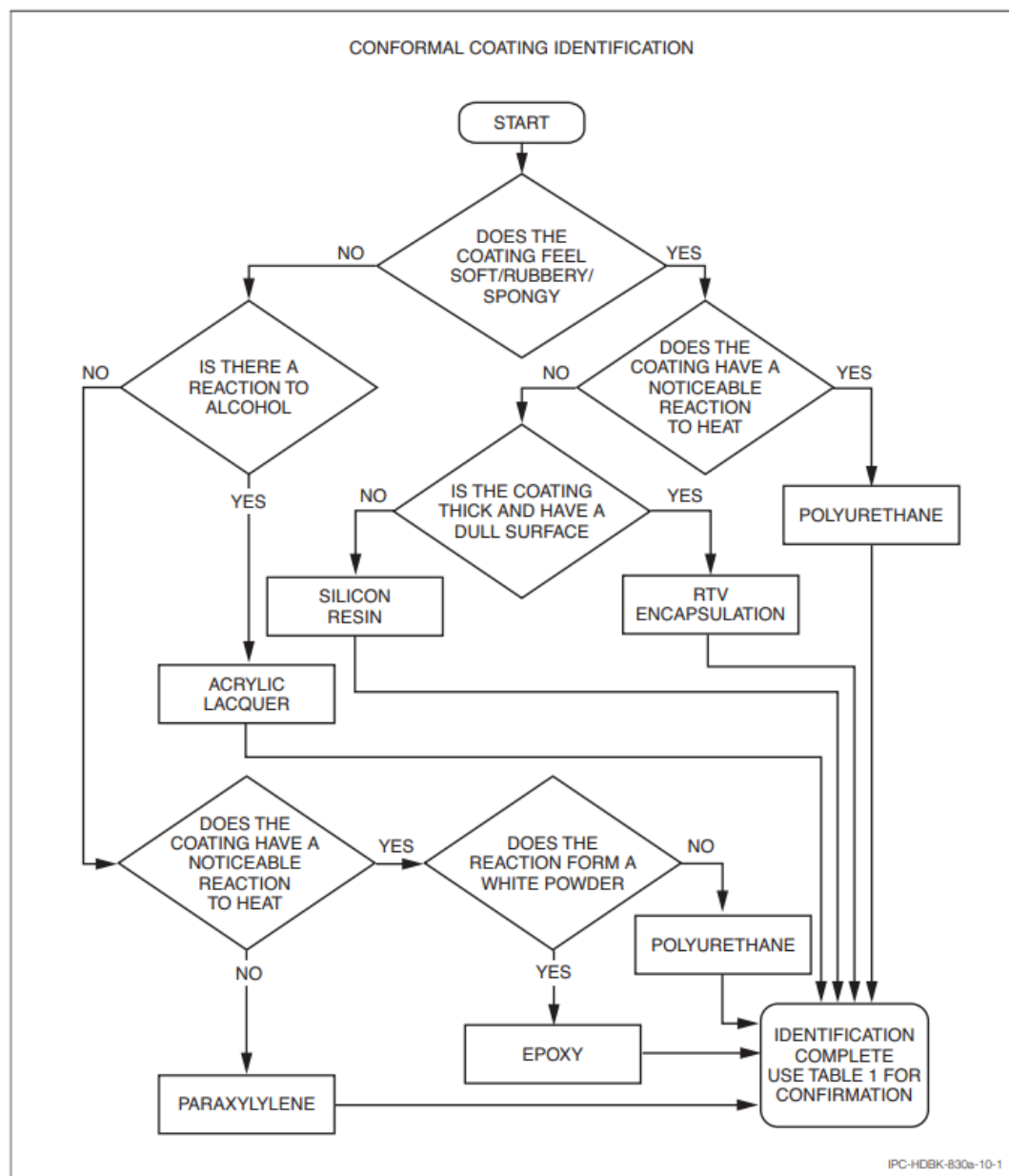


Figure 2. Conformal Coating Identification.

Table 1. Conformal Coating Characteristics.

Characteristics	Conformal Coating Types				
	Epoxy	Acrylic	Polyurethane	Silicone Resin	Paraxylene
Hard	✓		✓		
Medium Hard		✓	✓		
Soft			✓	✓	
Heat Reaction	✓	✓	✓		
Surface Bond – Very Strong				✓	✓
Surface Bond – Strong		✓		✓	
Surface Bond – Medium			✓	✓	
Surface Bond – Light				✓	
Solvent Reaction		✓			
Non-porous Surface	✓	✓	✓		
Glossy Surface	✓	✓	✓		
Semi-glossy Surface	✓			✓	
Dull Surface					✓
Rubbery Surface				✓	
Brittle	✓	✓			
Chips	✓	✓			
Peel and Flakes		✓	✓		✓
Stretches			✓	✓	
Scratch, Dent, Bend, Tear			✓	✓	✓

Table 2. Conformal Coating Removal Methods.

Conformal Coating	Removal Method				
	Solvent Method	Peeling Method	Thermal Method	Grinding Scraping Method	Micro Blasting Method
Paraxylene			✓	✓	✓
Epoxy			✓	✓	✓
Acrylic	✓		✓	✓	✓
Polyurethane	✓		✓	✓	✓
Silicone Thin	✓		✓	✓	✓
Silicone Thick		✓		✓	

3.1 Reasons for Removing the Coating

There are many reasons why a conformal coating may need to be removed or reworked on the PCB, but the initial thing is that something under the conformal coating is broken or the conformal coating is falsely applied. The major reasons why conformal coating needs to be removed or reworked are discussed here. Component assemblies may need to be reworked for functional and/or electrical failure. The PCB might fail after use in field or in testing phase, or it is not functioning as anticipated. The functionality of the component may have some problems because the initial design process did not allow for the addition of the conformal coating itself. The existing conformal coating can be of poor adhesion or poor quality, and/or has flux residues. The incorrect conformal coating has been applied on the first time, either at the client's or another facility, and needs to be stripped to apply the conformal coated properly.

3.2 Different Methods to Remove the Coating

After the identification of conformal coating is done, it is time to consider the removal methods. The removal of conformal coating may require the use of one or more methods and some of them are more effective than others. The easiest and simplest way to remove the conformal coating is before curing with cloths by gently scraping it away. After the conformal coating is cured, it is necessary to use more influential methods. These methods are mentioned in Chapter 3 and are now explained more precisely. Figure 3 shows a conformal coated PCB and demonstrates the area where removal is required and Figure 4 shows the PCB after the removal of the conformal coating.

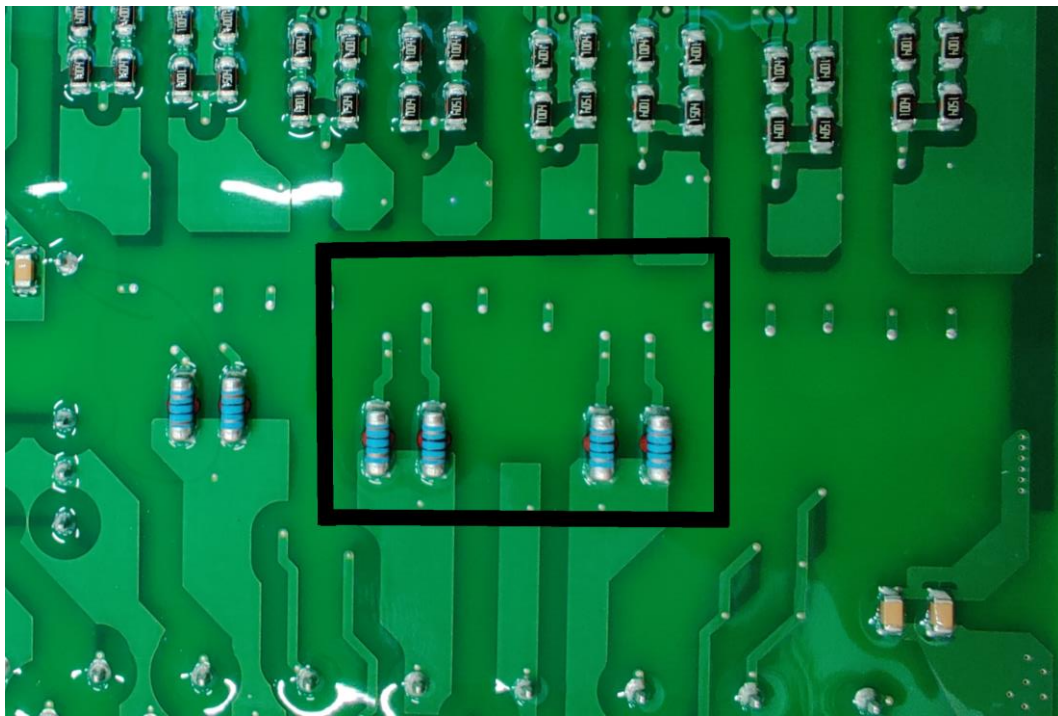


Figure 3. Conformal coating removal required at outlined area.

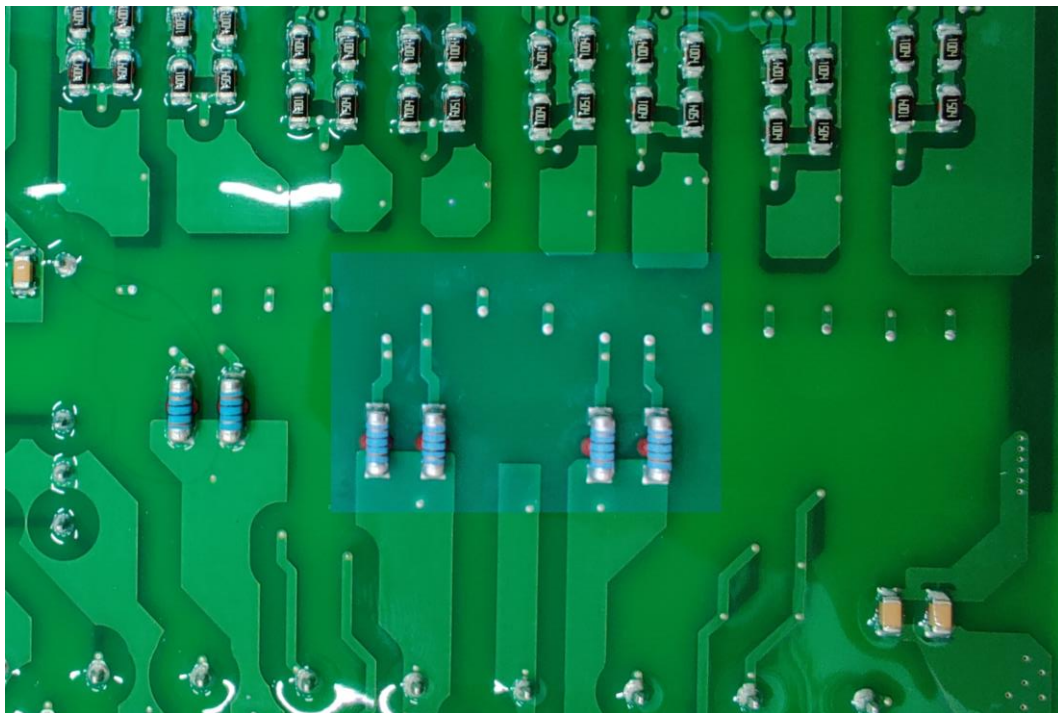


Figure 4. Removal complete.

Chemical stripping methods offer the highest possibility for complete conformal coating removal without harmfully affecting the PCB and components. Chemical

solvents are most used for removal liquid conformal coating. This also offers a low cost when only few PCB's need the removal of conformal coating. Chemical stripping can be broken down into two types of mechanisms, which are swelling or delaminating of the conformal coating and dissolving of the conformal coating. Conformal coatings that have poor chemical resistance can be dissolved by solvents and conformal coatings, which do not dissolve in solvent, need assistance with mechanical agitation to remove the blistered or soften conformal coating from the PCB. The PCB can be immersed in the chemical solvent for global stripping, or it can be applied locally by use of swabs or brushes. When the solvent is applied to the PCB, it needs a suitable period of time for the conformal coating to dissolve or soften and after that depending on the method it can be mechanically scrubbed as shown in Figure 5. /6, 11, 13/

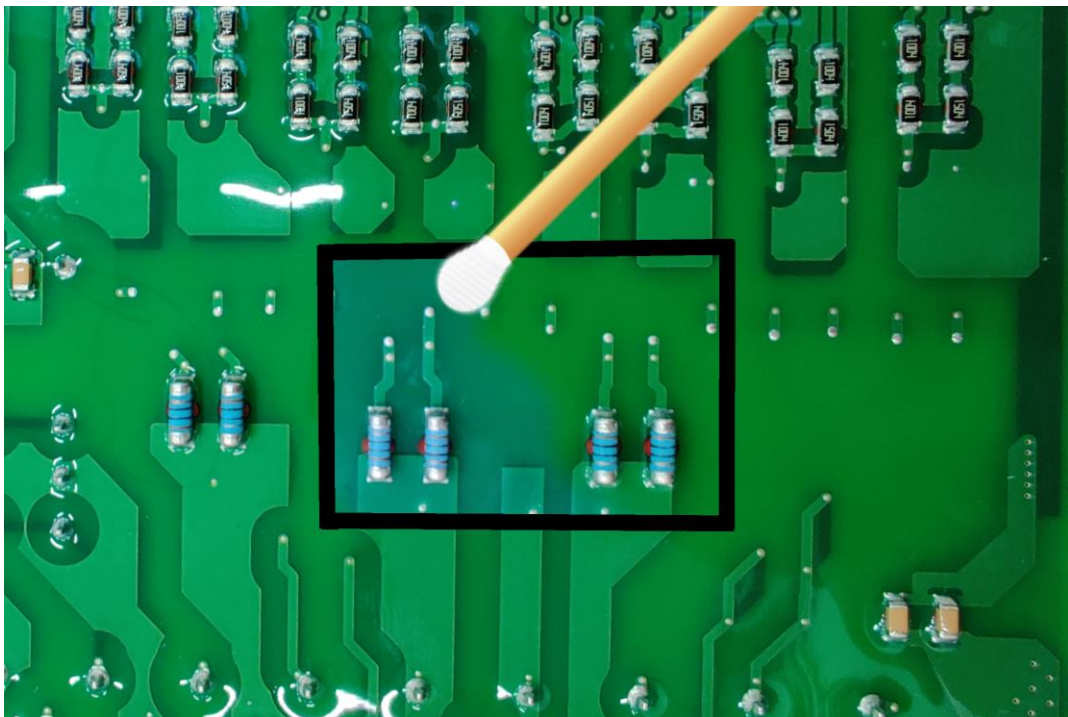


Figure 5. Chemical removal method.

Thermal removal is for some conformal coatings an accepted method and it is done by burning through the conformal coating with a hot gas rework machine or a soldering iron. This conformal coating removal method uses a controlled, localized heating, low temperature method for removing dense conformal coatings by

softening or overcuring mechanism. There are two different most often used methods for thermal removal. The first method uses various shapes, temperature-controlled tips of 300 °C to 400 °C, with dull edges to soften and remove the coating. The second method uses a localized controlled jet of hot air or inert gas to soften the coating material, which is pushed away or removed by a non-marring tool. When the heat is chosen and applied properly, these methods do not burn or char either the conformal coating or PCB, as shown in Figure 6. /6, 11, 14/

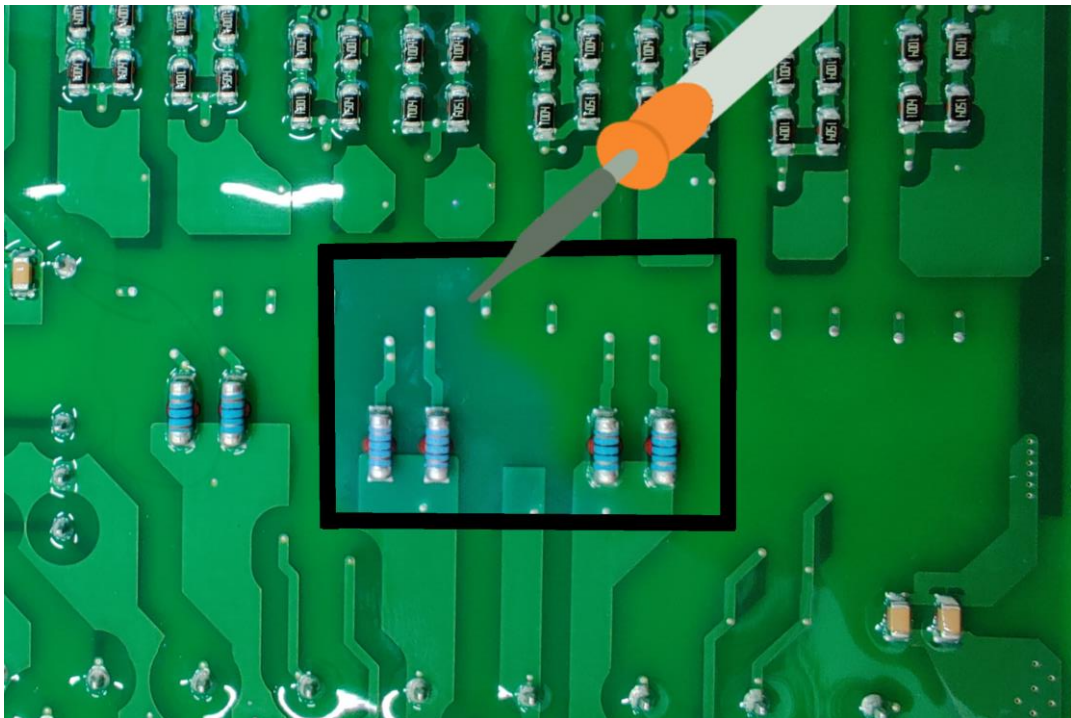


Figure 6. Thermal removal method.

Mechanical removal is done by various scraping, cutting, and grinding tools, depending on the conformal coating material. A dental style scraper or a knife is normally used when a scraping method is desired, as in Figure 7. A handheld drill or other rotary tool is normally used when the grinding technique is desired. Scraping and grinding methods are most often used on rigid or hard conformal coatings and not preferred for soft materials. These methods can generate static electricity so appropriate ESD controls should be in place. These methods must also be tightly controlled because it is very easy to damage the PCB. A dull knife or other dull

blade is used to slit the silicone or other rubber-like conformal coating material and to peel it off the PCB, when mechanical peeling method is desired. /6, 11, 15, 16/

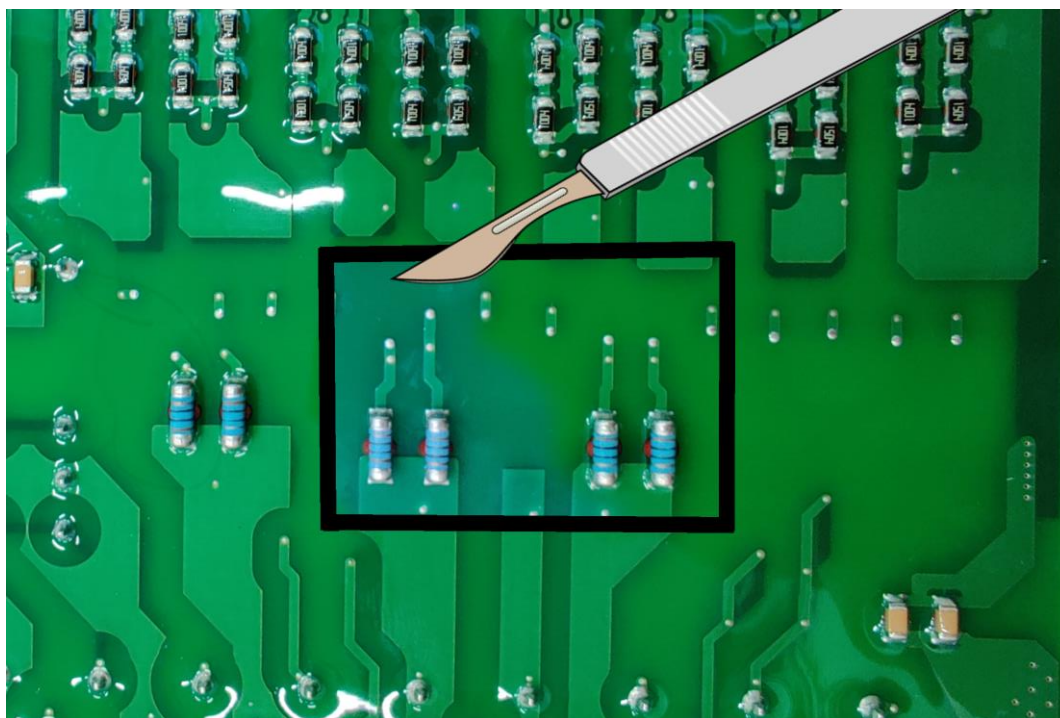


Figure 7. Mechanical removal method.

The principle in abrasive blasting is based on projecting a small particle onto the conformal coating surface with enough force to mechanically abrade the surface and eventually remove the conformal coating. This conformal coating removal method uses a micro abrasive blasting system and a very fine soft abrasive powder. The powder is propelled through a small nozzle, which is positioned around the area where the conformal coating needs to be removed. This technique requires practice in order not to damage the substrate beneath the conformal coating. Before the removal can be started, it is necessary to identify the conformal coating so the appropriate removal procedure and appropriate abrasive media can be chosen accordingly. Micro abrasive blasting will generate substantial static charges, ESD. It is recommended that the work area be flooded with ionized air, the PCB and the operator should be grounded when using micro abrasive blasting. The nozzle diameter, abrasive particles and air pressure must be matched to the area of conformal

coating to be removed and the underlying substrate to prevent damaging the PCB or components. /6, 11, 17/

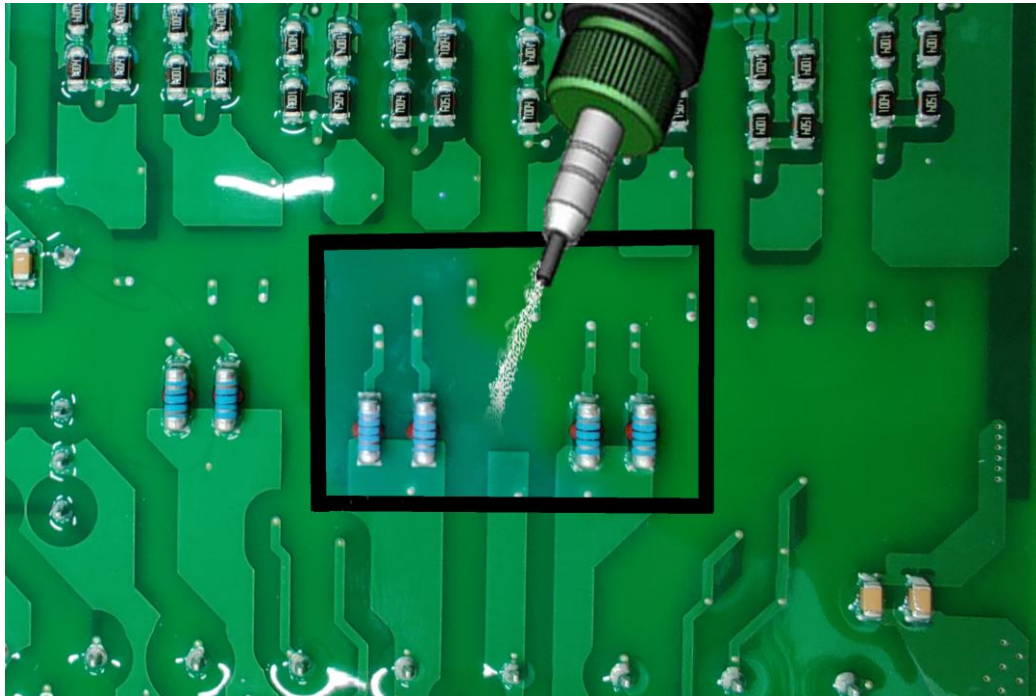


Figure 8. Abrasive removal method.

The suppliers of the conformal coating in use have given their own guidelines for removal of UV cure conformal coating. They recommend three different methods for all their UV cure conformal coatings and they are:

1. Mechanical removal: powder micro abrasion,
2. Thermal removal: burn through,
3. Chemical removal. /19, 20/

For the powder micro abrasion method, they recommend that to get the best results when removing UV cure conformal coating is to blast the coating for short periods with a high air assist because a longer exposure with lower air assist may damage the PCB. For abrasive powder material, they recommend using a carbo blast which is made from wheat starch crystals. /19, 20/

For the burn-through method, they recommend using a soldering iron with temperature of the soldering tip of at least 450 °C. Placing the tip to the rework area will

only melt the conformal coating into white solid powder rather than actually burn it and this makes it easy to remove from the substrate. The recommendation for the best result is to solder through the conformal coating for a short period of time with a high tip temperature and increasing the temperature by 20 °C if the conformal coating thickness is greater than 300 microns. /19, 20/

For a chemical removal method, they recommend using their own selection of stripping chemistry after UV cure, before a secondary moisture mechanism has completed. This selected stripper is not available in the EU because the strict laws. The recommendation for removals is local application or submerging the PCB in to stripping chemistry, which are done according to the instructions of IPC-7711/7722. /19, 20/

3.3 Risks Related to Coating Removal

All the methods used have their own risks for rework operators and people around them. The biggest risks come from the used conformal coating and its reaction to the rework and removal methods. Risks that come from the conformal coatings are usually listed in the safety data sheet or obtained by contacting the suppliers of the conformal coating. More of the risks of the rework are explained next method by method.

The chemical stripping method often involves solvent with strong smells and potential health hazards. Some chemical stripping solvents are identified or suspected carcinogens. Many solvents are also caustic and will attack the skin and other membranes. For chemical stripping, the ventilation of the area should be very good, preferably in methods, which exhausts vapor, such as a fume hood. Checking the safety data sheet of the stripping solvent for recommended personal protective equipment is required in any cases but is very necessary if local ventilation cannot control employee exposure to established hygienic standards. Safety glasses and chemically resistant gloves are required. Many stripping solvents are easily flammable and so safety measures should be taken to keep these materials away from point ignition sources and must be kept safe in flammable cabinets. Used stripped

conformal coating and solvents are normally disposed of as hazardous wastes and when handling these wastes, it is necessary to take protective measures. /6/

The thermal stripping method is often done by heated blades or streams of heated air, often 200 °C to 300 °C. Protection measures to avoid burning the skin must be taken when using thermal stripping method. For thermal protection, thermal gloves and safety glasses are recommended. In addition, the conformal coating might burn or pyrolyze when these high temperatures are involved. Released decomposition from thermal stripping may be respiratory hazards and irritants to eyes and can establish the exposure standard. When using thermal stripping, it is necessary to use fume extraction equipment. /6/

The mechanical removal method of conformal coating is done with bladed tools, such as scalpels or rotary mills. Cutting the skin is the main risk with bladed tools. Kevlar gloves and fixtures to hold the assembly are recommended. With rotary devices, the main risks are airborne particles and inhalation of such particulate matter. Dust respirators and safety glasses are suggested for such measures if local ventilation is infeasible to limit the operator's exposure to airborne particles. /6/

The abrasive blasting removal method of conformal coating can be compared to sandblasting, but abrasive blasting uses more refined media. The main risk of abrasive blasting is damaging the operator's skin by the speed of the blast media particles, which can be extremely high. Avoiding contact with the stream of particles should be taken to consideration. This removal method is also a dusty form of conformal coating removal and is done in glove-box form containment. It is also necessary to avoid inhaling the blast media particles and the particles of removed conformal coating. /6/

3.4 Areas Where the Coating Should be Removed

For the ABB Relion 615 and 620 relays, there are roughly 80 different module cards and all of those have different test points for module card testers. Before even starting to find the test point, it was decided that for all the cards it is not necessary to find all the test points, just the test point that the module card testers use. This is

because module cards can have hundreds of test points and only fraction of them is used on testers to see if the module card is functioning in the right way. All test points can be found on the module cards CAD drawings, Figure 9 shows the possible test points on one of the module cards in use.

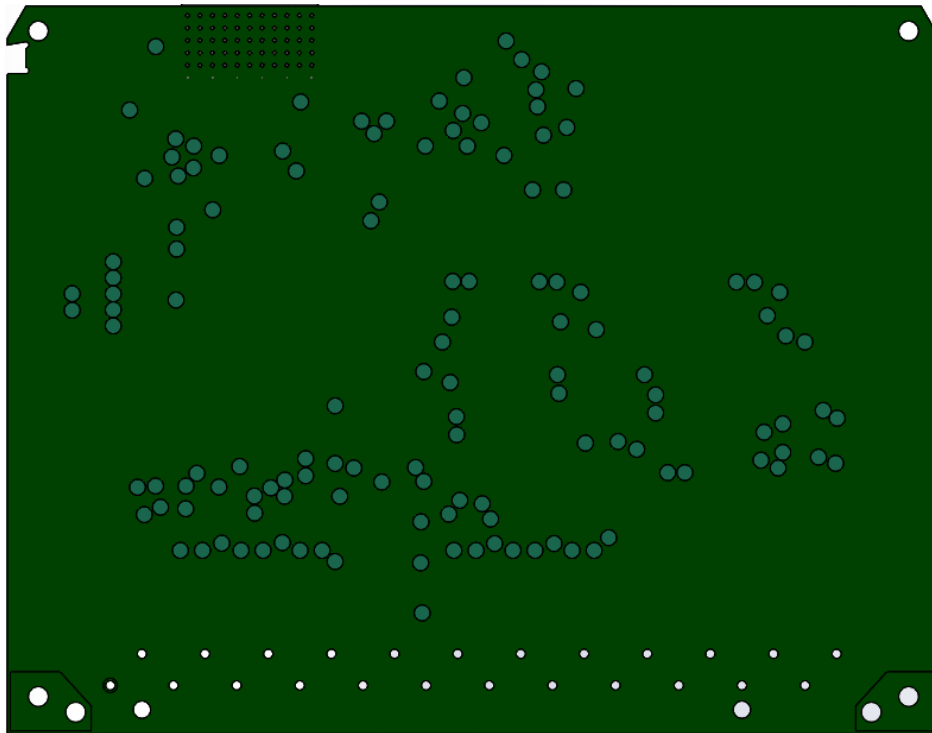


Figure 9. Module cards test points.

For Relion 615 and 620 there are roughly 15 different module testers for the cards and all of them have own test points that connect to the module cards test points. Like the module cards also the module testers have many unnecessary test points that are not needed to see module cards functionality. All test points can be found on the module testers layout drawings, Figure 10 shows the possible test points on one of the module cards in use.

First, it was necessary to check which module cards can be tested in which module tester. Secondly, the CAD drawing of the module cards was necessary to gather at least one card drawing for one module tester. The module testers layout drawings were also gathered at the same time. At this stage, the necessary test point in the module tester was also checked in the production quality teams premises where all the module testers are in the storage unit. Thirdly and lastly, it was time to check

which test point was used in the testers and where they are located in the layout drawings of the module testers and mainly where the needed test point are in the module cards. Figure 10 shows the necessary test point in the layout drawings of the module testers in the red oval and Figure 11 shows the necessary test point as blue circles.

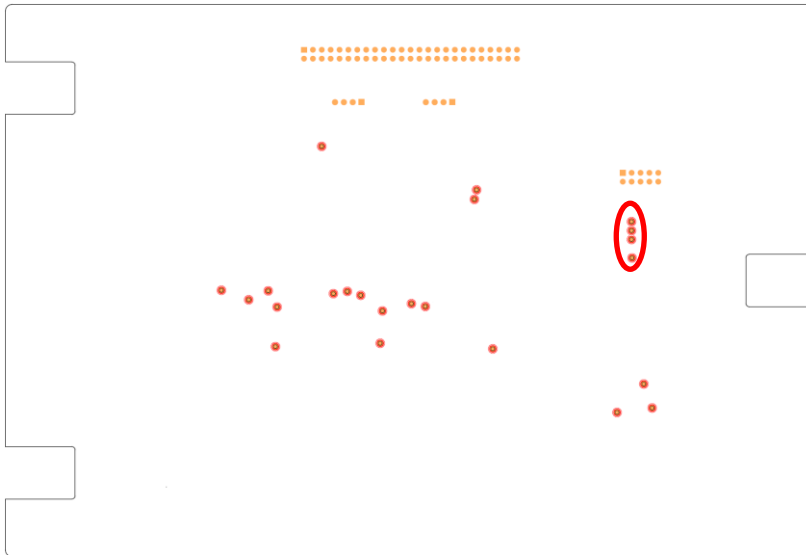


Figure 10. Module testers test points and necessary test points.

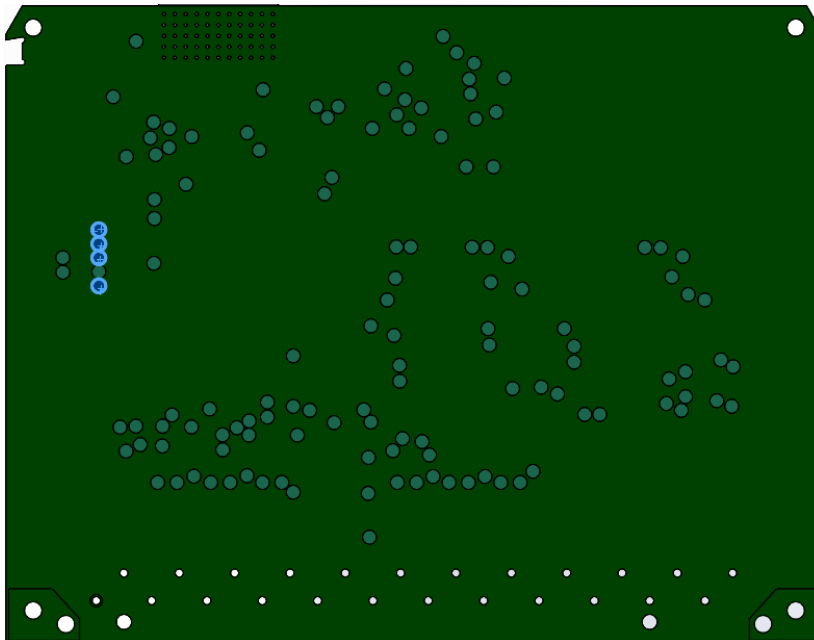


Figure 11. Module cards necessary test points.

3.5 Different Removal Methods in Practice

As stated in Chapter 3.2, in practice only the thermal and abrasive method were possible to use for conformal coating removal. The reason for choosing these two main methods was that it was not possible to get the right kind of chemicals for the chemical method, due to the EU legislation. It is not possible to use other mechanical methods because the varnish in use hardens so hard that it cannot be removed from the card without breaking it.

The different conformal coating removal methods were initially tested with as many different settings as possible in both methods. Firstly, these methods were used on the so-called solder mask area where there is nothing under the conformal coating other than the PCB itself and after this also the areas of test points were exposed to removal methods, which are normally tinned. These test points are also the main places to remove conformal coating. With the combination of these results it was intended to be found the most optional one to remove the conformal coating by cutting the bad result from the good ones. The conformal coating removal work was done at the production quality teams' premises, which had all the necessary tools and its own working space for conformal coating removal. Figure 12 show the test point in module cards PCB. Figure 13 shows the unwanted result were the cards solders mask is broken and Figure 14 shows the wanted result where just the test point is clean from the conformal coating.

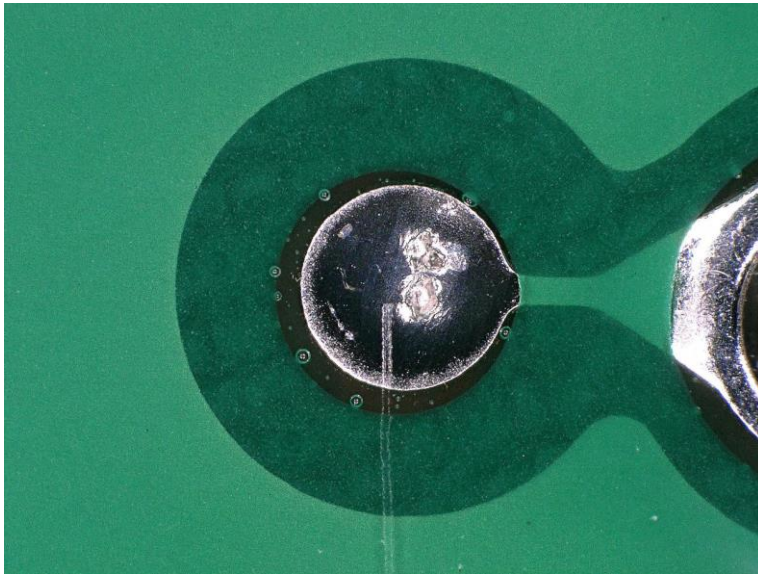


Figure 12. Test point on module cards PCB.



Figure 13. PCB's broken solder mask.



Figure 14. Test point cleaned from the conformal coating.

3.5.1 Thermal Removal Method

The thermal removal method was tested with 10 different temperature settings and two different tools, following the conformal coating supplier's instruction for heat exposure, mentioned earlier in Chapter 3.2. The thermal method was done with a Weller WXR 3 shown in Appendix 2, with soldering tool WXP 65, which had a soldering tip chisel of 2.4 mm (Figure 15) as burn through method and with hot air tool WXHAP 200 and here the conformal coating was peeled off with wooden stick (Figure 16) as hot air method. With soldering iron on burn through method the contact time on conformal coating was 10 seconds in test 1 to 9, as shown in upper part of Table 3. In test 10 it was necessary to test what the required time for the conformal coating is to melt down into powder. This was done because the first nine test settings did not show the required change in the conformal coating and the soldering irons temperature could not be set higher. With hot air method, the 10 second exposure was enough at the test settings on as shown in the lower part of Table 3.



Figure 15. Burn Through Method.

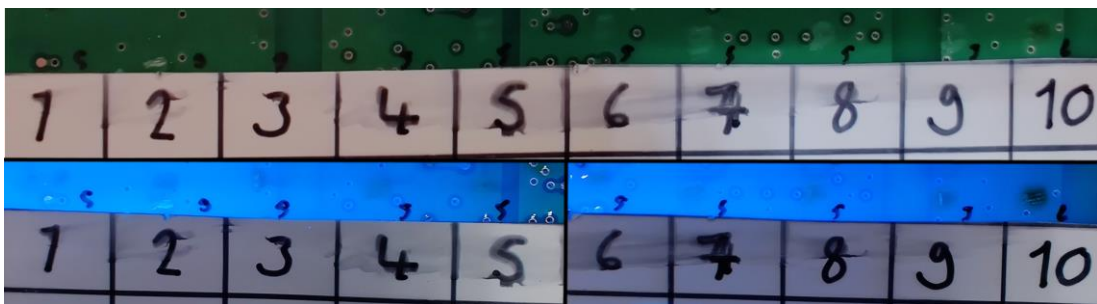


Figure 16. Hot Air Method.

Table 3. Testing temperatures used in the Thermal Removal Method.

Thermal Removal Method (Soldering)										
Test	1	2	3	4	5	6	7	8	9	10
Degree	340°C	360°C	380°C	400°C	410°C	420°C	430°C	440°C	450°C	450°C
Thermal Removal Method (Hot Air)										
Test	1	2	3	4	5	6	7	8	9	10
Degree	370°C	390°C	410°C	430°C	450°C	470°C	490°C	510°C	530°C	550°C

Initially, the burn through method was tested on the solder mask area of the PCB and with tests 1 to 9 holding the soldering iron in place for 10 seconds. After the checkup, it was necessary to do the test again and with the 10th test mentioned earlier the exposure time was evaluated to one minute. The final test results are shown in Figure 17 for burn through method without and with the UV light for better evaluation. After the solder mask area test it was time to test the burn through method to test points and there the same methods were used. The result is shown in Figure 18 without and with the UV light for better evaluation. After these results were estimated, it was clearly seen that the best results come with test method 10 where temperature of the soldering iron was 450 degree and the exposure time was one minute. When using this method, the operator must be careful because too long an exposure time can damage the PCB.

**Figure 17.** Burn through method tests on solder mask.

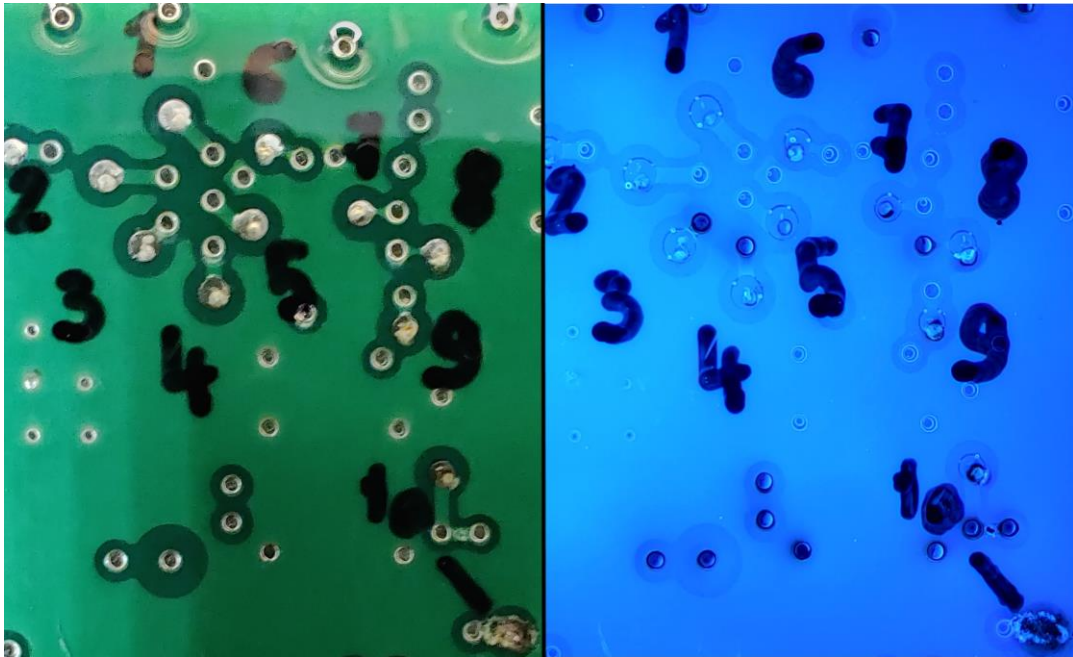


Figure 18. Burn through method tests on test points.

Next, the hot air method was tested on the solder mask area of the PCB and with tests 1 to 10 exposing the wanted area for 10 seconds. With this method, it was necessary to scrape the softened conformal coating and here it was done by wooden stick. The results of the first test are shown in Figure 19 for hot air method without and with the UV light for better evaluation. After the solder mask area test, it was time to test the hot air method to test points and there the same methods were used. The result is shown in Figure 20 without and with the UV light for better evaluation. After these results were estimated, it was seen that some good results were obtained with test method 9 but clearly the best results come with test method 10 where the hot air temperature was 550 degree and the exposure time was 10 seconds, after which the conformal coating was scraped off with wooden stick. In addition, both the burn though and hot air removal methods were tested to the thicker area of the conformal coating but there no required results were obtained.



Figure 19. Hot air method tests on solder mask.

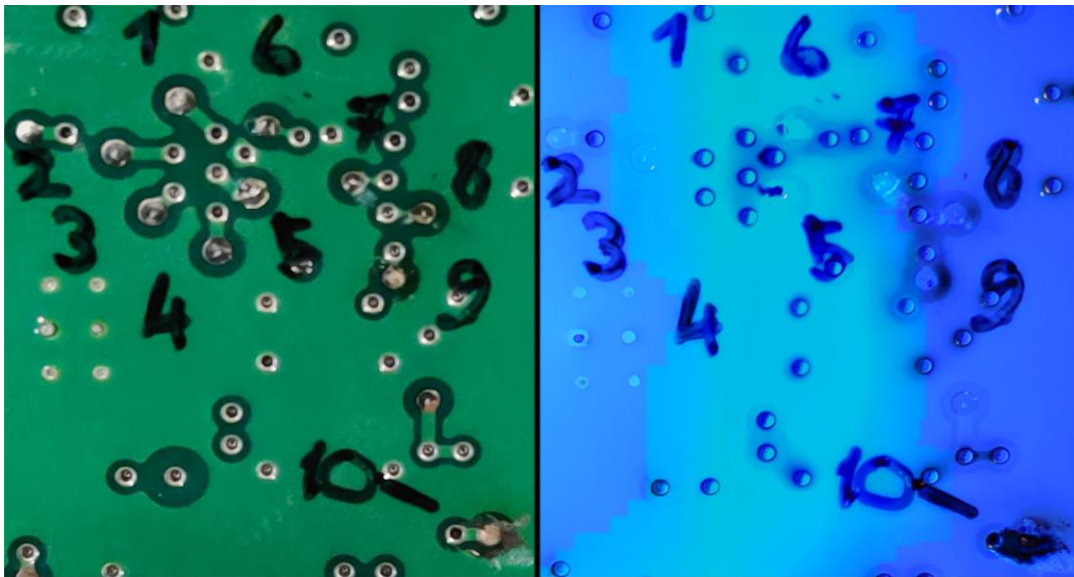


Figure 20. Hot air method tests on test points.

3.5.2 Abrasion Removal Method

The abrasion method was initially tested at 45 different settings, varying the powder flow and air pressure. The abrasion method was done with a Swam-Blast Turbo-Max work chamber (Appendix 3) and with a Swam-Blast MV-2L micro sandblaster (Appendix 4). The work chamber can be used with ordinary light as shown in Figure 21 and with UV light, which is better for working with the removal of conformal coating with UV traceability. Figure 21 also shows the sandblaster nozzle and point ionization, with effectively reduce the ESD from reaching levels that could potentially damage components during the removal process. The rework chamber also

contains several point ionizers, with helps to reduce the ESD so the system meets NASA ESD requirements /18/.

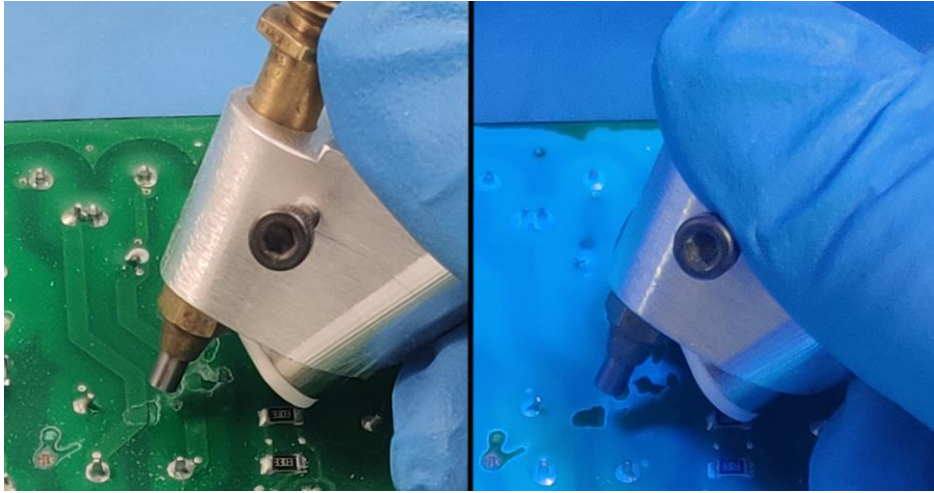


Figure 21. Abrasive method in practice.

Some ESD tests had been done for the micro sandblaster before where they tested the two ionizers and how they behave to test a plate of FMX 004 that was connected to the input ($1\text{ M}\Omega$) of oscilloscope with a passive probe of 100:1 (Figure 21). One of the test results is shown in Figure 22, where the ionizers attached to the work chamber were tested and Figure 23 where the ionizers that were on the sandblaster nozzle were tested.



Figure 22. Ion Balance test.

Bar Ionizer (approx. 15 cm from the source)

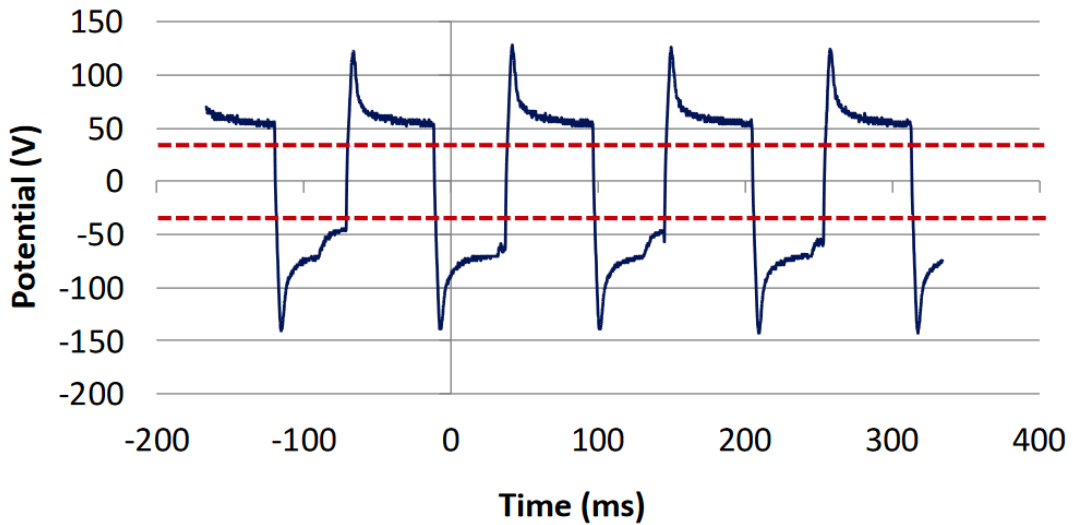


Figure 23. Test result for work chambers ionizers.

Nozzle Ionizer (approx. 1 cm from the source)

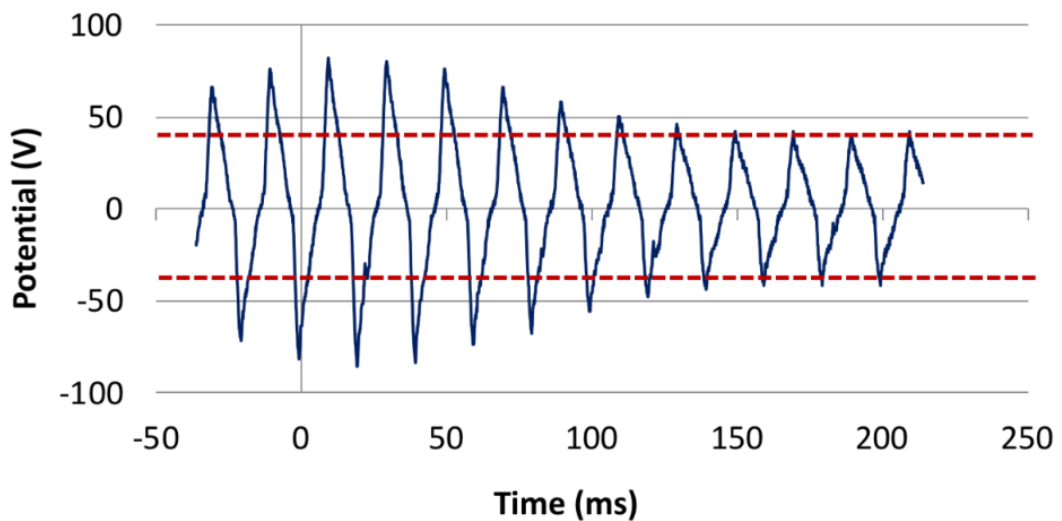


Figure 24. Test result for sandblasters nozzle ionizer.

The observation was that the peak offset voltage remained under 100 V and offset voltage requirement of IEC 61340-5-1:2016 and ANSI/ESD S20.20 are: $-35 < V_{\text{off-set}} < 35$. The decay time for 10 % drop from initial value was approximately 2s. Electrostatic potentials of $V > 100$ V were observed, and relatively high electrostatic fields of $E > 20$ kV/m were occasionally observed. A micro abrasive blasting technique has many critical variables that may increase the risk of ESD, such as gas

pressure, flow rate of the blast media, nozzle diameter, blast media itself, coating material and tracing of PCBA. In accordance with the manufacturer's instructions, ionization is mandatory for the adequate ESD control and is fast enough to minimize charge accumulation.

Initially, the abrasion method tests were started on the PCB's solder mask area according to Table 4 settings. The nozzle was approximately one centimeter away from the PCB and it was exposed to the abrasion powder approximately one second. The results of the test point tests are shown in Figure 25 and under UV light for better evaluation on Figures 26. After these tests it was time to test the abrasion method on the test points and there the same methods were used. The results of the test point tests are shown in Figure 27 and under UV light for better evaluation in Figure 28.

Table 4. Abrasive Method's test settings.

Abrasive Removal Method										
Test	1	2	3	4	5	6	7	8	9	10
Air Pressure	50 psi	60 psi	70 psi	80 psi	90 psi	50 psi	60 psi	70 psi	80 psi	90 psi
Powder Flow	1	1	1	1	1	2	2	2	2	2
Test	11	12	13	14	15	16	17	18	19	20
Air Pressure	50 psi	60 psi	70 psi	80 psi	90 psi	50 psi	60 psi	70 psi	80 psi	90 psi
Powder Flow	3	3	3	3	3	4	4	4	4	4
Test	21	22	23	24	25	26	27	28	29	30
Air Pressure	50 psi	60 psi	70 psi	80 psi	90 psi	50 psi	60 psi	70 psi	80 psi	90 psi
Powder Flow	5	5	5	5	5	6	6	6	6	6
Test	31	32	33	34	35	36	37	38	39	40
Air Pressure	50 psi	60 psi	70 psi	80 psi	90 psi	50 psi	60 psi	70 psi	80 psi	90 psi
Powder Flow	7	7	7	7	7	8	8	8	8	8
Test	41	42	43	44	45					
Air Pressure	50 psi	60 psi	70 psi	80 psi	90 psi					
Powder Flow	9	9	9	9	9					



Figure 25. Abrasive Method tests on solder mask.

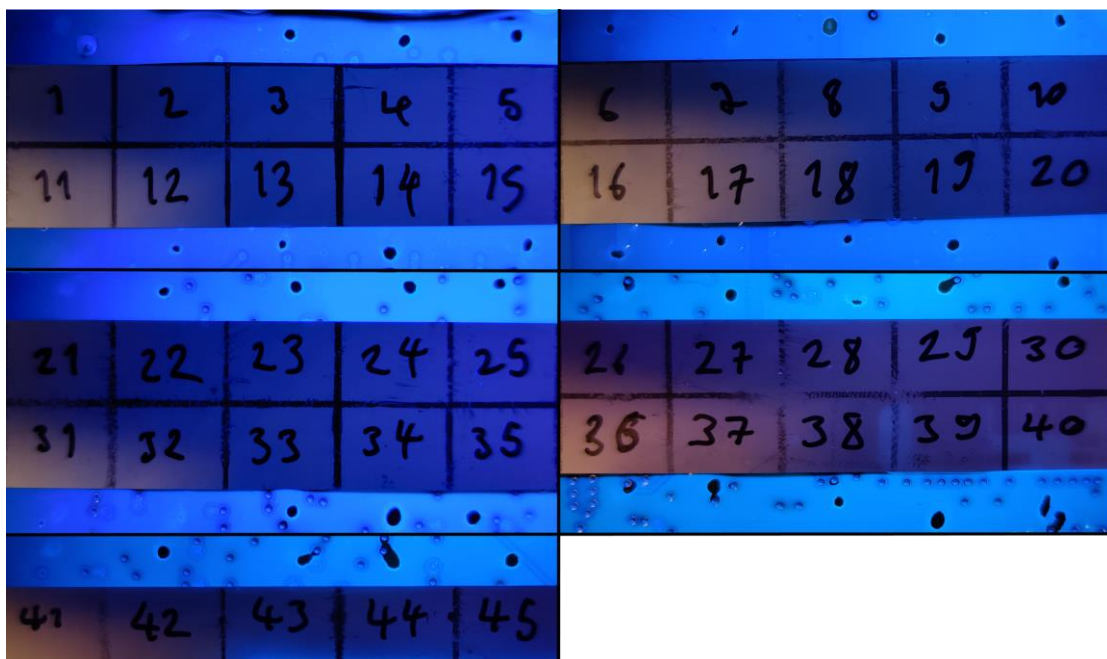


Figure 26. Abrasive Method test on solder mask under UV light.

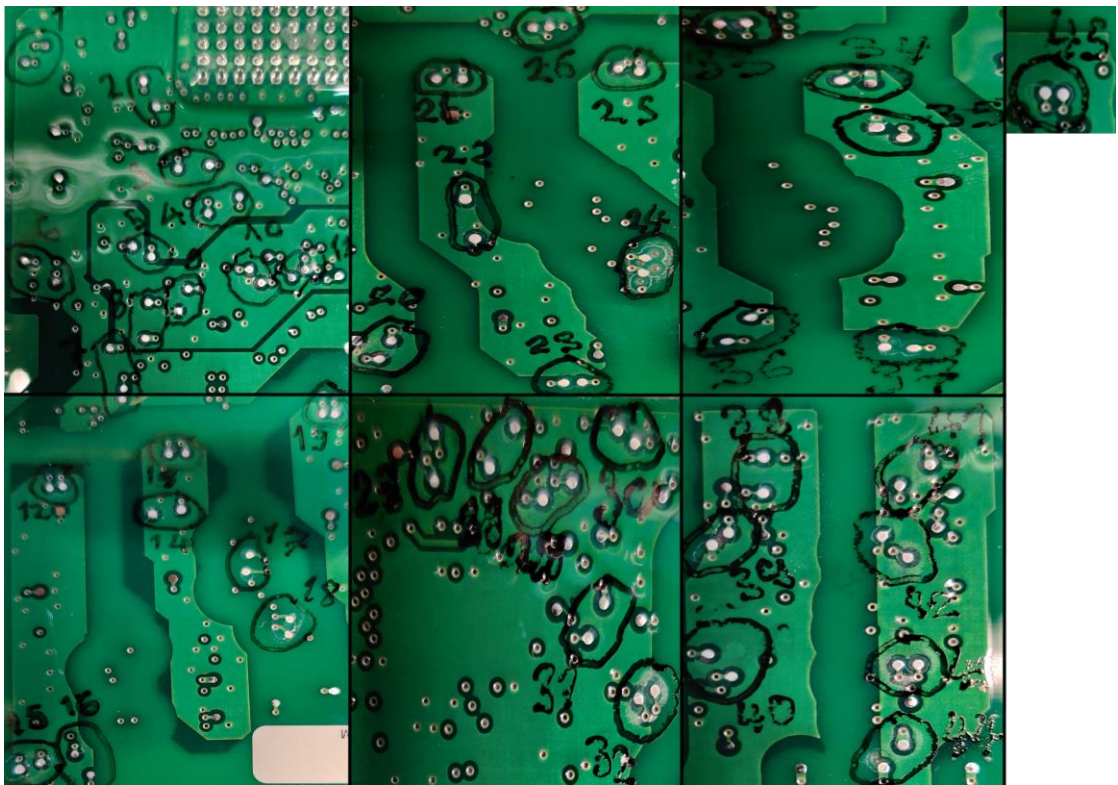


Figure 27. Abrasive Method test on test points.

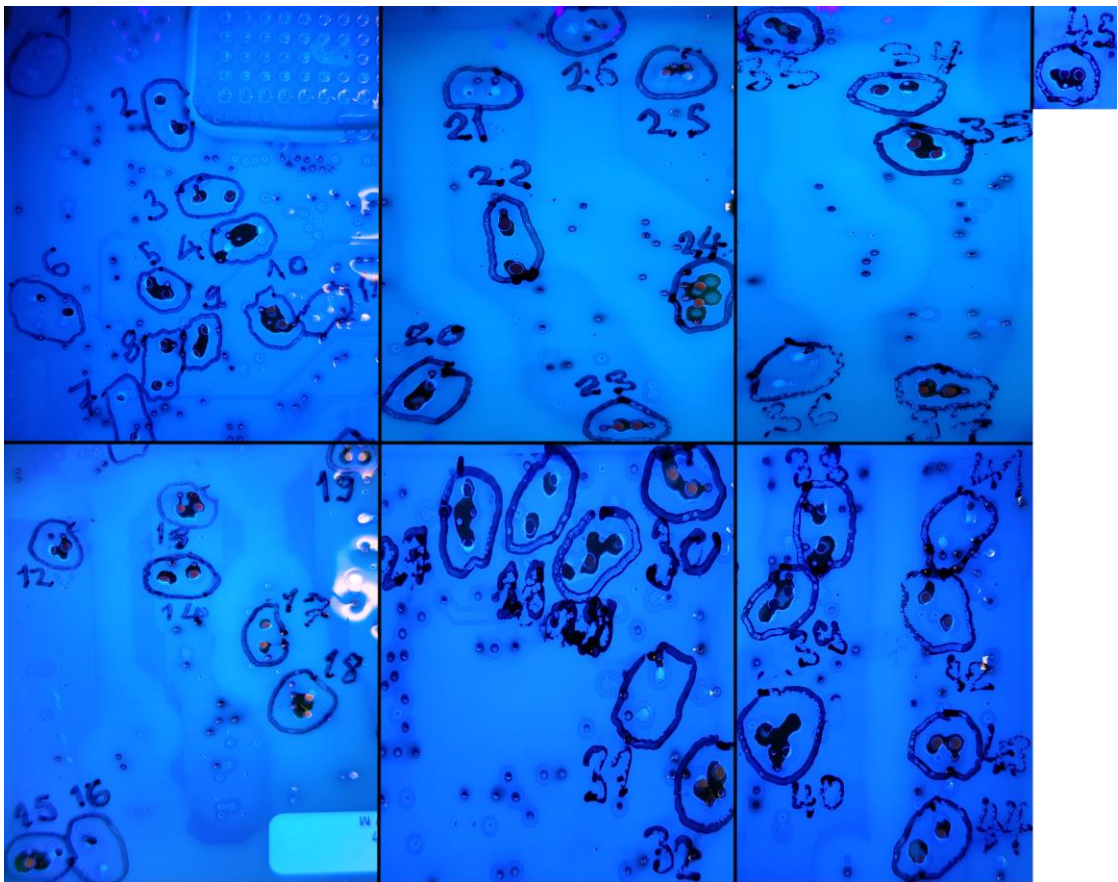


Figure 28. Abrasive Method test on test points under UV light.

When these tests were done, the traces left by the abrasion method were evaluated under a microscope because this method can break the solder mask easily. This is shown in Figure 29 so finding the optimal setting required more effort than in the thermal method. This means that from these tests the best results were chosen and tested again on a different PCB to be certain of the required result. Finally, the most optimal setting was found at test method 3 where the air pressure was 70 psi and the powder flow was set to 1. A test of its own was also done for the thicker conformal coating according to Figure 30. The biggest setting for air pressure was chosen because the penetration features of the method. For this thicker conformal coating, the best result came with setting of the air pressure setting 90 psi and the powder flow setting 1.

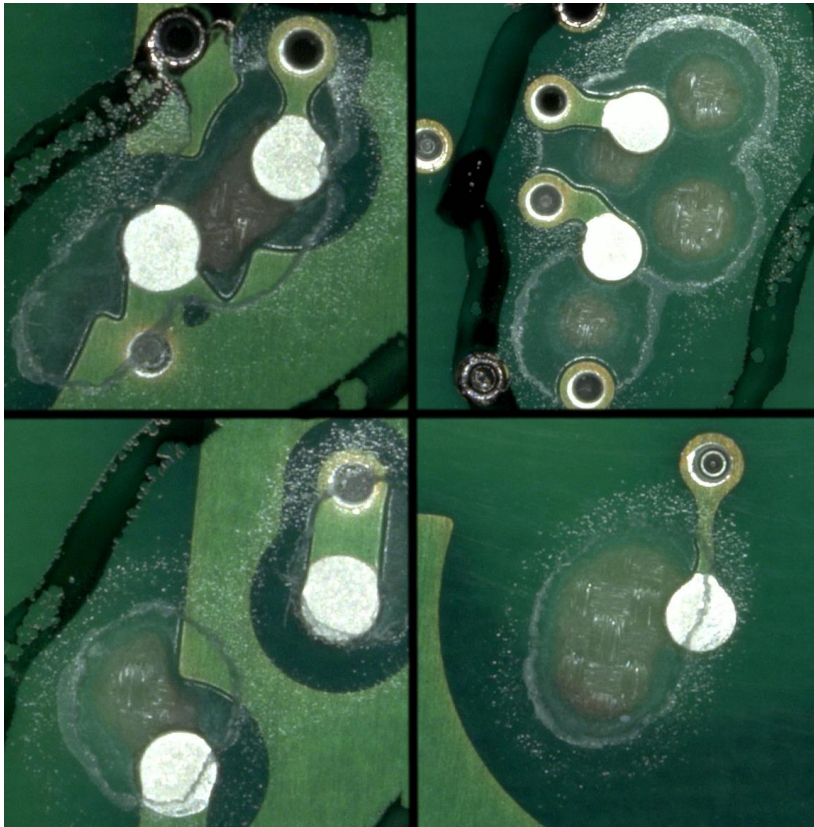


Figure 29. Broken solder mask.

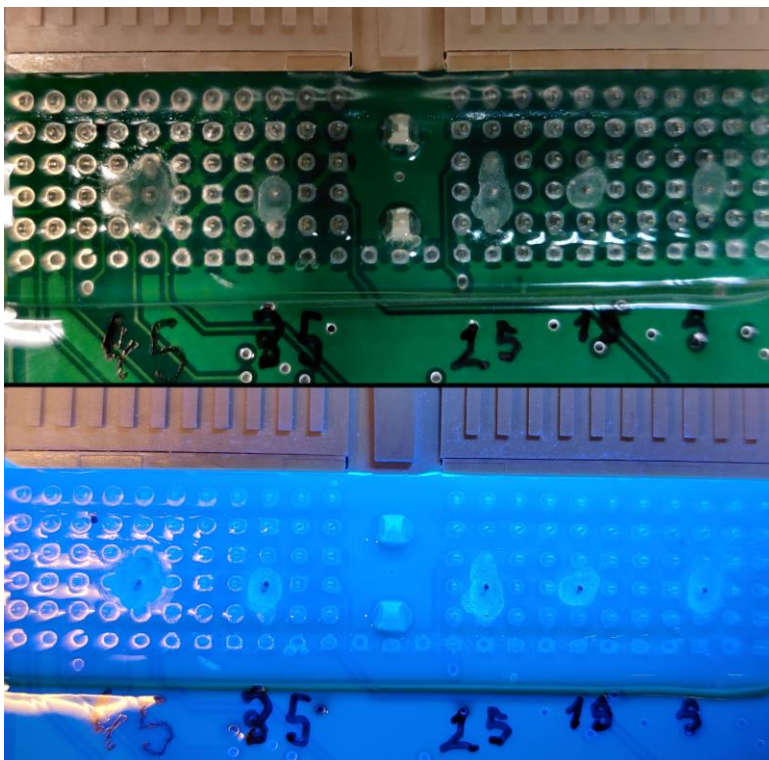


Figure 30. Abrasive Method on thick coating.

4 RETESTING OF COATED PCB

The retesting of the conformal-coated module cards was next after the optimal conformal coating removal method was found for both main methods. In the retesting, it was checked whether the conformal coating was definitely removed from the test points on the conformal-coated module cards. At the same time, it also became clear whether the test points found in section 3.4 are correct or need further research. Since in section 3.4 the test points were found for each module card in use, it was easy at this point to view and mark the test points on to the module cards for testing. The test points were marked with a black permanent marker as show in Figure 31, making them visible under UV light in the rework chamber, as well as without UV light when removing the conformal coating with a thermal method. For each test station at least two different module cards were tested, and if the card did not pass the tests, the reasons were examined, whether it failed due to a wrong test point or if the test point was not cleaned properly or whether the card was broken. After the selecting enough module cards for every module tester and marking the necessary test points for conformal coating removal, then the conformal coating was removed.

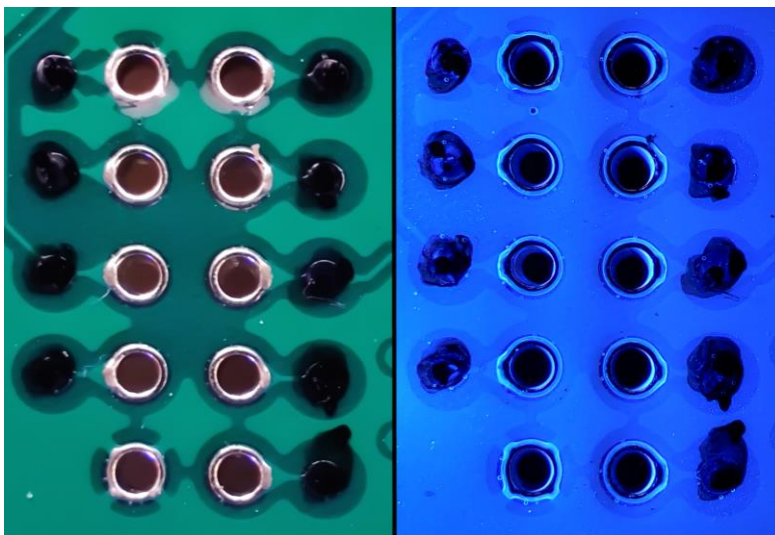


Figure 31. Marked test points.

When the conformal coating removal was done, the module cards needed a cleaning operation with isopropyl alcohol to make sure the card is clean before putting it in the test stations. After cleaning, the test point was checked to be certain that they are clean enough for the test stations test pins, which are shown in Figure 32. Then

the module card went to the test station and the barcode of the module card was read to the machine for the module card test software. When the sequence was done the software declared if the module card passed the test or if it failed on some point. For a few cards, it had to be examined in more detail why it could not pass through certain tests, when the module cards test data was reviewed and all the incorrectly found test points were found. These cards therefore had to be re-examined for invalid test points from the layout drawings, in one of them it was necessary to check the module cards test specification document and schematic document so that the right test points can be found. After the re-examination, these failed module cards passed the module test.



Figure 32. Test stations test pins.

5 REPLACING COMPONENTS ON COATED PCB

To replace components on a conformal coated PCB, a three power supply module cards were selected. These module cards were initially excavated from mechanically broken module cards, so these cards needed go through the process of conformal coating removal and testing. The conformal coating was removed by abrasive method and after cleaning the cards, they were put to the module test to be sure they are working correctly. When it was sure that the three selected module cards were working correctly, it was time to choose which the components to be removed and replaced. The purpose was to swap the same component between two power supply module cards and in the end one card would have two components swapped. These swappable was selected to be one surface mount chip component shown in Figure 33 and one through hole component shown in Figure 34.

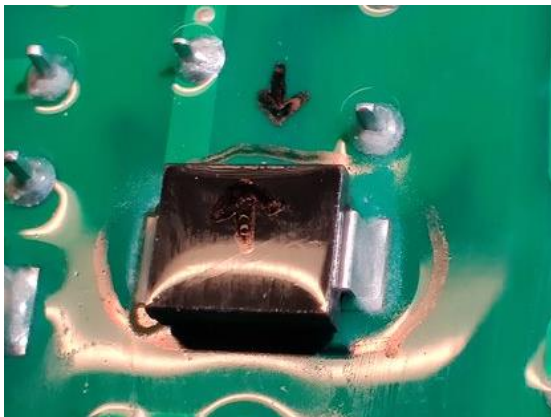


Figure 33. Surface mount chip component.

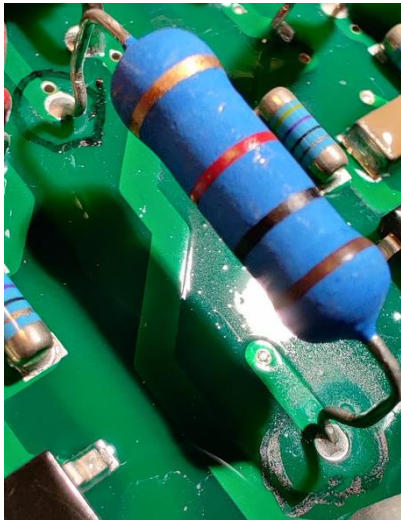


Figure 34. Through hole component.

Initially the conformal coating was removed from the legs of the component with the abrasive method and cleaned after the removal. It was also necessary to be very careful not to blast any other part of the PCB and not to break down the component. For the surface mounted chip component, it was necessary to remove the conformal coating just from the flat legs UV light for better evaluation, as shown in Figure 35. For the through hole component it was necessary to remove the conformal coating on both sides of the PCB under UV light for better evaluation, as shown in Figure 36. After the removal of conformal coating it was time to remove the components.



Figure 35. Removed coating from surface mount chip component's legs.

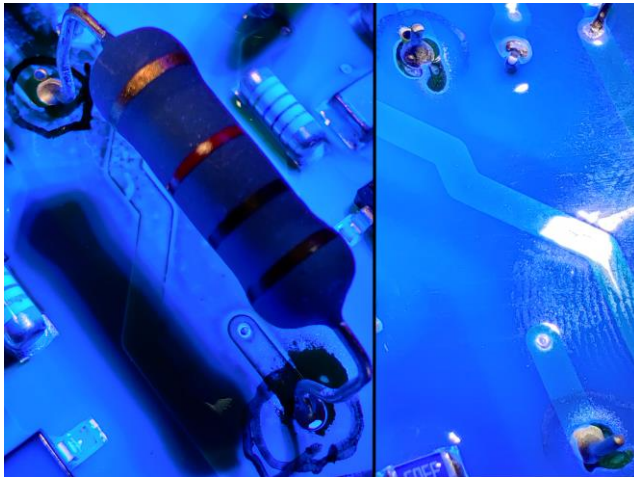


Figure 36. Removed coating from through hole component's legs.

The surface mount chip component was removed first with a hot tweezer method. The WXMT micro desoldering tweezer was installed to the soldering station and preheated for removal. For removal, the tweezer tip was placed in a position over the legs of the component and squeezed gently. When the solder was melted completely from both legs of the component, it could be lifted away. In some cases, like here the chip components has adhesive between the body and the PCB. When adhesive is used, it is necessary to turn the component slightly to allow it to be removed from the PCB. After the component is lifted away, it can be placed onto heat resistant surface. The result after removing the surface chip component is shown in Figure 37. /11, 25/



Figure 37. Removed surface chip component.

After both PCBs had gone through the component removal it was time to place the component to a different module card than before. One of the pads were prefilled with solder and then the component was placed in position. Then prefilled pads solder was melted completely to get the component dropped down onto pad. After a brief waiting time, the other side was soldered by applying additional solder as needed. When the surface chip component was back in the both power supply module card as shown in Figure 38, it was time to retest the module card in the module tester to make sure they are still working correctly. /11, 27/



Figure 38. Reattached surface chip component.

The through hole component was the last component to be removed and reattached. This was done with WXDP 120, desoldering iron with vacuum system, which was installed to the soldering station first and preheated for removal. For removal, the desoldering iron was placed in position over the component legs. When the solder was melted completely from legs of the component, the vacuuming process of the melted solder was started while using circular motion to the joint. When this was done, it was necessary to continue the vacuum while lifting the tip from the leg to clean all molten solder from heated chamber. This process needed to be repeated for the other leg. Then a flat nose pliers were used to gently rotate the legs to laterally break any remaining solder and lifted the component away. The result after removing the through hole component is shown in Figure 39. /11, 24/



Figure 39. Removed through hole component.

After the component removal had been done for both PCBs, it was time to place the component to a different module card than before. The component was placed in the right position and right way. Then solder was applied and melted completely to get the component to stay on the right place. After a brief waiting time, the other side was soldered by applying additional solder as needed. When the through hole component was back in the both power supply module card as shown in Figure 40, it was time to retest the module card in the module tester to make sure they are still working correctly. /11, 26/

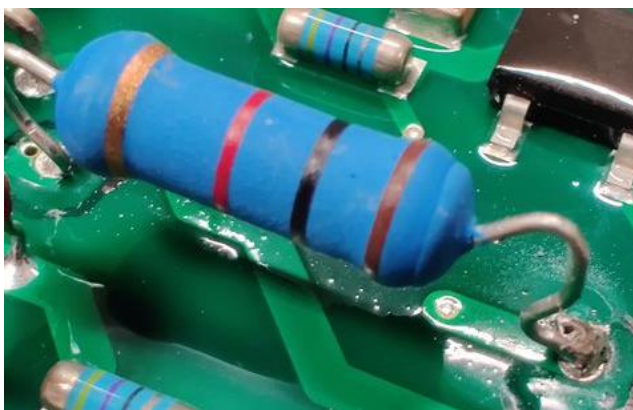


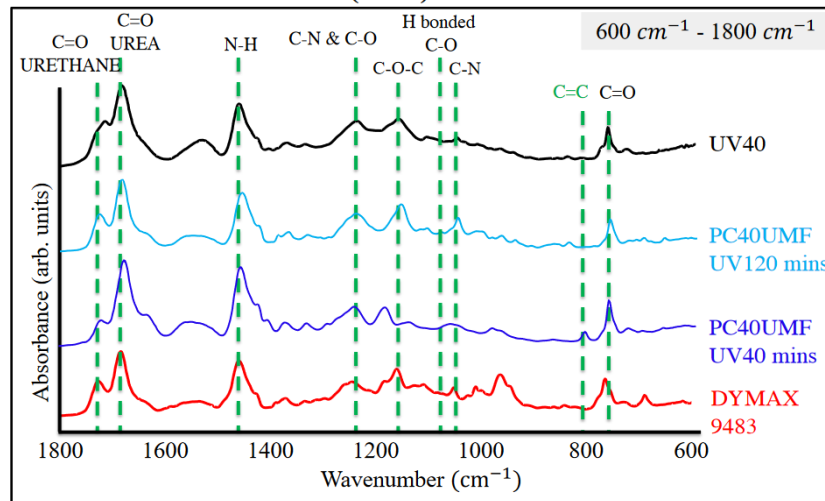
Figure 40. Reattached through hole component.

6 RECOATING THE PCB

After reworking and testing the PCB, recoating it is done with the same conformal coating or in some cases with same kind of a conformal coating. The recoating should be done by either the supplier's equipment manuals or the supplier's standard repair practices guidelines. If this information is not available, common reapplication instructions can be found in IPC-7711/7721. The reapplication of conformal coating can vary depending on how much conformal coating has been removed. For small areas, a typical method is often done with a brush or swab by spreading the replacement conformal coating. For larger areas, a typical method is to spray the replacement conformal coating. In both ways the new conformal coating needs to overlap the existing conformal coating to create a seal between the new and old conformal coating. /6, 11, 21/

For comparison of the same kind of conformal coating one study was found where the conformal coating in use was also. The study had investigated different curing conditions for various conformal coatings to measure coating adhesion to tin and mechanical properties. Three same kind of polyurethane acrylate (PUA) conformal coatings had been compared to each other. Initially the curing of these UV curable conformal coating had been measured with the Fourier-transform infrared spectroscopy (FTIR) which measures how much light a sample absorbs at each wavelength. The results of FTIR are shown in Figure 41, with explanations. Two tensile tests of conformal coating had been conducted as well in the study, in Figure 42 it is shown how the conformal coating behaves in stress after curing and in Figure 43 it is shown how the conformal coating behaves in a mechanical test. Figure 44 shows the adhesion test where just the best conformal coatings had been tested. These tests show that the UV40 in use is not generally the best possible conformal coating compared to others, but suitable for the coating of modular cards. /23/

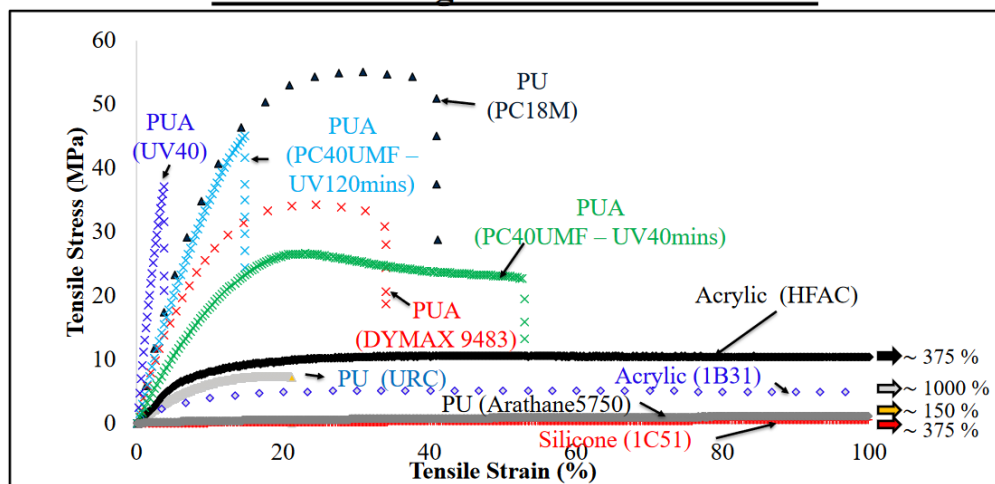
POLYURETHANE ACRYLATE (PUA)



- Presence of C=C peak at 809 cm^{-1} in PC40UMF 40mins cured → Coating is partially cured
- Shifting of C = O (Urethane) peak to 1708 cm^{-1} in UV40 → More brittle than other PUA

Figure 41. FTIR Results and Discussion of PUA. /23/

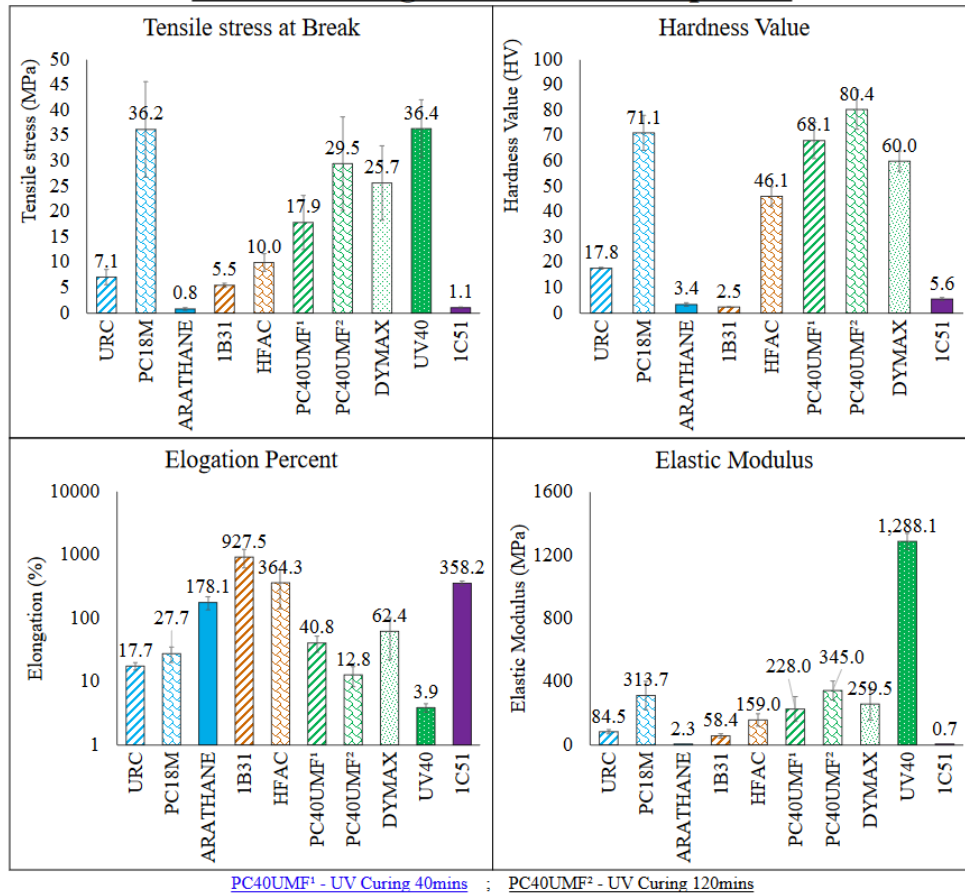
Tensile Testing – Stress-Strain Curve



- PUA (UV40) is the most brittle coating
- Acrylic (IB31) has the highest elongation percent
- PU (PC18M) & PUA (PC40UMF- partial UV cure) show good strength/ductility combination

Figure 42. Stress-Strain Curve of different conformal coatings. /23/

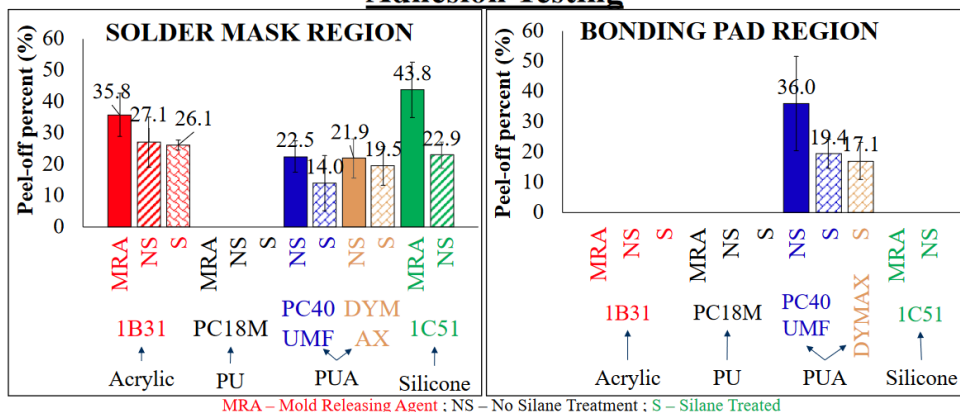
Tensile Testing - Mechanical Properties



- Most ductile conformal coating : **1B31 (AR)**
- Most brittle conformal coating : **Humiseal UV40 (PUA)**
- Soft conformal coatings : **Arathane (PU), 1B31 (AR) and 1C51 (SR)**

Figure 43. Mechanical Properties of different conformal coatings. /23/

Adhesion Testing



- **PC18M (PU)** shows excellent adhesion to solder mask and (Au-Pd) bonding pad region
- **1C51 (SR) with mold releasing agent** shows highest peel-off percent
- **PU, Acrylic and Silicone** showed excellent adhesion strength in bonding pad region

Figure 44. Adhesion Testing of different conformal coatings. /23/

6.1 Ensuring That the PCB is Clean Enough

Before the recoating can be started the PCB should be cleaned and checked for damage because all conformal coating removal methods have a high possibility to leave damage to the PCB with residue, either chemical or particulate in nature. The cleaning of PCB must be done thoroughly prior to other rework and repair operations, such as replacing components, or reapplication of the conformal coating. If water is used in cleaning operation, it should be either distilled water or deionized water. Usually local tap water is more corrosive to metals than the removal strippers themselves are. A recommendation is that the reworked area should be cleaned with an appropriate cleaning agent, starting with flux residues, followed by isopropyl alcohol to clean the area completely. This give a good result for re-attaching components or reapplication of conformal coating. /6, 11, 22/

6.2 Risks Related to Recoating

When recoating the PCB, the risks are same as when the coating is done for the first time for the PCB and the rework risks should also be noted. For all the conformal coating materials, the material safety data sheets should be available also for all strippers, solvents, and such. These material safety data sheets should be in place where they are accessible for all operators working in the area. All the conformal coating application methods brings health and safety concerns to operators. /6/

In recoating, the manual application method should be addressed more seriously, as the spray process can get in direct contact with the operator. Skin irritation and inhaling or ventilation are the most common hazards when applying conformal coating. It is important to have a proper ventilation in the area where application, curing and reworking of the conformal coating is done. After PCB is recoated, the curing should come next and during this process common hazards come from the fumes of conformal coating. /6/

When reapplying the coating for PCB, the operator should have goggles for eye protection, lab coat and gloves for skin protection and half mask for respiratory

protection. It is also important to have a well-ventilated working area. In curing the operator should take care to avoid eye and skin exposure to the UV energy. /6/

6.3 Tools Needed for Recoating

The most important tools for recoating are the personal safety equipment mentioned in Chapter 6.2: jacket or work clothes, which are ESD-certificated and also these protect the operator from the drops of coating. The nitrite gloves and goggles also protect operators from the very irritating conformal coating, respirator for the fumes of the conformal coating.

For recoating, the working area needs good ventilation and this was done by assembling a new fume hood for coating purposes only (Figure 45). For curing the conformal coating, it was necessary to get a UV Light-Curing Conveyor (Appendix 5) and with this, the coating will cure in one passthrough so the fumes will not spread any further than the working area.



Figure 45. Fume hood for coating.

Lastly the recoating itself needs the conformal coating substance which is dispensed into a smaller container, as shown in Figure 46 for the work and the thicker

conformal coating was attached to the syringe gun, as in Figure 47. For applying and spreading the conformal coating a brush or swab can be used, shown in Figure 48.

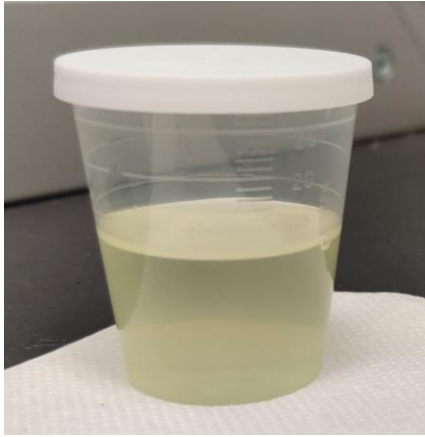


Figure 46. Conformal coating in smaller container.



Figure 47. Syringe gun for conformal coating.



Figure 48. A brush and swab.

6.4 Recoating in Practice

For the practical part of the recoating, three different module cards were selected which were the communication module, the transformer module and the three power modules which were used in components replacement in Chapter 5, whereby five module cards were recoated in total.

The recoating was started by preparing the workspace, after which the cards were cleaned before the recoating, so that no dirt remained under the varnish, which could interfere with the adhesion of the coating. As the cards dried, the necessary protection was put on and a UV Light-Curing Conveyor is started to allow it to warm up properly before the first recoated card was placed in for curing. After drying from the cleaning process, the cards were transferred to a fume hood where they were recoated. The wanted result for recoating is shown in Figure 49.

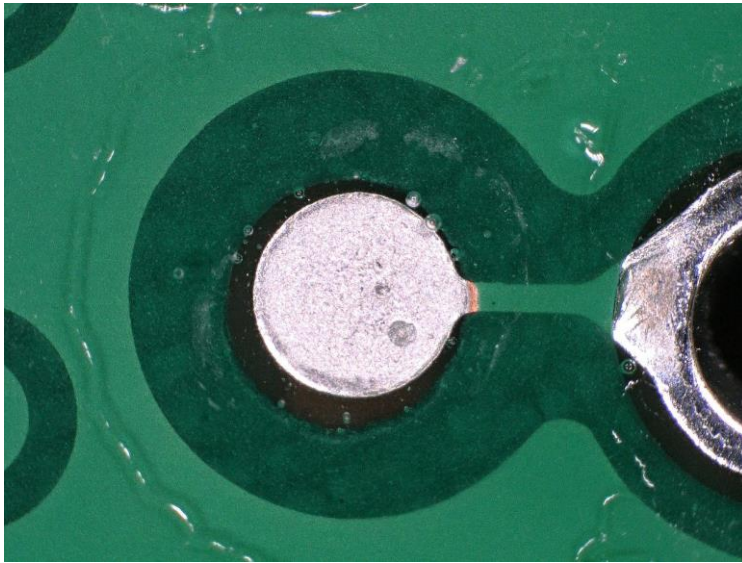


Figure 49. Wanted result for recoating.

The cards were recoated one by one so that each area where the varnish had been removed was refilled with conformal coating. The operation was initiated by dipping the brush in the conformal coating and then applying a thin layer of coating so that it also overlapped the existing coating. After each removed area was refilled with coating, the card was further inspected with UV light to ensure that every area was filled. The card was then placed in a UV Light-Curing Conveyor and allowed to pass through it whereby the conformal coating cured. After that, the card was checked with UV light once more to make sure everything recoated. Figure 50 shows the thinner areas test point before and after recoating. Next, the thicker conformal coating area was recoated for cards where it was removed. This was done with a syringe gun with a tip that had a small hole and the rest of the recoating process was the same way as when thinner coating was used. Figure 51 shows the thicker areas test points before and after recoating.

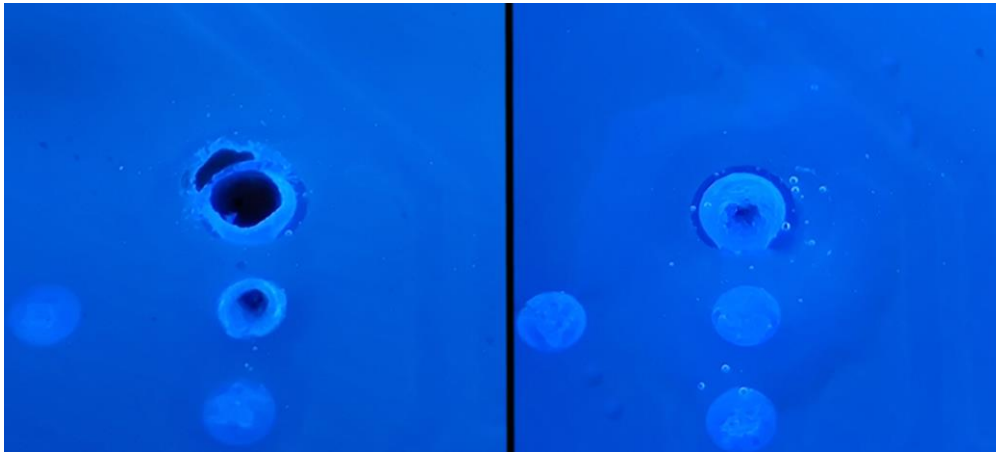


Figure 50. Thin coating area before and after recoating.

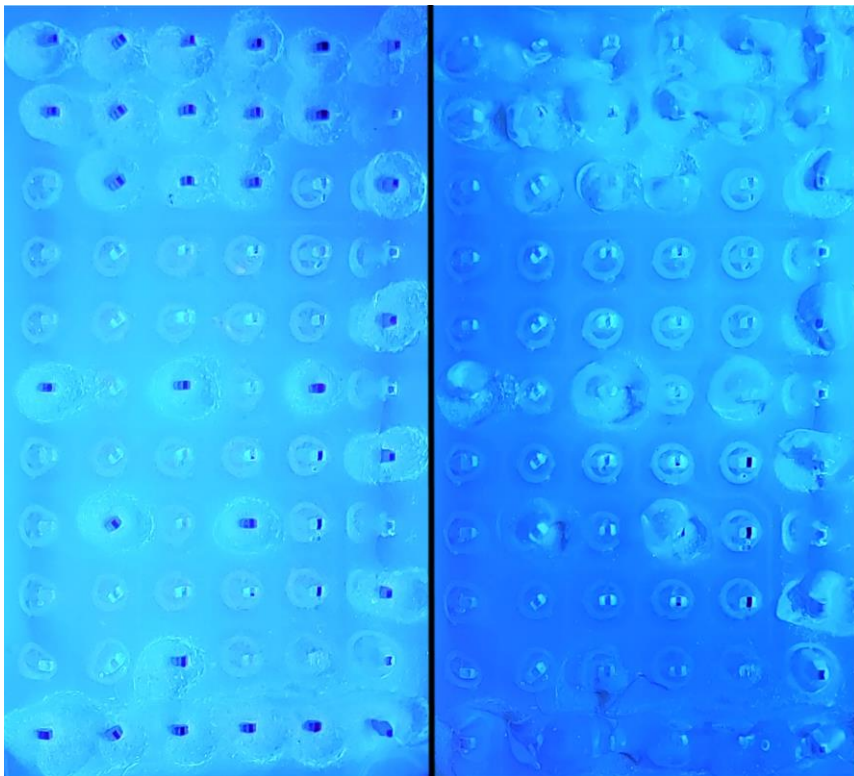


Figure 51. Thicker coating area before and after.

7 TESTING OF RECOATED PCB IN WEATHER TESTS

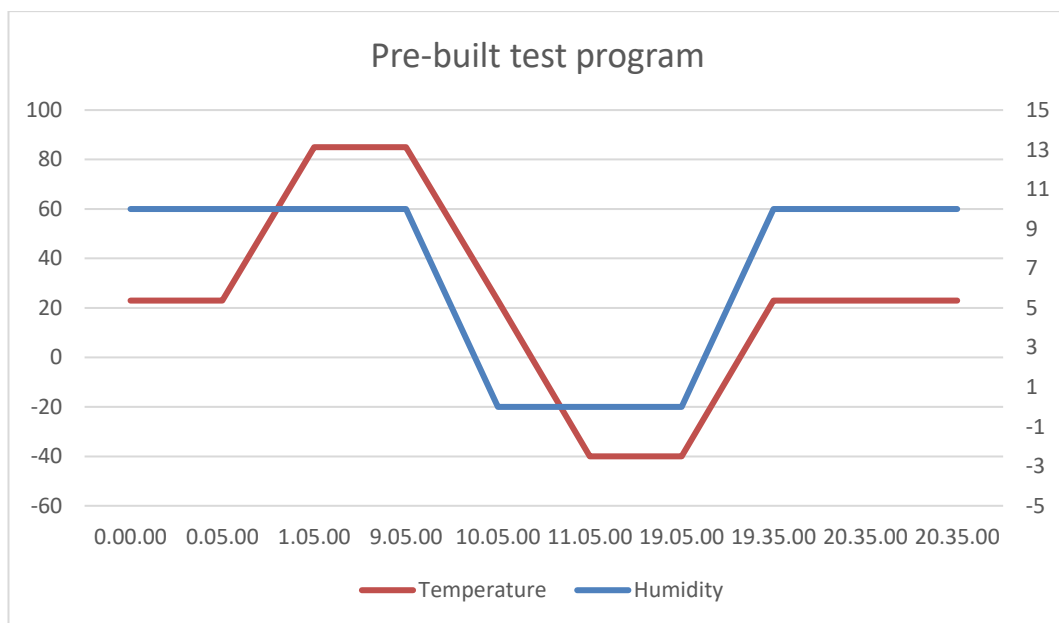
As a final step, the recoated cards were placed in the Weiss Technik's Climate Tests Chamber WK3, where it was possible to test temperature test from -42°C to $+180^{\circ}$ or climatic test from $+10^{\circ}\text{C}$ to $+95^{\circ}\text{C}$ and the humidity can range from 10% to 98% /23/. By putting the card in the test chamber, it was determined whether the recoated area of the card remained at the temperatures promised for the storage of the relay. From the recoated cards, three different module cards were selected and placed in test chamber. These three module cards were a communication module with a thinner conformal coating recoated, a transformer module with a thicker conformal coating recoated, and a power module with both conformal coating areas recoated.

A pre-built program was selected as a test program, which goes through the promised temperatures and humidity for relay storage. The basic principle of the program is shown in Table 5 and in Figure 52, in which the duration, temperature and humidity of the cycles are seen more clearly. The test program lasted for 20 hours and 35 minutes and it was repeated three times to detect any changes, therefore, it lasted for two and half days.

After the test program was completed, the cards and their re-varnished areas were initially inspected visually, and the most obscure areas were further examined under a microscope. No unwanted changes were observed, so with the right kind of repair method the conformal-coated module cards can be repaired and given back to the relay production.

Table 5. Test programs settings.

No.:	Time:	Temperature:	Humidity:
1	0:00:00	23.0	10.0
2	0:05:00	23.0	10.0
3	1:00:00	85.0	10.0
4	8:00:00	85.0	10.0
5	1:00:00	23.0	10.0
6	1:00:00	-40.0	0
7	8:00:00	-40.0	0
8	0:30:00	23.0	10.0
9	1:00:00	23.0	10.0
10	0:00:00	23.0	10.0

**Figure 52.** Relay storage test program.

8 SUMMARY

As might be expected, removing the conformal coating from the cards was challenging and time consuming. The practical possibilities for removing the conformal coating were not great, because out of four main methods, it was possible to use only two main methods, which were the thermal method and abrasive method. With the abrasive method, the time taken to blow one test point clean is about one second and one card has a maximum of 20 test points, which means that it takes less than a minute to blow one card, unlike the thermal method, where it can easily take a minute to clean one test point. For this reason alone, the best possible removal method of conformal coating from the used methods was the abrasive method with the founded setting for the micro sandblasting unit.

It was necessary to wear protective equipment when removing conformal coating, for both thermal and abrasive method. Respirators were more protective in thermal method use against the generated fumes and less protective in abrasive method against the floating particles but still a necessary protection. The use of goggles in both removal methods is recommended, thus avoiding contact with generated fumes and floating particles. The replacement of components was better than initially expected, the conformal coating came off easily from the legs of the component on the module cards. After the weather cabinet, the condition of the cards remained as good as before the weather cabinet so there is no reason not to recoat the module cards and put them back in production

Based on this thesis, it is possible to develop detailed work instructions for the conformal coating removal method for the thermal removal method and the abrasive removal method. With the help of this thesis, it is possible to expand the rework methods to other conformal-coated module cards for the Relion family products. For further development for the reworks, templates for the cards should be done, which show the test points immediately and can be marked directly without having to look at the test points of the cards from separate images. A smaller stand for micro sandblasting for the conformal coating removal should be invested to facilitate the work; it can be the same style as the stand at the soldering station. For the

abrasive method, a metallic or hard plastic test point template that is held over the test point during the removal of the conformal coating could prevent the solder mask from breaking. A possible development for the UV Light-Curing Conveyor would be a safeguard at the end of the conveyor for UV light and to prevent cards from dropping on the floor. The possibility to find a similar type of conformal coating should be investigated as an alternative source and at this point the possibility to remove the conformal coating with the chemical and mechanical method should also be investigated.

After all, the research was successful and the best possible conformal coating removal method was found, both component replacement and recoating were successful as desired. Conformal-coated cards were found repairable if they are perceived as broken in production. In addition, development ideas were thought through the process, which can in the long run improve the rework of conformal-coated cards.

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APPENDIX A

Conformal Coating Comparison Guide

A-1 Due to the numerous variations in conformal coating formulations, the IPC Conformal Coating Handbook Task Group encountered some difficulties in compiling a simple, fair and user-friendly selection guide. Ratings based on the general chemistry type may not accurately reflect the capabilities of each subtype. Rating each subtype may not be possible without revealing individual commercial products; moreover, it will make the guide too cumbersome to use. A consensus was finally reached by listing 5 strengths for each coating type, and 5 weaknesses for each subtype differentiated by cure mechanism. As such, the comparison is general in nature.

5 Strengths of Coating Type	5 Weaknesses of Cure Type
ACRYLIC <ul style="list-style-type: none"> • Ease of rework. • Simple drying process. • Good moisture resistance. • High fluorescence level. • Ease of viscosity adjustment. 	Solvent Evaporation <ul style="list-style-type: none"> • High VOC potential. • Difficult to maintain viscosity. • Requires close monitoring of solvent concentration, hence Creates a 2-part scenario. • Flammability. • High probability of reversion under temperature and humidity stress conditions.
	Heat Cure <ul style="list-style-type: none"> • Cure is dependent on thickness. • Component mass affects time and temperature of cure process. • Susceptible to cure inhibition. • Shrinkage (3% - 10%), potential for damaging fragile (e.g., glass) components. • Should be used with caution for low temperature components.
	UV Cure <ul style="list-style-type: none"> • Incomplete cure in shadowed areas. • Pungent odor, potential skin irritant. • Can become very brittle at higher temperature. • Difficult to rework. • Type of UV and intensity affect cure.

5 Strengths of Coating Type	5 Weaknesses of Cure Type
EPOXY <ul style="list-style-type: none"> • Useful to about 150 °C [302 °F]. • Harder durometer, abrasion resistance. • CTE closer to epoxy printed board substrate. • Higher T_g. • Good dielectric properties. 	Solvent Evaporation <ul style="list-style-type: none"> • Higher chloride contamination potential. • Process intensive, difficult to maintain viscosity, complex mix ratios. • Potential for high stress during temperature cycling conditions. • Difficult to rework. • High probability of reversion under temperature and humidity stress conditions.
	Heat Cure <ul style="list-style-type: none"> • Cure is dependent on thickness. • Component mass affect time and temperature of cure process. • Selective coating quality (edge definition) could be impacted. • Shrinkage (3% - 10%), potential for damaging fragile (e.g., glass) components. • Should be used with caution for low temperature components.
	UV Cure <ul style="list-style-type: none"> • Incomplete cure in shadowed areas. • Pungent odor, potential skin irritant. • Can become very brittle at higher temperature. • Difficult to rework. • Type of UV and intensity affect cure.
	Catalyzed <ul style="list-style-type: none"> • Cure inhibition. • Short work life. • Contamination sensitive. • Difficult to rework. • Pungent odor.

APPENDIX 1/2.

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5 Strengths of Coating Type	5 Weaknesses of Cure Type
<p>POLYURETHANE</p> <ul style="list-style-type: none"> • Good dielectric properties. • Good moisture resistance. • Solvent resistance. • Less reversion potential. • Abrasion resistance. 	<p>Solvent Evaporation</p> <ul style="list-style-type: none"> • Moisture affects cure rate and desired properties. • Long complete cure time (up to 30 days). • Health and safety concerns. • Potential for high stress during temperature cycling conditions. • High probability of reversion under temperature and humidity stress conditions. <p>Heat Cure</p> <ul style="list-style-type: none"> • Cure is dependent on thickness. • Component mass affects time and temperature of cure process. • High VOC potential. • Should be used with caution for low temperature components. • Reacts violently with presence of water. <p>UV Cure</p> <ul style="list-style-type: none"> • Incomplete cure in shadowed areas. • Pungent odor, potential skin irritant. • Can become very brittle at higher temperature. • Difficult to rework. • Type of UV and intensity affect cure.

5 Strengths of Coating Type	5 Weaknesses of Cure Type
<p>SILICONES</p> <ul style="list-style-type: none"> • Stable over wide temperature range (in general, -55 °C to 200 °C) [-67 °F to 392 °F]. • Flexible, provides dampening and impact protection. • Good moisture, humidity, and UV/sun light resistance. • High dielectric strength. • Low surface energy to enable effective penetration under components. 	<p>Room Temperature Vulcanization (RTV)</p> <ul style="list-style-type: none"> • Requires humidity (minimum 20% RH) to cure and only intermittent solvent resistance. • Low abrasion resistance. • Short pot life. • TCE is ~300-350 ppm/ °C. • If proper house keeping is not followed, there is a potential for cross contamination. <p>UV Cure</p> <ul style="list-style-type: none"> • Incomplete cure in shadowed areas. • Potential skin irritant. • Low abrasion resistance. • Only intermittent solvent resistance. • If proper housekeeping is not followed, there is a potential for cross contamination. <p>Catalyzed (Addition)</p> <ul style="list-style-type: none"> • Low abrasion resistance. • Potential for cure inhibition. • Adhesion may be difficult. • Only intermittent solvent resistance. • If proper housekeeping is not followed, there is a potential for cross contamination.

APPENDIX 1/3.

IPC-HDBK-830A

August 2013

5 Strengths of Coating Type	5 Weaknesses of Cure Type
<p>POLY-PARA-XYLELENE C, D, N</p> <ul style="list-style-type: none"> • Excellent uniformity regardless of part geometry- no pinholes, fillets, or bridging. • Chemical inertness/barrier properties- insoluble in organic solvents, acids, or bases, with very low permeability rates. • Minimal added mass and low outgassing. • Biocompatibility allows uses in many medical applications. • Low environmental impact process. 	<p>Vapor Deposition Polymerization</p> <ul style="list-style-type: none"> • Parts are processed by batches in a vacuum chamber, not an in-line process. • Masking required for no-coat areas. • Coating removal and rework generally requires specific equipment. Abrasion and micro-blasting are the more common techniques. • Limited UV resistance and operating temperature limit, around 120 °C [248 °F] in the presence of oxygen. • Cannot be doped.

5 Strengths of Coating Type	5 Weaknesses of Cure Type
<p>FLUORINATED POLY-PARA-XYLELENE</p> <ul style="list-style-type: none"> • Excellent uniformity regardless of part geometry- no pinholes, fillets, or bridging. • Chemical inertness/barrier properties- insoluble in organic solvents, acids, or bases, with very low permeability rates. • High temperature stability (450 °C [842 °F]) and increased UV stability. • Low dielectric constant, 2.28. • Low environmental impact process. 	<p>Vapor Deposition Polymerization</p> <ul style="list-style-type: none"> • Parts are processed by batches in a vacuum chamber, not an in-line process. • Masking required for no-coat areas. • Coating removal and rework generally requires specific equipment, abrasion/micro-blasting most common technique. • The coating is deposited at a rate slower than the conventional poly-para-xylelenes. • Requires special deposition equipment different than that for the C, D, and N poly-para-xylelene varieties.

5 Strengths of Coating Type	5 Weaknesses of Cure Type
<p>AMORPHOUS FLUOROPOLYMER</p> <ul style="list-style-type: none"> • Low dielectric constant. • High glass temperature. • Low surface energy. • Low water sorption. • Good solvent, oil and common acid resistance. 	<p>Solution Deposition</p> <ul style="list-style-type: none"> • Requires special liquids for polymer swelling. • Limited solubility which limits film thickness. • May require glass temperature anneal. • Requires special surface treatment for greatest adhesion. • Poor resistance to some acids and alkalines.
	<p>Vacuum Deposition</p> <ul style="list-style-type: none"> • Requires pressure of 10 Torr - 5 Torr [0.193 PSI - 0.097 PSI] or less. • May require glass temperature anneal. • Requires special surface treatment for greatest adhesion. • Poor resistance to some acids and alkalines. • Poor abrasion resistance.

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Product Information

WXR 3

3-Channel Power Unit, 420 W (600 W)
Product no.: T0053500699N



Benefits

- › All-in-one Station
- › Benchtop controller capability e.g. Zero Smog Systems
- › Automatic tool recognition and power management
- › Compatible with all WX tools
- › Storage medium in hand piece
- › Blue LED backlighting
- › Multilingual menu navigation

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Product Information

Technical Data

Dimensions L x W x H (mm)	273 x 235 x 102
Dimensions L x W x H (inches)	10,75 x 9,25 x 4,02
Weight (approx.) in kg	6.7
Voltage	230 V (50/60 Hz)
Power	420 W (600 W)
Channels	3
Temperature range (depends on tool) °C	100 - 450 (550)
Temperature range (depends on tool) °F	200 - 850 (999)
Temperature accuracy °C	±9
Temperature accuracy °F	±17
Temperature stability °C	±2
Temperature stability °F	±4
Equipotential bonding socket	Via 3.5 mm pawl socket on back of device (Hard grounded)
Display	255 x 128 dots / Backlighting
Air consumption l/min	---
Operating pressure in bar/psi	---
Capacity l/min	18, max.
Vacuum	---

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TURBO-Max™, TURBO-Station™ & TURBO-Cab™

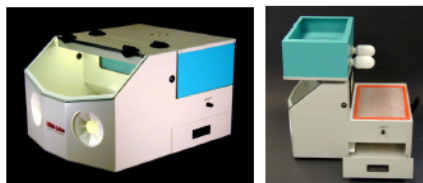
Work Chamber and Dust Collector all in One.....

The **TURBO-Max™** and **TURBO-Station™** utilize the same filter and fan. Size is the difference. Both have the same:

- Efficient backward inclined impeller generating 258 scfm of vacuum to evacuate and collect the spent abrasive media
- Filter which is best used with abrasive media 25 microns and larger
- Easily removable drawer for collecting and disposing of spent abrasive powder
- Tempered glass viewing window
- Room on top for placing optional micro sandblaster



TURBO-Max™ with a SWAM-Blaster®
Model MV-2L

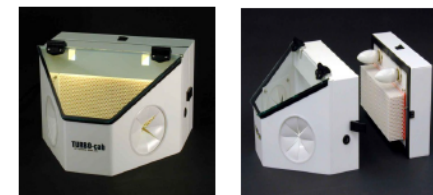


TURBO-Station™ with side view and open
clean out drawer

Specifications	TURBO-Max™	TURBO-Station™	TURBO-Cab™
Power Requirements	115 VAC, 60 Hz, 1 amp 230 VAC, 50 Hz, .5 amp	115 VAC, 60 Hz, 1 amp 230 VAC, 50 Hz, .5 amp	115 VAC, 60 Hz, 1 amp 230 VAC, 50 Hz, .5 amp
Weight (approx)	102 pounds	60 pounds	25 pounds
Approx Size (OD)	27"W x 35"D x 19"H	20"W x 24"D x 16"H	16"W x 16"D x 10"H
Approx Work Area (ID)	24"W x 19"D x 18"H	20"W x 12"D x 14"H	16"W x 11"D x 10"H

The **TURBO-cab™** is the perfect solution when work items are small and bench or counter space limited.

Dual fans generate approximately 50 scfm of vacuum to keep spent media or debris inside. The fan/light package can be separated from the front with 2 latches for easy cleaning. The filter is replaceable and is best for use with abrasive powders measuring 25 microns or larger. The viewing window is made of replaceable tempered glass.



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APPENDIX 4. – Model MV-2L, Data Sheet.



Model MV-2 and MV-2L Micro Sandblasters

The *SWAM-BLAST® Micro Sandblasters* introduce a precise amount of finely graded abrasive powder into a controlled stream of compressed air through the abrasive pathway and out a manually or automatically positioned nozzle tip.



Total process control can be achieved with independently adjustable powder flow control and air pressure regulation. When detail is required, the powder flow is turned down to reduce the amount of the powder being vibrated into the abrasive/air pathway thus allowing the use of very small nozzle tips. For more aggressive requirements, the air pressure, powder flow and the nozzle tip diameter can be increased. An assortment of nozzle styles and sizes, a wide variety of powder types and particle sizes, and interchangeable orifice plates are available to accomplish various applications.

The unique design of the Model MV-2 and MV-2L offers "Maximum Versatility". Front and back panels unlatch to easily access components and carbide lined fittings throughout the abrasive/air pathway for routine maintenance. The powder tank is mounted to a hinged plate that allows it to tilt to the side and with the push of a button, the vibrator activates to simply walk the powder out for rapid powder changes.

The Model MV-2 works very well with a nozzle range from .007" up to .040". For more aggressive applications that require a larger nozzle range, the Model MV-2L is suitable for nozzle sizes .018" up to .060".

CRYSTAL MARK, INC. offers additional options for the Model MV-2 and MV-2L as well as work chambers, dust collectors and air dryers in various sizes and configurations to meet your specific requirements.



Tilt Tank for quick powder changes

Job Shop Services Available

Power Requirements	115 VAC, 60 Hz, 1 amp 230 VAC, 50 Hz, 1 amp
Air Requirements	40 psi (276 kPa) minimum 140 psi (956 kPa) maximum
Weight	43 pounds (20 kg)
Size	13"Wx11"D x 13"H

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UVC-8 UV Light-Curing Conveyor

CE Marked

The Dymax UVC-8 Conveyor is designed for curing UV/Visible light-curable adhesives, coatings, and inks. This cost-efficient and versatile conveyor system is perfect for both production and lab environments, and can be used in a number of different industries. Typical substrates that are bonded, coated, or encapsulated include paper, plastic, metal, glass, laminated materials, printed circuit boards, and many others.

The UVC-8 Conveyor is equipped with a 220 mm wide Teflon[®]-coated belt and can be outfitted with one, two, or three UV lamps. The distance between the lamp and the belt can be manually adjusted (between 60-100 mm) as well as the belt speed (0.5-12 m/min). This enables the operator to tailor the curing conditions to the specific application. The conveyor also features a digital control panel where various parameters such as operating hours, lamp current, and the UV set point can be monitored.



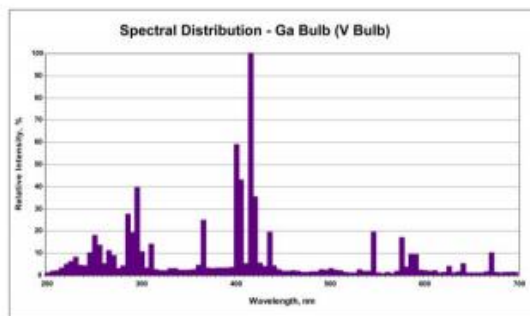
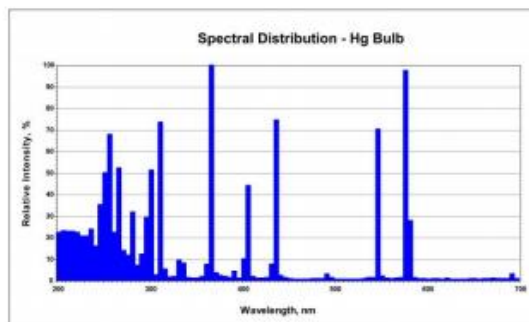
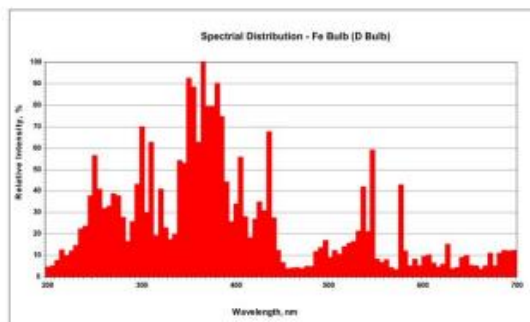
UVC-8 Light-Curing Conveyor System

SPECIFICATIONS		
Electrical Requirements	3 x 400V/N/PE, 50 Hz	
Number of Lamps	1, 2, or 3 UV lamps	
Lamp Power	2000 W per bulb	
Intensity (UVA)	800 mW/cm ² (typical Intensity new bulb at 60 mm distance)*	
Vertical Clearance	Adjustable 60-100 mm	
Dimensions (W x L x H)	1,100 mm x 1,000 mm x 1,200 mm	
Working Height (Floor to Belt)	900 mm on wheel kit or 900 - 950 mm with adjustable screws	
Control	Compact PLC	
Belt	<i>Belt Material</i>	Teflon [®] -coated fiberglass
	<i>Belt Width</i>	220 mm
	<i>Belt Speed</i>	Adjustable from 0.5-12 m/min
Bulbs	Metal Halide (Fe) - Standard Mercury (Hg) Gallium (Ga)	
Air Exhaust	500 m ³ /h	
Net Weight	180 kg	

* As measured with a Dymax ACCU-CAL™ 50 Radiometer (320-395 nm)

APPENDIX 5/2.

FEATURES	
Maintenance-free, Teflon®-coated belt with adjustable belt drive (0.5-12 m/min range)	Ideal for curing on a variety of substrates including glass, metal, plastic, printed circuit boards, and paper
Controlled and consistent cure times	Fully shielded lamp enclosures
Reliable, heavy-duty conveyor design	Fast cures for high throughput
Optional intensity adjustment (40-100%)	220 mm belt width
Ideal for use in laboratories and for small-size production	Aluminum lamp reflectors
Lamp height adjustment (60 – 100 mm) to accommodate various part heights	Optional dichroic lamp reflectors and IR filters for curing on temperature sensitive substrates are also available
Digital control panel, compact PLC	Optional PLC with UV monitoring on request



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