

# Protection of Printed Circuit Boards and Electronic Components from Water and Salt Water by Using 3M™ Novec™ Electronic Grade Coatings

## Introduction

Protection against water – both vapor and liquid – has become increasingly critical to the lifetime performance of electronic devices. This is especially true as electronics become more mobile and are used in more challenging environments.

One effective method of providing this protection is to coat the internal surfaces of the electronic device components, including its printed circuit boards and connections. To demonstrate this, tests were conducted to show the capability of 3M™ Novec™ Electronic Grade Coatings (EGC) to protect metals against moisture, liquids and corrosion under a variety of water and salt water immersion conditions.

3M™ Novec™ Electronic Grade Coatings (EGC) are thin, low viscosity coatings designed to protect printed circuit boards and electronic components from moisture and corrosion. These polymer coatings dry to thin, transparent films with excellent hydrophobic and oleophobic properties. Available in both thermal curing and non-curing versions, they are easy to apply – whether by liquid dipping, spraying (controlled) or brush. These coatings are non-ozone depleting and RoHS compliant.

The 3M™ Novec™ Electronic Grade Coatings portfolio includes a number of coatings. For this evaluation, 3M™ Novec™ 1710 and 2708 Electronic Grade Coatings were chosen for testing. These coatings are fluorinated polymers delivered as a solution in a segregated-hydrofluoroether 3M™ Novec™ Engineered Fluid. These low viscosity and low surface tension solutions allow for easy wetting over a variety of surfaces, helping to ensure outstanding coverage.

At 8% solids content, Novec 2708 coating is recommended as a final coating. A yellow-orange dye is incorporated into the polymer backbone. This dye will fluoresce under UV light, thus aiding inspection and detection in the quality control process. Although used in this trial for experimentation purposes, at 10% solids content, Novec 1710 coating is recommended to be used as a concentrate to replenish coating solids in application baths or as a component with other materials to create unique liquid solutions, rather than as a final coating.

In this testing, both of the Novec coatings added considerable protection to the components to which they were applied. The protection they provided substantially reduced the effect of water, corrosion and other contaminants that could electrically shorten the lifetime and performance of the electronic device.

## Experiment Overview

Testing began by applying the coating over rigid printed circuit boards with electrical test patterns. The circuit boards were then connected to an external power supply that maintained a constant voltage. Based on a modification of the IPX7<sup>1,2</sup> testing standard (see IPX7 Test Method and 3M Modifications plus Test Results), powered test boards were immersed in water or salt water for an extended time period. The resistance of the circuit was then measured over time and charted to determine the effect of the water on the circuitry.

## Test Boards

For this study, IPC-Association Connecting Electronics Industries approved printed test boards IPC-B-25A<sup>3</sup> were used. The IPC-B-25A test board meets guidelines for testing solder masks (IPC-SM-804C) and conformal coatings (IPC-CC-830B) and is shown in Figure 1.

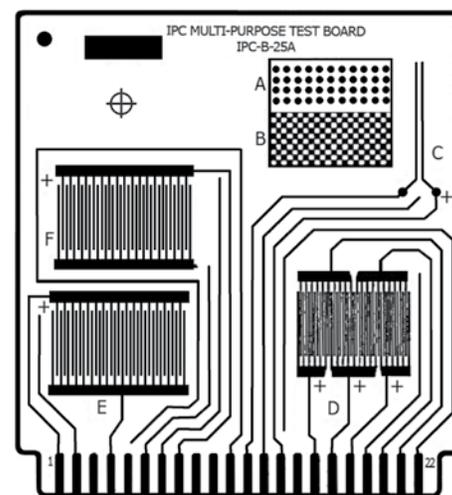


Figure 1. The IPC-B-25A printed test board

## Board Preparation and Coating Application

The boards were cut vertically to isolate the test pattern D from patterns E and F. Test patterns D, E and F were then used separately in the water immersion test.

Prior to coating, the boards were cleaned with 3M™ Novec™ 72DA Engineered Fluid in a vapor degreaser. Novec 72DA fluid is effective at removing surface contaminants and particulates that, if left on the circuit board, might impact coating performance.

3M recommends either spray coating (in a controlled environment) or dip coating as application methods. For this study, both methods were used to demonstrate the flexibility of application options and to measure any differences resulting from the application methods. For testing, boards with different targeted thicknesses of the coatings were generated by spraying, dipping or a combination of these processes.

For dip coating, the process began with a chamber filled with 3M™ Novec™ Electronic Grade Coating. The chamber was on a table which moved up and down at a controlled rate. The removal rate of the boards controlled the thickness of the coating. In general, the faster the board is removed, the thicker the coating. To coat the boards, they were dipped, held in solution for 30 seconds and removed from the coating solution at a rate of 12 inches per minute. The boards were allowed to dry and then wire leads were soldered to the board's contacts. These contacts and the lead connected to the open structure comb pattern were insulated by covering with 100% silicone, leaving just the comb structure test pattern exposed. The board was then placed in the immersion test chamber.

Spray coating can be done manually or by automated spray equipment (3M does not recommend manual spray application without worker exposure control).<sup>\*</sup> For this study, boards were coated using a hand operated air driven sprayer. The volume of coating applied was varied so a thickness of 2µm (2 microns) or less was achieved. Wire leads were then soldered to the boards and insulated with silicone as described above.

**IPX7 Test Method and 3M Modifications**

The water immersion test was based on a modification of the IPX7 test standard that has been established by the International Electrotechnical Commission (IEC).<sup>4,5</sup> The IP Code, sometimes referred to as the Ingress Protection Rating,<sup>6,7</sup> classifies the degree of protection against intrusion into the interior of a device. The IPX standard and tests have been used by the electronics industry for evaluating the ability of water, dirt, dust and other contaminants to ingress into an enclosure. Protection from these contaminants is critical as they have the potential to create conditions that could shorten the service life of an electronic device.

Although there are multiple levels of IPX protection classifications, IPX7 is often referenced for water immersion testing. It provides an indication as to how well an electronic device would survive if immersed in water. This test calls for an unpowered electronic device to be immersed in 1 meter of water for 30 minutes. After the 30 minutes, the device is removed and the power turned on. If it operates as it was designed, the device is considered to meet the IPX7 classification.

While the IPX7 test method uses actual commercial devices, device enclosures can vary in their design and ingress capability. For this reason, this study eliminated the enclosure and evaluated the performance of coatings applied directly on exposed test boards.

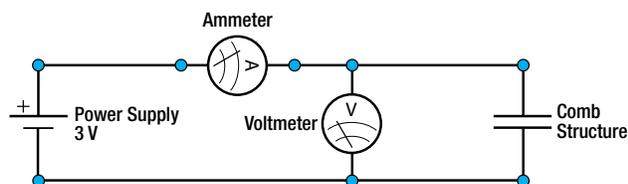
To test at a rigorous level (beyond the IPX7 test protocol), testing in salt water was also carried out. To ensure that a device's electronics would survive these conditions, plus add another level of performance requirements, the sample boards were tested under power. A comparison of these test methods are described in Table 1.

<sup>\*</sup> Before using this product, please read the current product Material Safety Data Sheet (available through your 3M sales or technical service representative or at [www.3M.com/Novec](http://www.3M.com/Novec)) and the precautionary statement on the product package. Follow all applicable precautions and directions. Always practice smart and safe industrial hygiene practices.

Test Method	Immersion Depth	Liquid Media	Time (Min)	Powered
IPX7	1 Meter	Water	30	No
A	1 Meter	Water	60	3 Volts
B	1 Meter	5% aqueous NaCl	60	3 Volts

**Table 1:** IPX7 and 3M test conditions A and B

Using a Solartron™ model 1287 potentiostat<sup>8</sup> in conjunction with a Solartron™ model 1260 impedance analyzer, a constant current of 3 volts was applied to the test pattern. Current leakage across the open comb structure test pattern (D, E or F from Figure 1) during the 60 minute immersion test was then measured. After 60 minutes, the board was removed, rinsed with water and evaluated. The 3M system for Test Methods A and B is depicted in Figure 2.



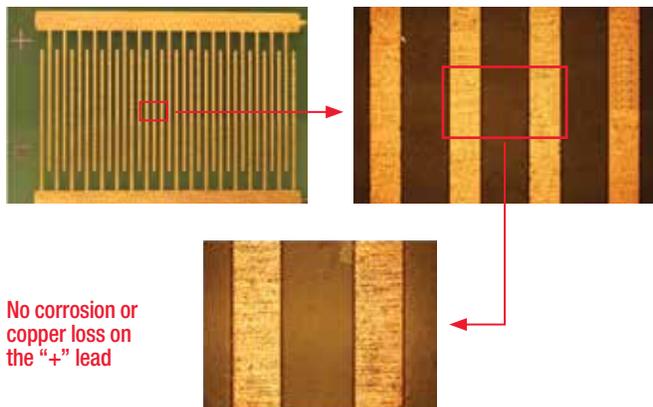
**Figure 2.** Electrical wiring for Test Methods A and B

**Test Results**

While the IPX7 is a test to show water ingress, our testing eliminated the enclosure, ensuring that test boards were completely exposed to the aqueous solutions.

To make the testing more aggressive, modifications were made beyond the IPX7 protocol: 1) immersing in both water and salt water, 2) powering the electronics during testing and 3) extending the immersion time to 60 minutes. In all of these cases, the coated sample boards did not demonstrate the corrosion and degradation of the metal traces to the extent that the uncoated samples boards showed.

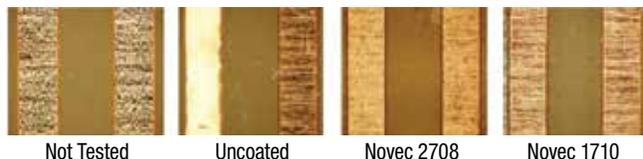
Test Method A was used to test IPC-B-25A printed test board patterns D, E and F coated with Novec 1710 or 2708 coating. There was no corrosion, dendritic growth, copper loss or line thinning observed (Figure 3). When Test Method A was used on uncoated test patterns, there was significant corrosion and line thinning (Figure 4).



**Figure 3.** Example: Test patterns coated with Novec 1710 coating and Novec 2708 coating performed similarly after Test Method A.

Test Method B replaced the water with a 5% aqueous sodium chloride solution. This method made for an extremely aggressive test, as exemplified by the striping of the copper trace lines from the test boards during the immersion time. Even within this environment, the Novec coatings protected the surfaces. When Test Method B was used to test boards coated with 3M™ Novec™ 1710 or 2708 Electronic Grade Coating, there was minimal corrosion in spots along the edge of copper traces. Uncoated test patterns, when tested with Test Method B, were completely corroded and much of the copper tracings were removed from the board, thus creating electrical connection opens (Figure 4).

#### Test Method A



#### Test Method B

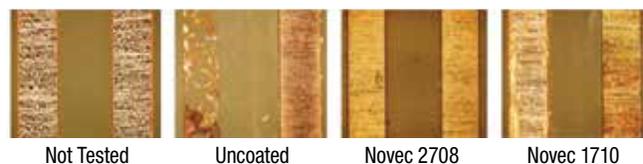
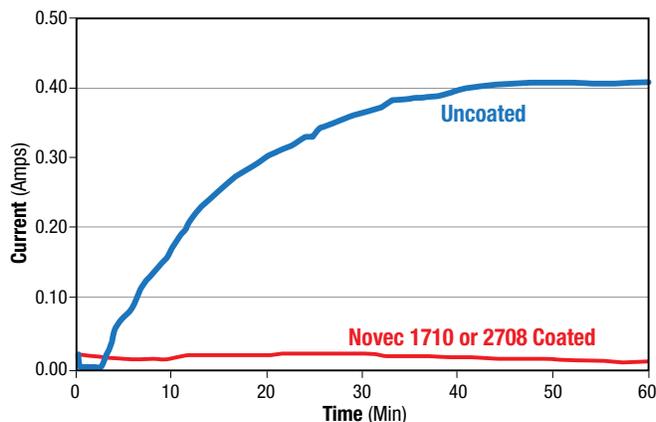


Figure 4: Summary of Novec 1710 and Novec 2708-coated test patterns after Test Method A and Test method B. Note that the uncoated lines show signs of loss of the copper traces.

For the coated boards, current leakage (as measured by the potentiostat) across the test circuit was negligible at less than 0.01 amps. In contrast, for the uncoated boards, current leakage across the test circuit was immediate and significant (exceeding 2 amps) when using either Test Method A and B. The uncoated test pattern under these conditions typically failed within 60 minutes as shown by complete copper loss on the positively charged side of the pattern. Boards coated with Novec 1710 or 2708 coatings did not fail (Figure 5).

#### Test Method A



#### Test Method B

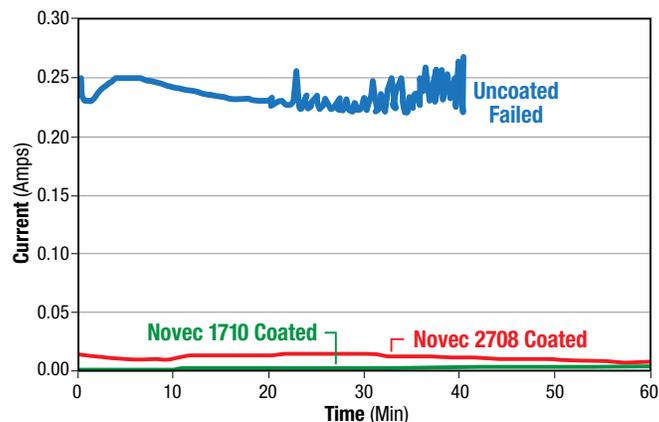


Figure 5: Solartron™ potentiostat data showing current flow

Uncoated test boards had extensive corrosion when immersed in both water and salt water. This was evident by observing current flow immediately across the test pattern when exposed to the test fluid. In contrast, test boards coated with Novec 1710 coating or Novec 2708 coating showed no current flow even after 60 minutes.

## Summary and Conclusions

3M™ Novec™ Electronic Grade Coatings provide an effective barrier for metals and surfaces including electronic circuit boards, helping to protect them from moisture, liquids, corrosion, line thinning and dendritic growth. This protection adds to the performance and longevity of the surfaces, metal connections and an electronic device's service life.

## References

- <sup>1</sup> The IP Code is a test standard published by International Electrotechnical Commission (IEC) and describes the level of protection provided by an enclosure. For an explanation of the IP code see: <http://www.ce-mag.com/archive/06/ARG/bisenius.htm>
- <sup>2</sup> IP Code Defined: <http://www.osram.com/media/resource/hires/342330/technical-application-guide---ip-codes-in-accordance-with-iec-60529-gb.pdf>
- <sup>3</sup> IPC-Association Connecting Electronics Industries is an organization that sets standards used by the electronics manufacturing industry: <https://www.ipc.org/default.aspx>
- <sup>4</sup> IEC 60529: Degrees of protection provided by enclosures (IP Code). International Electrotechnical Commission, Geneva: <http://www.iec.ch/>
- <sup>5</sup> IP Ratings vs. NEMA Ratings: <http://www.bisonprofab.com/ip-ratings-explained.htm>
- <sup>6</sup> Understanding the IP (Ingress Protection) Ratings: <http://www.maximintegrated.com/app-notes/index.mvp/id/4126>
- <sup>7</sup> Interpreting the acronym officially in the standard text: [http://www.iso.org/iso/iso\\_catalogue/catalogue\\_tc/catalogue\\_detail.htm?csnumber=39578](http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=39578)
- <sup>8</sup> Solartron Analytical is a manufacturer of electronic instruments: <http://solartronanalytical.com/>

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To request additional product information or sales assistance, contact 3M Customer Service at one of the numbers below or visit [3M.com/Novec](http://3M.com/Novec).

For other 3M global offices or information on other 3M products for electronics, visit our website at [3M.com/electronics](http://3M.com/electronics).

## Product Comparison Summary

Property	3M™ Novec™ 1710 Electronic Grade Coating	3M™ Novec™ 2708 Electronic Grade Coating
Solids	10 wt% fluoropolymer	8 wt% fluorinated polymer
Solvent	3M™ Novec™ 7100DL Engineered Fluid	3M™ Novec™ 7200 Engineered Fluid
Shelf Life	4 years from date of manufacture in unopened container	1 year from date of manufacture in unopened container
<b>Coating Solution</b>		
Appearance	Clear, colorless to light-colored liquid solution	Transparent, orange, liquid solution
Specific Gravity	1.5 g/mL	1.4 g/mL
Boiling Point of Solvent	61°C (142°F)	79°C (174°F)
Flash Point	None (per closed cup method)	None (per closed cup method)
Environmental	Low in toxicity, non-ozone depleting, nonflammable, VOC exempt (U.S. EPA), RoHS compliant, contains no chlorine or bromine	Low in toxicity, non-ozone depleting, nonflammable, low-VOC, RoHS compliant, contains no chlorine or bromine
System	One Part	One Part
<b>Dry Fluoropolymer Coating</b>		
Appearance	Transparent, colorless	Transparent, light yellow to orange (depending on thickness)
Coating Thickness	Typically 1 to 10 microns (depending on application method)	Typically 0.5 to 25 microns (depending on application method)
Solvent & Chemical Resistance	Yes	Yes
Tg (glass transition temperature)	44.5°C (112°F)	53°C (127°F)
Thermal Stability of Dry Film	Can withstand 175°C for 24 hours and maintain repellency	Can withstand 175°C for 24 hours and maintain repellency
Contact Angles (static, dip coated/dried on glass substrate)	105° (water), 65° (hexadecane)	105° (water), 65° (hexadecane)
Solder-Through Repairability	Yes	Yes

### The 3M™ Novec™ Brand Family

The Novec brand is the hallmark for a variety of patented 3M compounds. Although each has its own unique formula and performance properties, all Novec products are designed in common to address the need for safe, effective, sustainable solutions in industry-specific applications. These include precision and electronics cleaning, heat transfer, protective coatings and surface modifiers, fire protection, lubricant deposition and several specialty chemical applications.

3M™ Novec™ Engineered Fluids • 3M™ Novec™ Aerosol Cleaners • 3M™ Novec™ 1230 Fire Protection Fluid • 3M™ Novec™ Electronic Grade Coatings • 3M™ Novec™ Electronic Surfactants

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