ROSIN VS. NON-ROSIN WAVE FLUX
WHICH CREATES MORE RELIABLE ELECTRONIC ASSEMBLIES?

Adam Murling and Ron Lasky, Ph.D.
Indium Corporation
Clinton, NY, US
amurling@indium.com; rlasky@indium.com

ABSTRACT
Is there a benefit to using wave soldering fluxes that contain rosin versus ones that do not? Rosin-based fluxes are some of the original types of fluxes used in the early years of the electronics industry. They are based on material obtained from pine trees and other plants, primarily conifers. Rosin-based fluxes are non-corrosive at room temperature, hygroscopic, and normally cure at room temperature to entrap potentially corrosive activators. In comparison, non-rosin fluxes − especially water-wash − contain aggressive acids that need to be cleaned off after the wave soldering process. If the assemblies are not cleaned, the residue can cause corrosion and dendritic growth.

A manufacturer can choose either a rosin-containing or a non-rosin-containing flux based on the solvent used, the ratio of flux to solvent, and the current cleaning process, to name a few. The choice is made as a result of multiple factors that come into play when wave soldering, such as thermal profile, type of flux, flux application, solder alloy type, preheat time, temperature, and wave contact time.

In this series of experiments, the independent variable was the flux type. The previously mentioned variables were varied in a designed experiment format. To evaluate the quality of the resulting assemblies, the current IPC surface insulation resistance (SIR) test was employed. Data were collected to determine the reliability of three rosin-containing and three non-rosin-containing wave fluxes. In addition, microphotographs of typical resulting solder joints were taken to observe workmanship and esthetic properties of the solder joints.

Key words: wave soldering fluxes, wave soldering, SIR testing

INTRODUCTION
It is not a stretch to say that flux is as old as the electronics industry. In that time, there have been many attempts to classify and reclassify flux to meet industry standards. The selection of flux used for a particular product is often decided by the manufacturers, especially if the manufacturers are facets of the military or aerospace industry. If the choice of flux is unrestrained, several variables need to be considered to make an appropriate selection. This paper focuses on the surface insulation resistance (SIR) differences between rosin-containing and rosin-free flux formulations.

After wave soldering, it used to be common practice to clean the underside of the board by using some form of rotary brushing and suitable solvent to remove flux and flux residues. That changed with the advent of no-clean fluxes. This suite of fluxes eliminated the need for manufacturers to clean their boards post-soldering. This did not mean that there was zero residue left on the board from the flux, but that the residue remaining was non-corrosive to the board or components, and would not jeopardize the long-term reliability of the assembly.

Today, there are 24 different types of fluxes, with four main categories including rosin, resin, organic, and inorganic. Each of these categories is then broken down into six activity levels, as shown in Table 1 (see end of paper for enlarged table).

Table 1. IPC Flux Characteristics

Flux Composition	Flux/Flux Residue Activity Levels	% Halide[1] (by weight)	Flux Type[2]	Flux Designator
Rosin (RO)	Low	<0.05%	L0	ROL0
		<0.5%	L1	ROL1
	Moderate	<0.05%	M0	ROM0
		0.5-2.0%	M1	ROM1
	High	<0.05%	H0	ROH0
		>2.0%	H1	ROH1
Resin (RE)	Low	<0.05%	L0	REL0
		<0.5%	L1	REL1
	Moderate	<0.05%	M0	REM0
		0.5-2.0%	M1	REM1
	High	<0.05%	H0	REH0
		>2.0%	H1	REH1
Organic (OR)	Low	<0.05%	L0	ORL0
		<0.5%	L1	ORL1
	Moderate	<0.05%	M0	ORM0
		0.5-2.0%	M1	ORM1
	High	<0.05%	H0	ORH0
		>2.0%	H1	ORH1
Inorganic (IN)	Low	<0.05%	L0	INL0
		<0.5%	L1	INL1
	Moderate	<0.05%	M0	INM0
		0.5-2.0%	M1	INM1
	High	<0.05%	H0	INH0
		>2.0%	H1	INH1

1. Halide measuring <0.05% by weight in flux solids and may be known as halide-free. This method determines the amount of ionic halide present (see Appendix B-10).
2. The 0 and 1 indicate the absence or presence of halides, respectively. See paragraph 3.3.1.2.2 for flux type nomenclature.

EXPERIMENT
The IPC-B-24 test boards (Figure 1) used in this experiment were cleaned in an ionic contamination tester containing 75% 2-propanol and 25% deionized water until the resistivity measured 150 M-Ohms. After the boards were removed from this bath, they were placed in an oven set to 50°C for two hours to ensure the boards were sufficiently dry. Once dry, each flux was applied to six boards, three of which were subjected to preheat and a down pattern wave solder, and the other three to pattern up. Each flux was dispensed at the optimum deposition rate (Table 2).

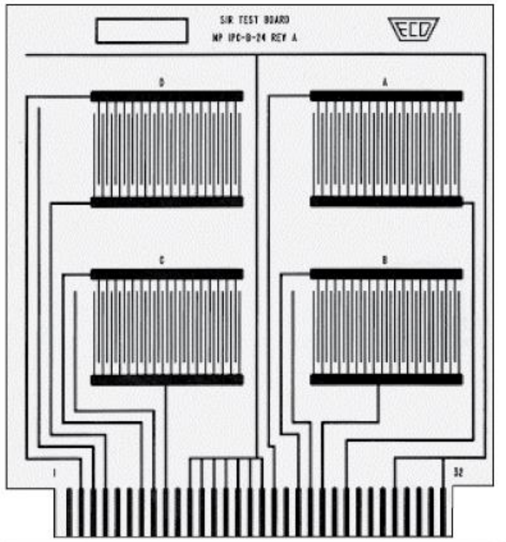

Figure 1. IPC-B-24 Test Board

Table 2. Deposition Rates

Flux	Deposition (mL/min)
A	29.5
B	39.0
C	52.0
D	37.5
E	23.0
F	31.0

All boards passed through the spray fluxer at a speed of 2 ft/min, which was then increased to 3 ft/min for the preheat and wave sections. After the flux was deposited, each flux was subjected to a ramp-style profile that increased by 2–4°C/s before contacting the solder wave (265°C) for 2–4 seconds. A schematic of a lead-free wave solder profile can be seen in Figure 2. Once the soldering process was finished, all of the soldered boards were submitted to SIR testing per IPC-TM-650 2.6.3.7 for 168 hours. Since all of the fluxes were no-clean, no cleaning processes were performed after soldering.

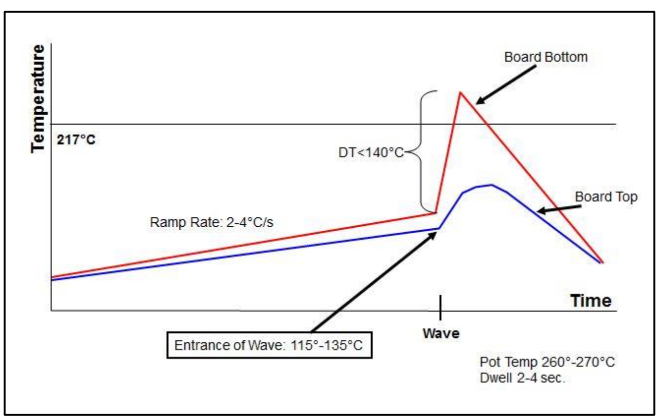

Figure 2. Lead-Free Wave Solder Profile

RESULTS

The results of the SIR test for each flux can be seen in Figures 3–15. All of the fluxes exhibited a resistance above the minimum limit of 1 x 10^8 ohms. No dendrite growth occurred on any of the samples. It is notable that Flux E, Board 2, Pattern D was shorted prior to testing and was removed from Figure 12. According to J-STD-004B, the passing requirements for the fluxes are that all SIR readings after 24 hours must be 1 x 10^8 ohms or higher over the remaining duration of the test.

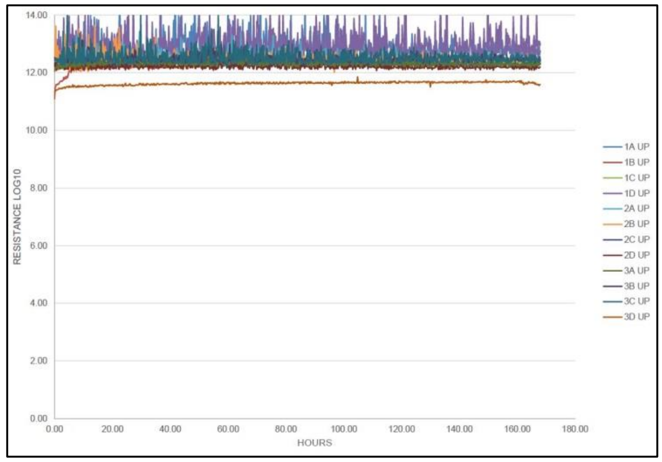

Figure 3. Flux A, (Rosin-Containing) Pattern Up SIR Results

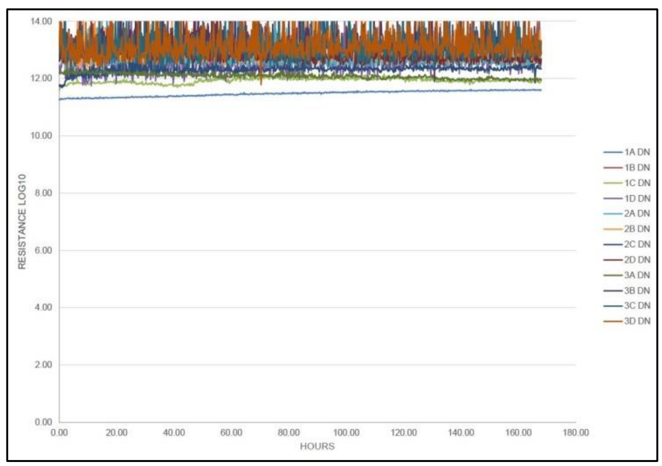

Figure 4. Flux A, (Rosin-Containing) Pattern Down SIR Results

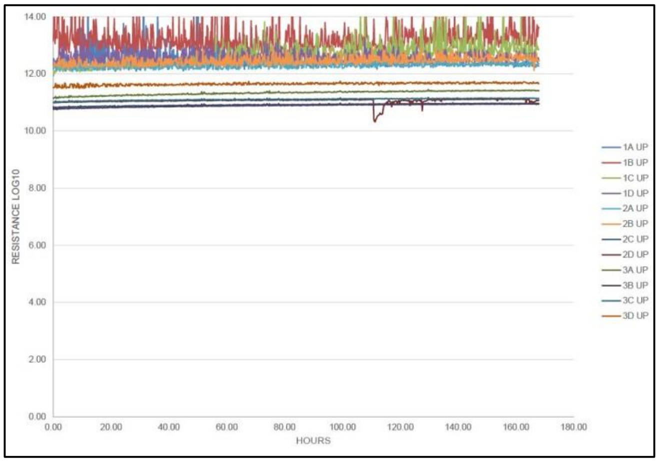

Figure 5. Flux B, (Rosin-Containing) Pattern Up SIR Results

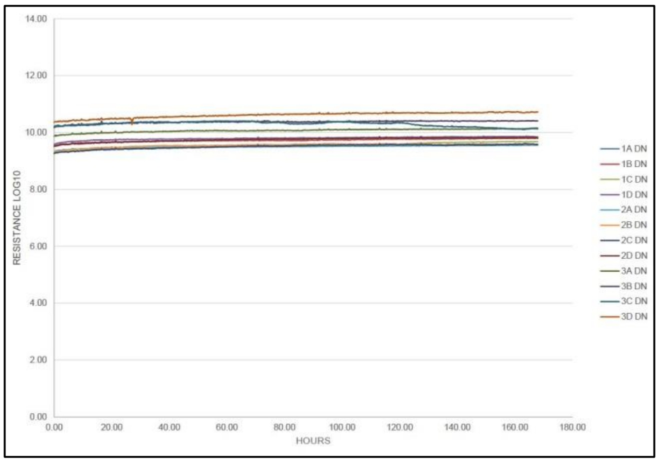

Figure 6. Flux B, (Rosin-Containing) Pattern Down SIR Results

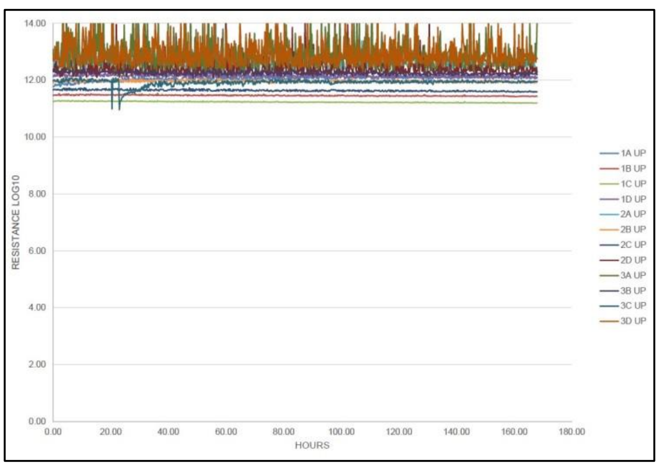

Figure 7. Flux C, (Rosin-Containing) Pattern Up SIR Results

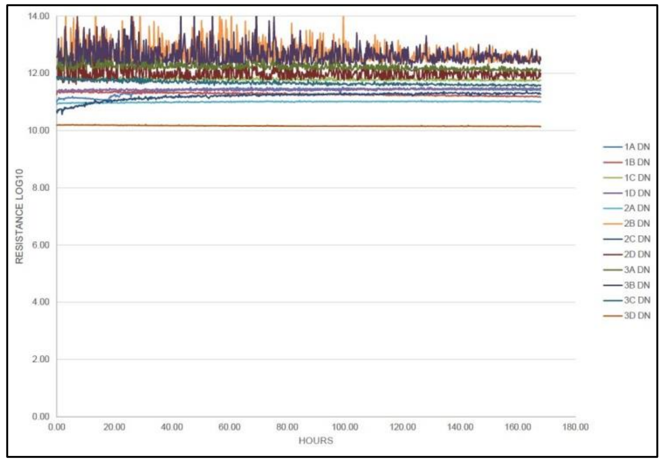

Figure 8. Flux C, (Rosin-Containing) Pattern Down SIR Results

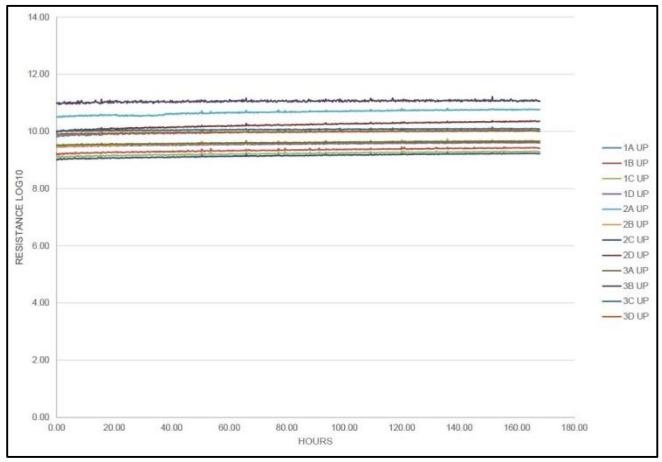

Figure 9. Flux D, (Organic) Pattern Up SIR Results

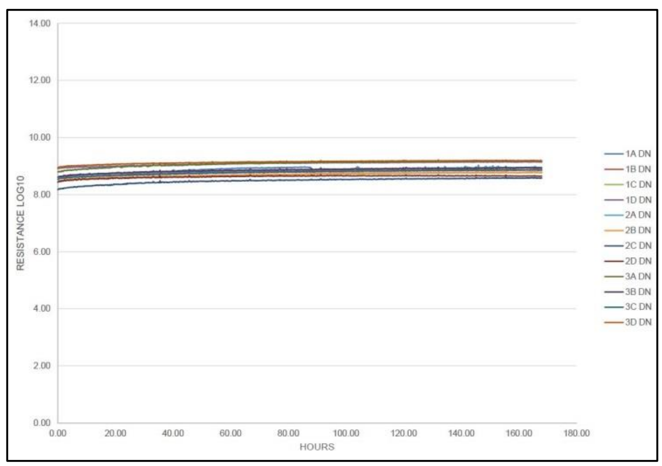

Figure 10. Flux D, (Organic) Pattern Down SIR Results

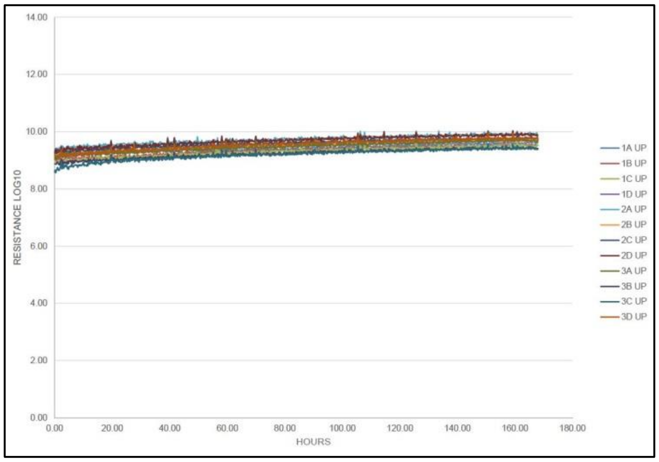

Figure 11. Flux E, (Organic) Pattern Up SIR Results

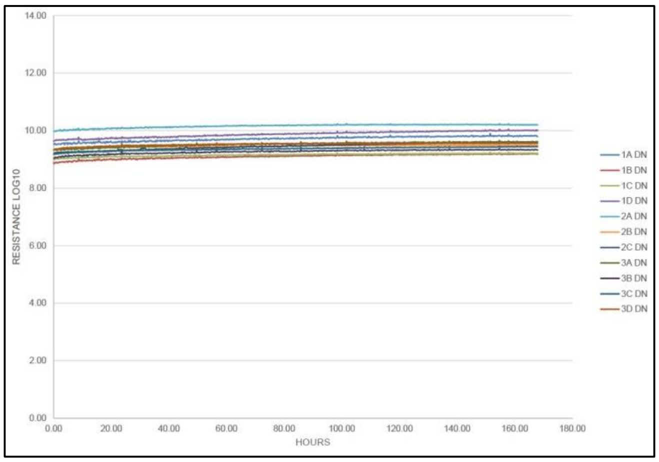

Figure 12. Flux E, (Organic) Pattern Down SIR Results

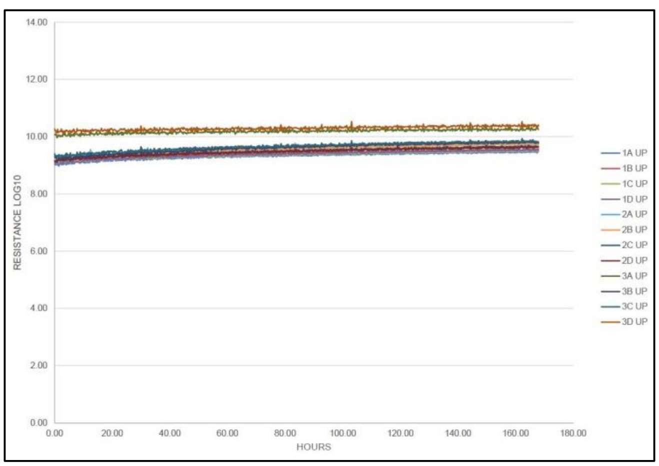

Figure 13. Flux F, (Organic) Pattern Up SIR Results

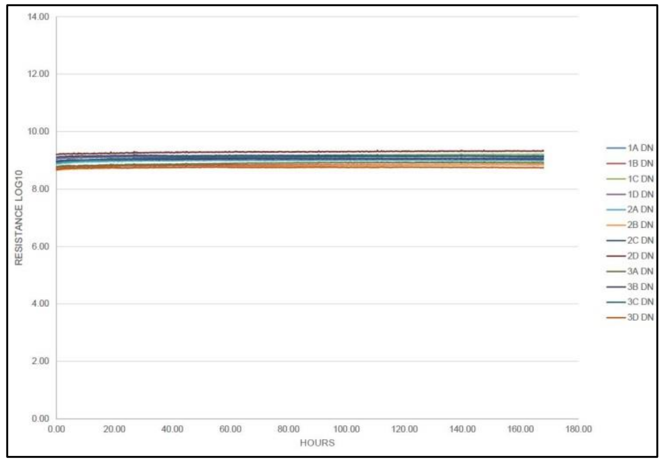

Figure 14. Flux F, (Organic) Pattern Down SIR Results

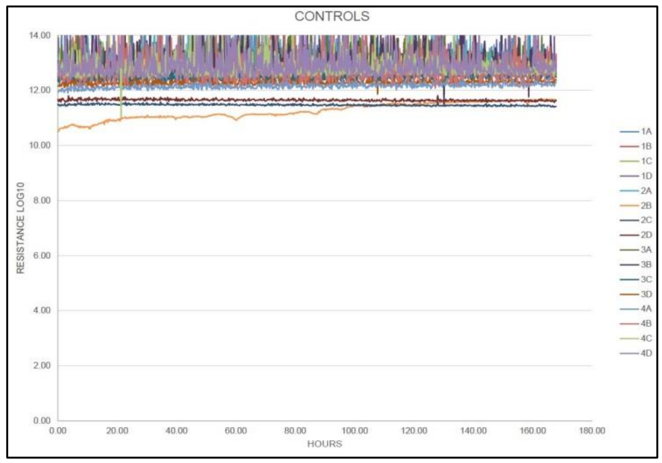

Figure 15. Controls

It was difficult to distinguish any type of differences between all of the passing fluxes by just using Figures 3–15. In an attempt to understand the data further, the SIR data was averaged per flux and placed on the same graph to observe any trends. The overall averages were calculated, specifically the pattern up and pattern down averages. The averages can be seen in Table 3**,** and a graphical representation is shown in Figure 16.

Table 3. Log_{10} SIR Averages (Ohms)

Flux	Overall Average	Pattern Down	Pattern Up	Rosin or Organic
A	12.52	12.62	12.42	Rosin
B	10.87	9.85	11.88	Rosin
C	11.88	11.62	12.13	Rosin
D	9.35	8.83	9.87	Organic
E	9.34	9.22	9.46	Organic
F	9.31	9.01	9.61	Organic

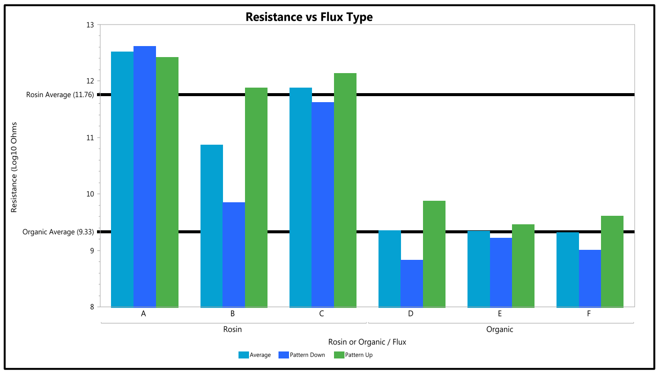

Figure 16. Resistance vs. Flux Type (Ohms).
Note that although all fluxes pass the minimum requirement ($\log_{10}$ R= 8), however rosin fluxes had a resistance two orders of magnitude better than organic fluxes.

Examples of passing and failing SIR boards can be seen in the following four figures (Figures 17-20). They are solely representative and were obtained through other laboratory research experiments.

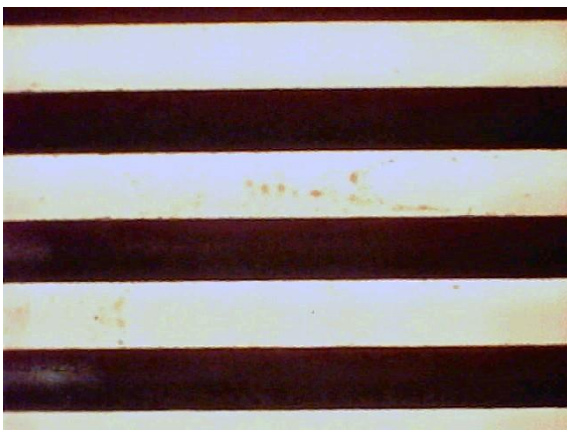

Figure 17. Example of a Failing SIR Board Backlight 30X Mag

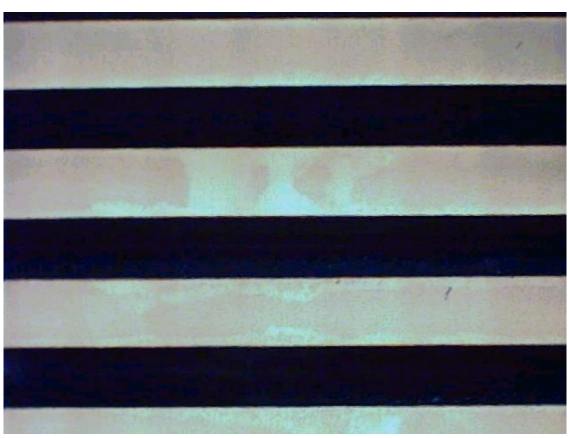

Figure 18. Example of a Passing SIR Board Backlight 30X Mag

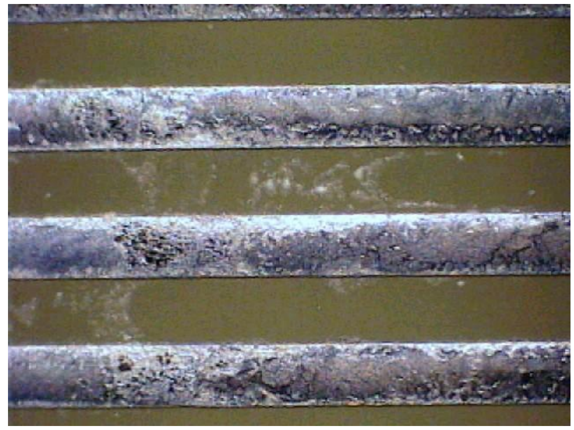

Figure 19. Example of a Failing SIR Board Top Light 30X Mag

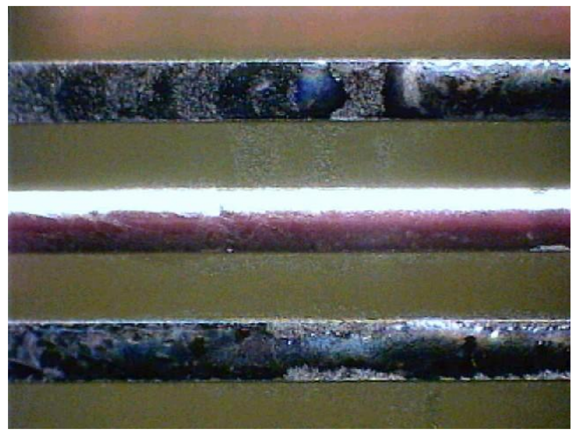

Figure 20. Example of a Passing SIR Board Top Light 30X Mag

CONCLUSION

Both the organic fluxes and the rosin-based, no-clean fluxes passed the SIR test, which made it difficult to ascertain a trend. This is why the data was broken down further and represented in Figure 16. Having the data presented this way makes it easier to see a clear disparity between the rosin-containing fluxes and their organic counterparts. The $\log_{10}$ of the overall average for the rosin-based fluxes was 11.76 ohms, while the organic fluxes were stable at 9.33 ohms. The rosin-based fluxes are more than 2 orders of magnitude greater in SIR than the organic fluxes. Having a higher resistivity implies that the material will be more resistant to dendritic growth and other defects. However, it is important to remember that the organic fluxes were above the minimum of $\log_{10}$ R = 8 ohms and passed per J-STD-004B.

Five out of the 6 fluxes' pattern down means were lower than the pattern up means, which is to be expected. It is intriguing that Flux A's SIR was better than the other 5, requiring future research and experimentation to arrive at a conclusion.

Table 1. IPC Flux Characteristics

Flux Composition	Flux/Flux Residue Activity Levels	% Halide[1] (by weight)	Flux Type[2]	Flux Designator
Rosin (RO)	Low	<0.05%	L0	ROL0
		<0.5%	L1	ROL1
	Moderate	<0.05%	M0	ROM0
		0.5-2.0%	M1	ROM1
	High	<0.05%	H0	ROH0
		>2.0%	H1	ROH1
Resin (RE)	Low	<0.05%	L0	REL0
		<0.5%	L1	REL1
	Moderate	<0.05%	M0	REM0
		0.5-2.0%	M1	REM1
	High	<0.05%	H0	REH0
		>2.0%	H1	REH1
Organic (OR)	Low	<0.05%	L0	ORL0
		<0.5%	L1	ORL1
	Moderate	<0.05%	M0	ORM0
		0.5-2.0%	M1	ORM1
	High	<0.05%	H0	ORH0
		>2.0%	H1	ORH1
Inorganic (IN)	Low	<0.05%	L0	INL0
		<0.5%	L1	INL1
	Moderate	<0.05%	M0	INM0
		0.5-2.0%	M1	INM1
	High	<0.05%	H0	INH0
		>2.0%	H1	INH1

1. Halide measuring <0.05% by weight in flux solids and may be known as halide-free. This method determines the amount of ionic halide present (see Appendix B-10).
2. The 0 and 1 indicate the absence or presence of halides, respectively. See paragraph 3.3.1.2.2 for flux type nomenclature.

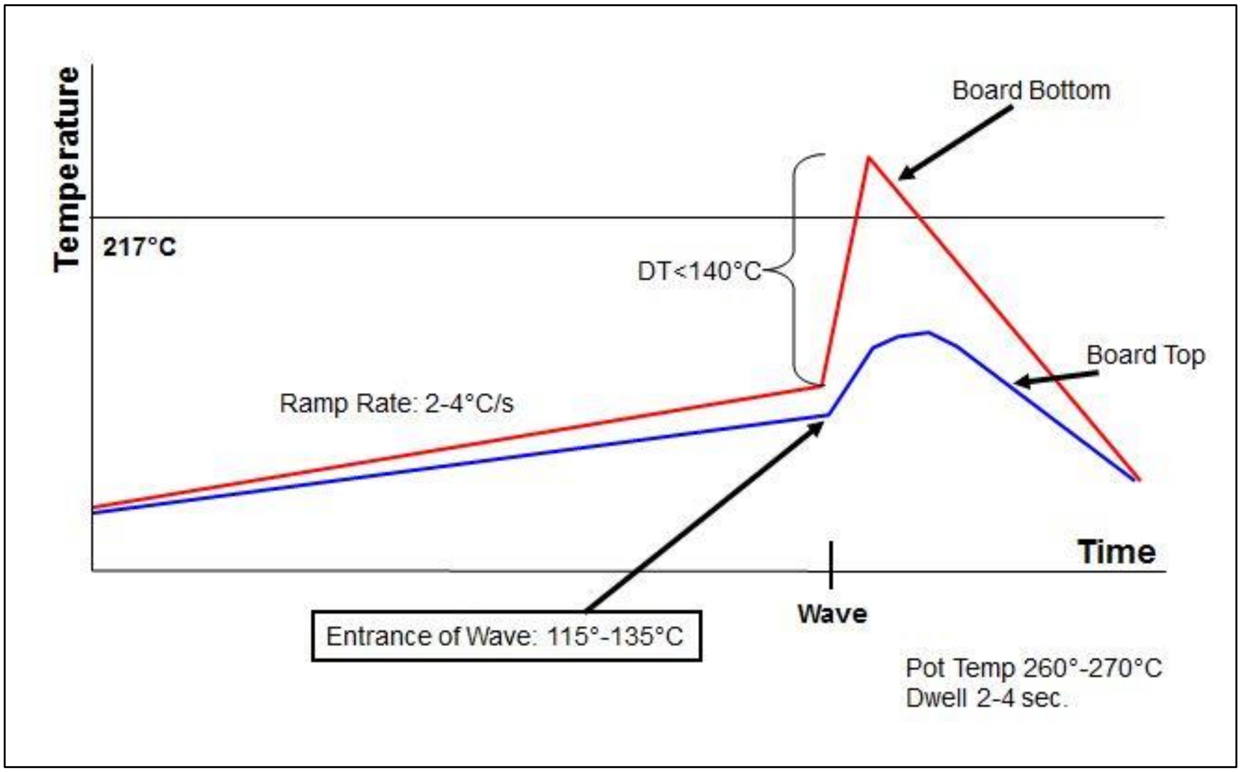

Figure 2. Lead-Free Wave Solder Profile

Figure 3. Flux A, (Rosin-Containing) Pattern Up SIR Results

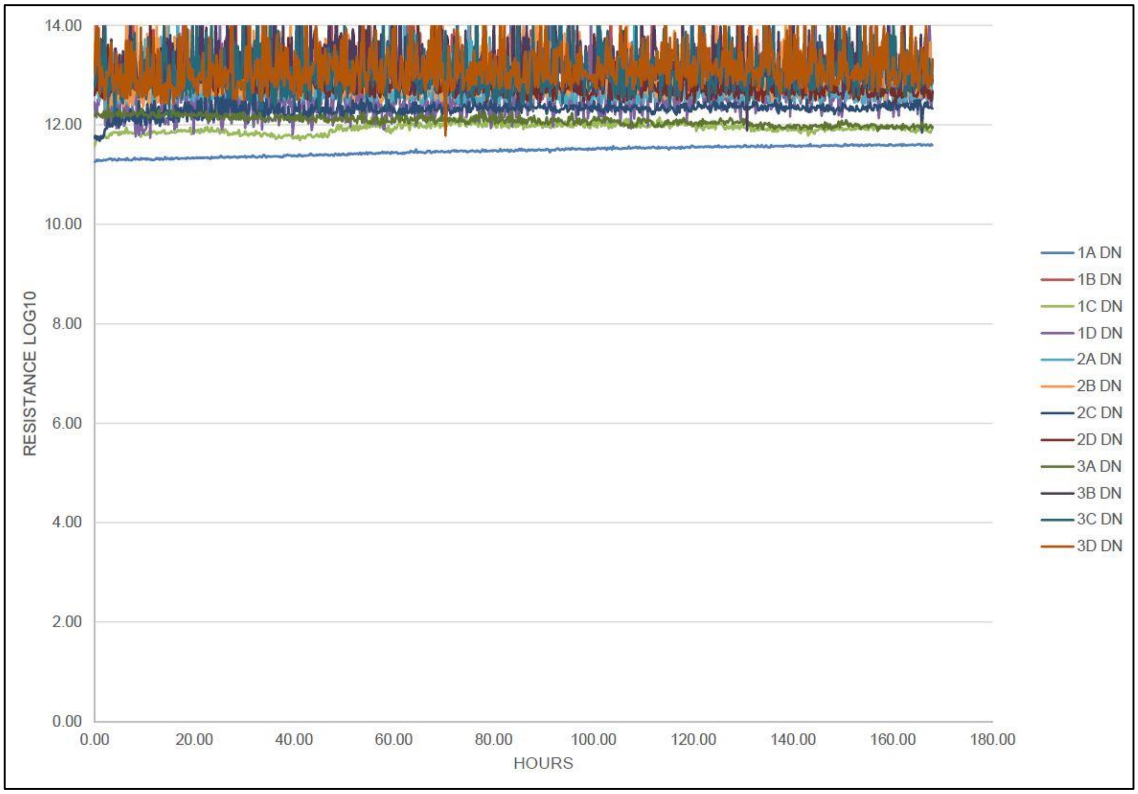

Figure 4. Flux A, (Rosin-Containing) Pattern Down SIR Results

Figure 5. Flux B, (Rosin-Containing) Pattern Up SIR Results

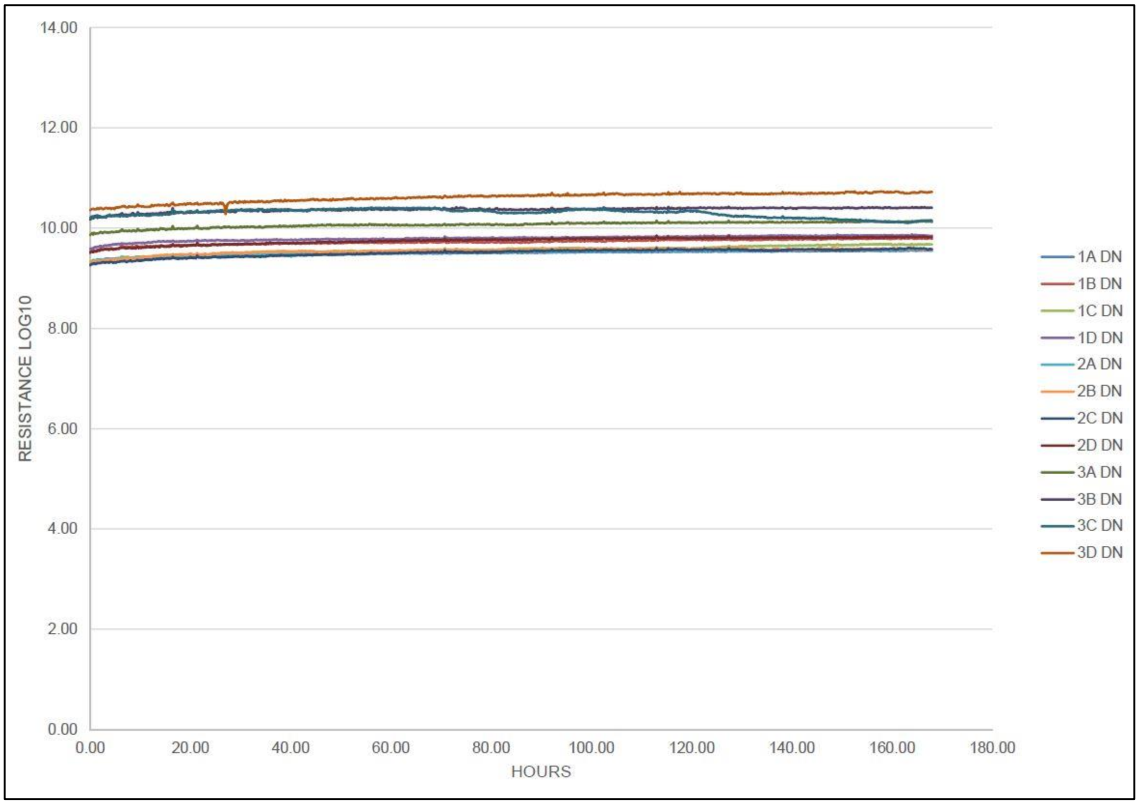

Figure 6. Flux B, (Rosin-Containing) Pattern Down SIR Results

Figure 7. Flux C, (Rosin-Containing) Pattern Up SIR Results

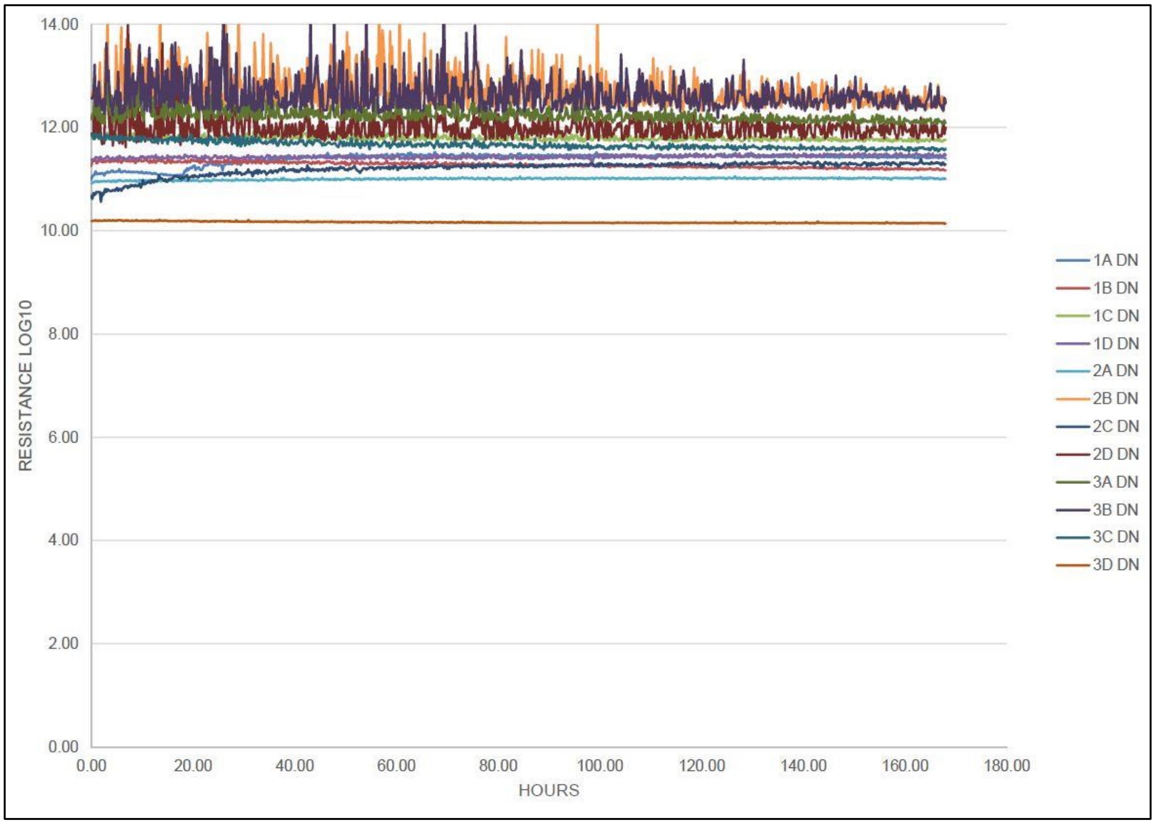

Figure 8. Flux C, (Rosin-Containing) Pattern Down SIR Results

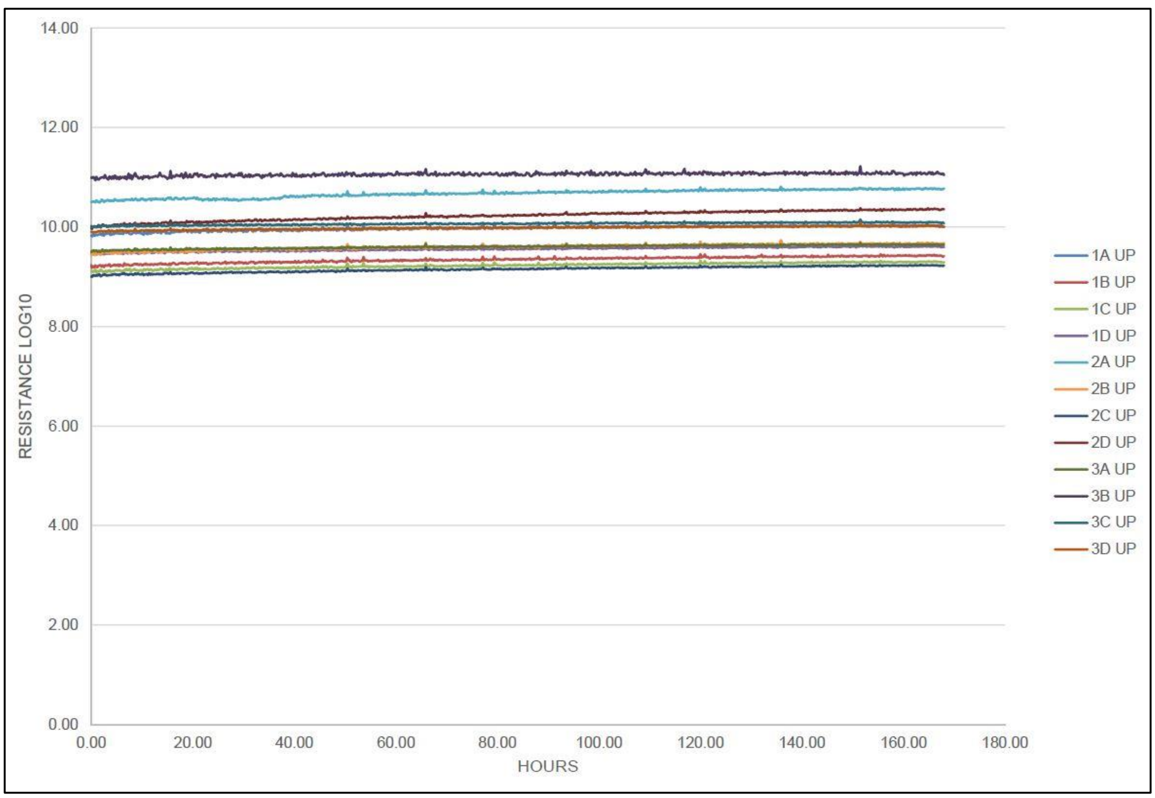

Figure 9. Flux D, (Organic) Pattern Up SIR Results

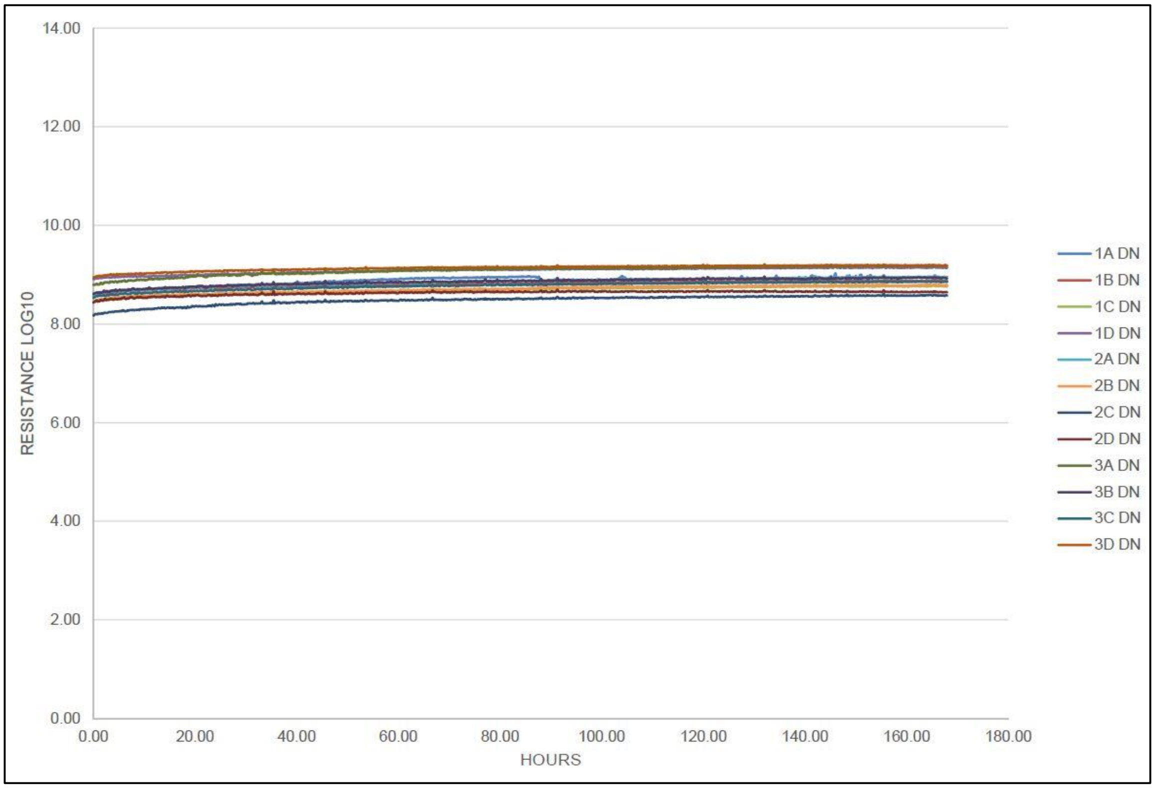

Figure 10. Flux D, (Organic) Pattern Down SIR Results

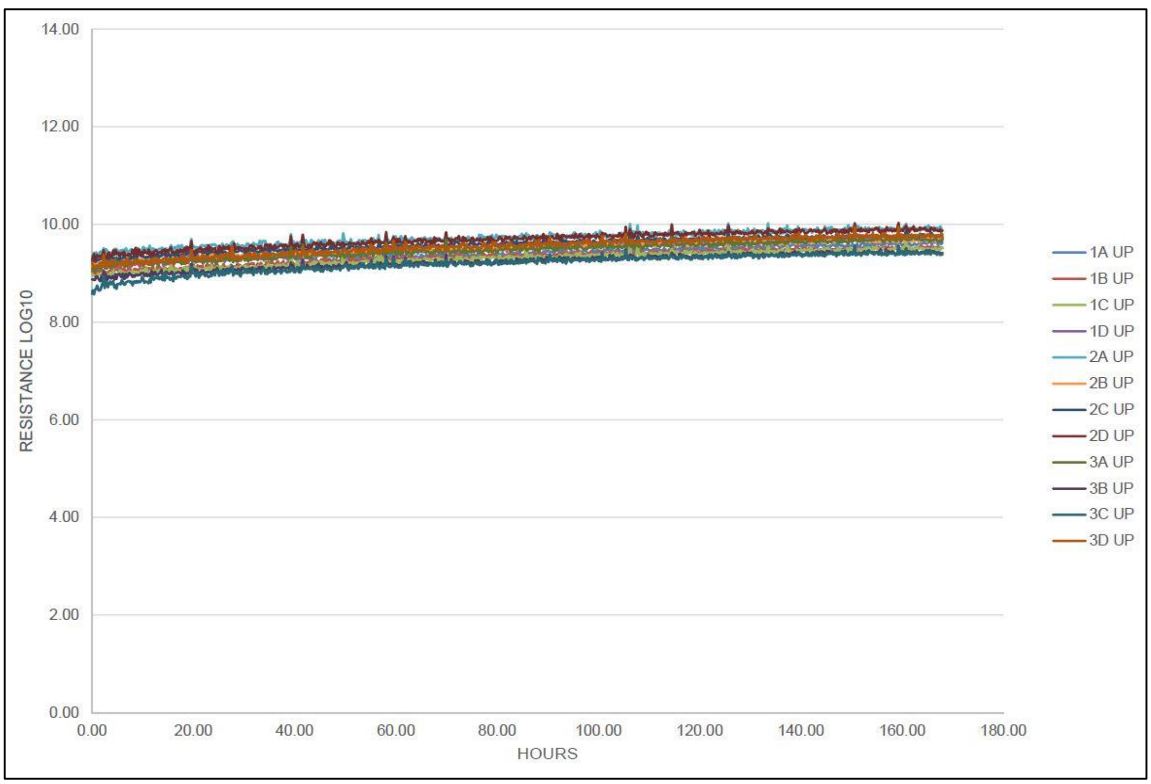

Figure 11. Flux E, (Organic) Pattern Up SIR Results

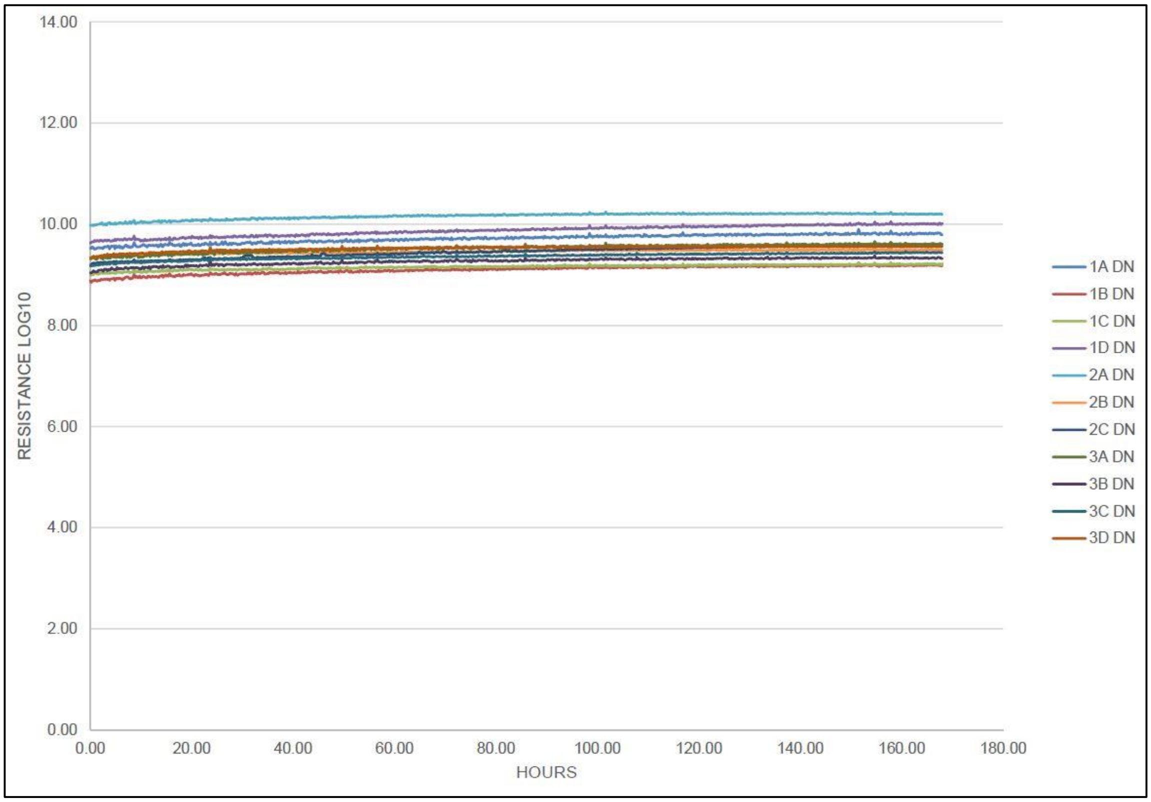

Figure 12. Flux E, (Organic) Pattern Down SIR Results

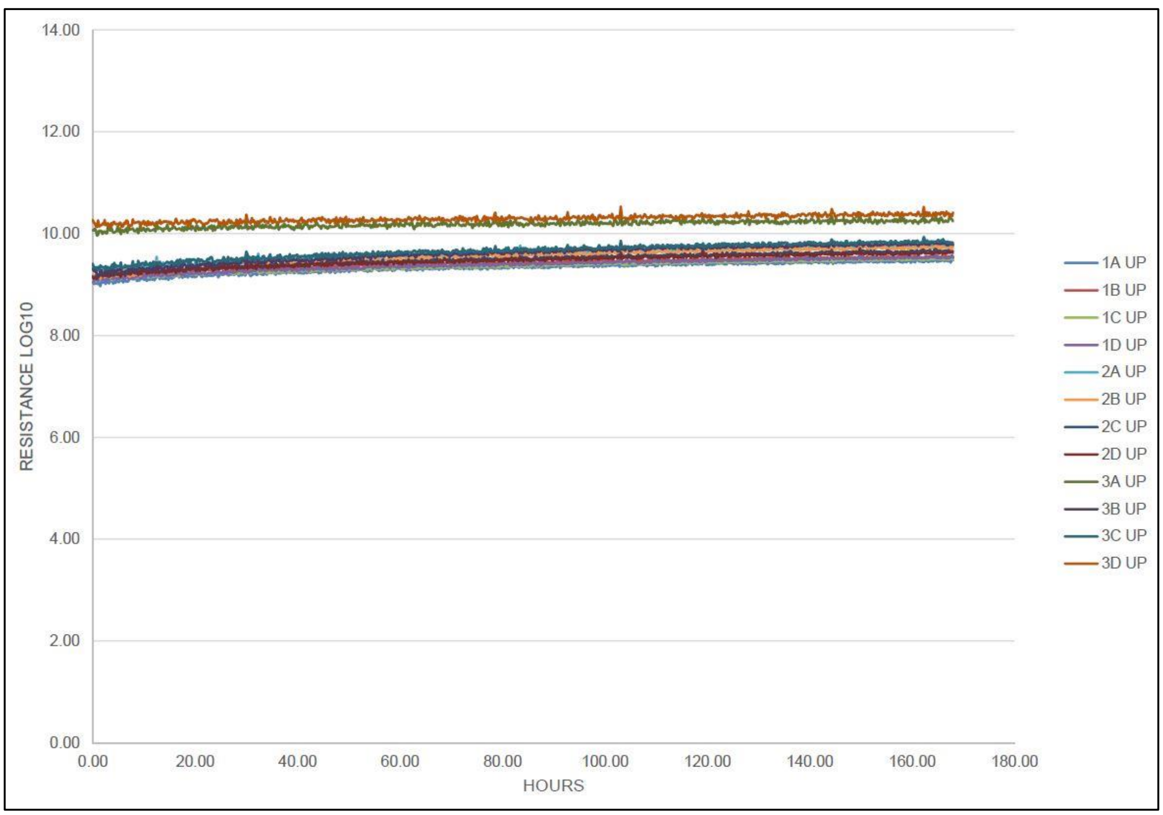

Figure 13. Flux F, (Organic) Pattern Up SIR Results

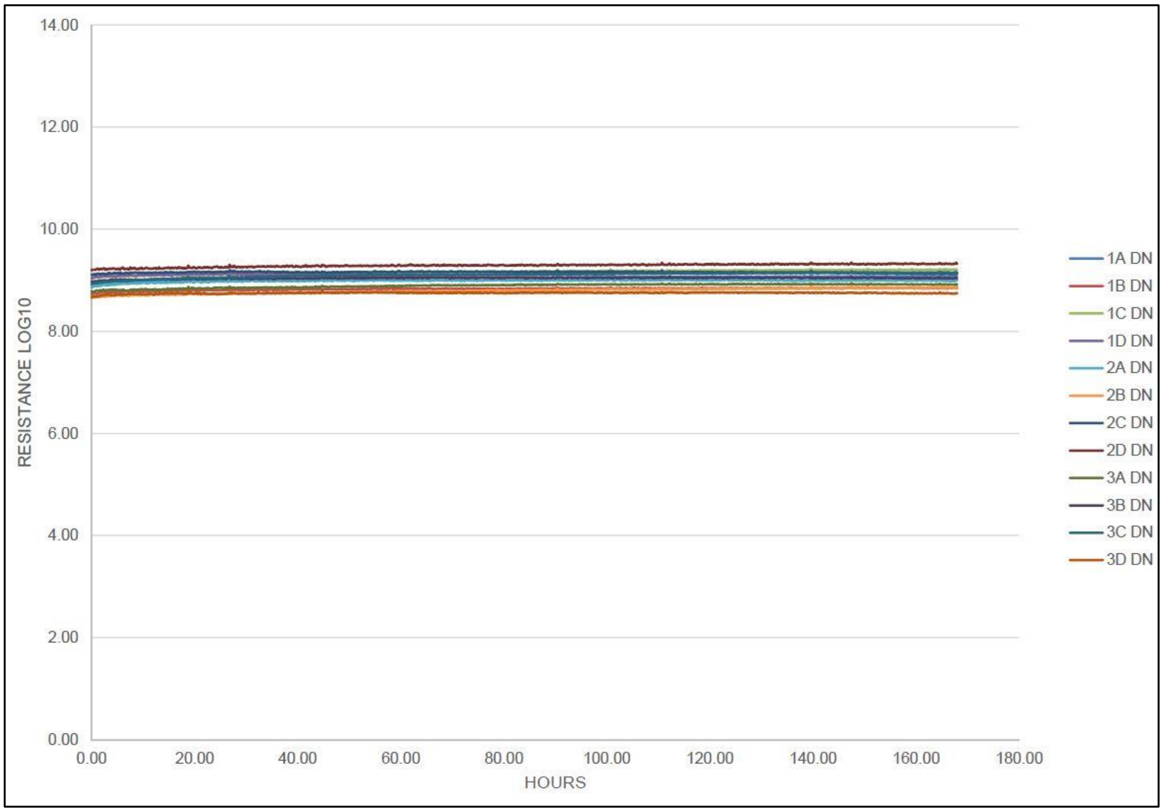

Figure 14. Flux F, (Organic) Pattern Down SIR Results

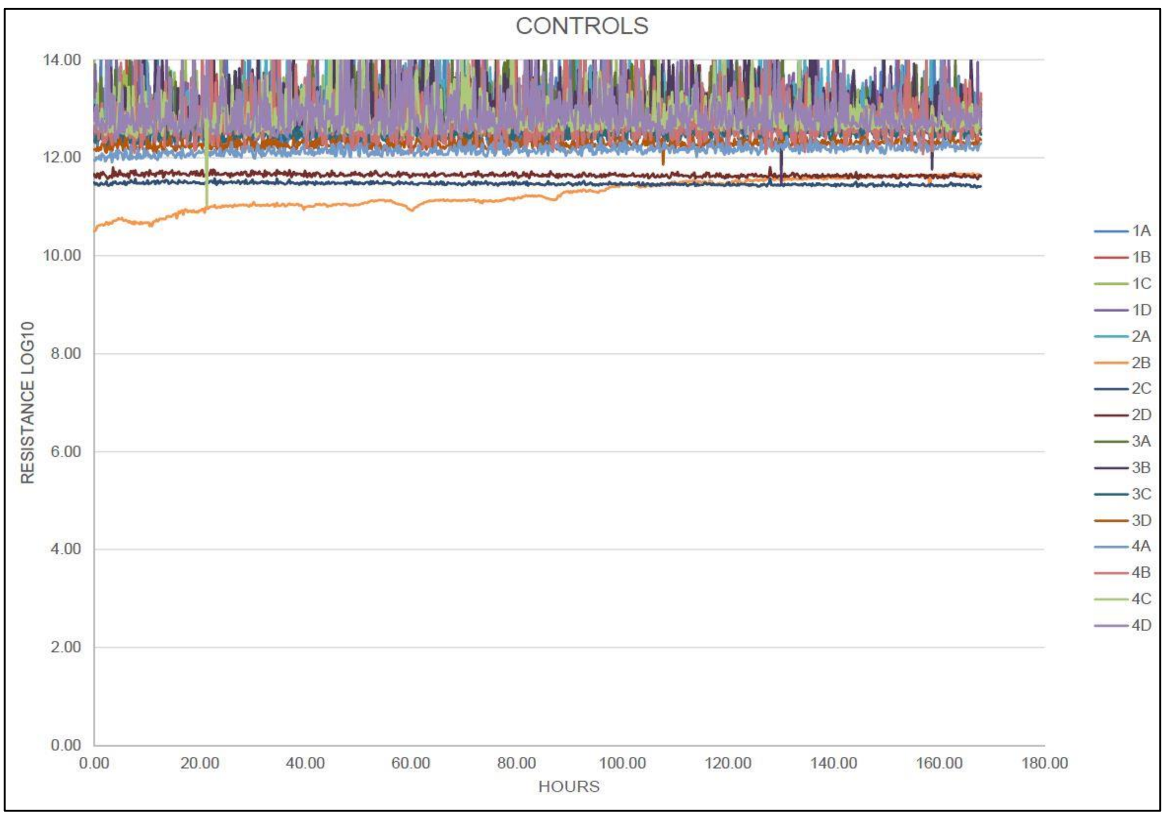

Figure 15. Controls

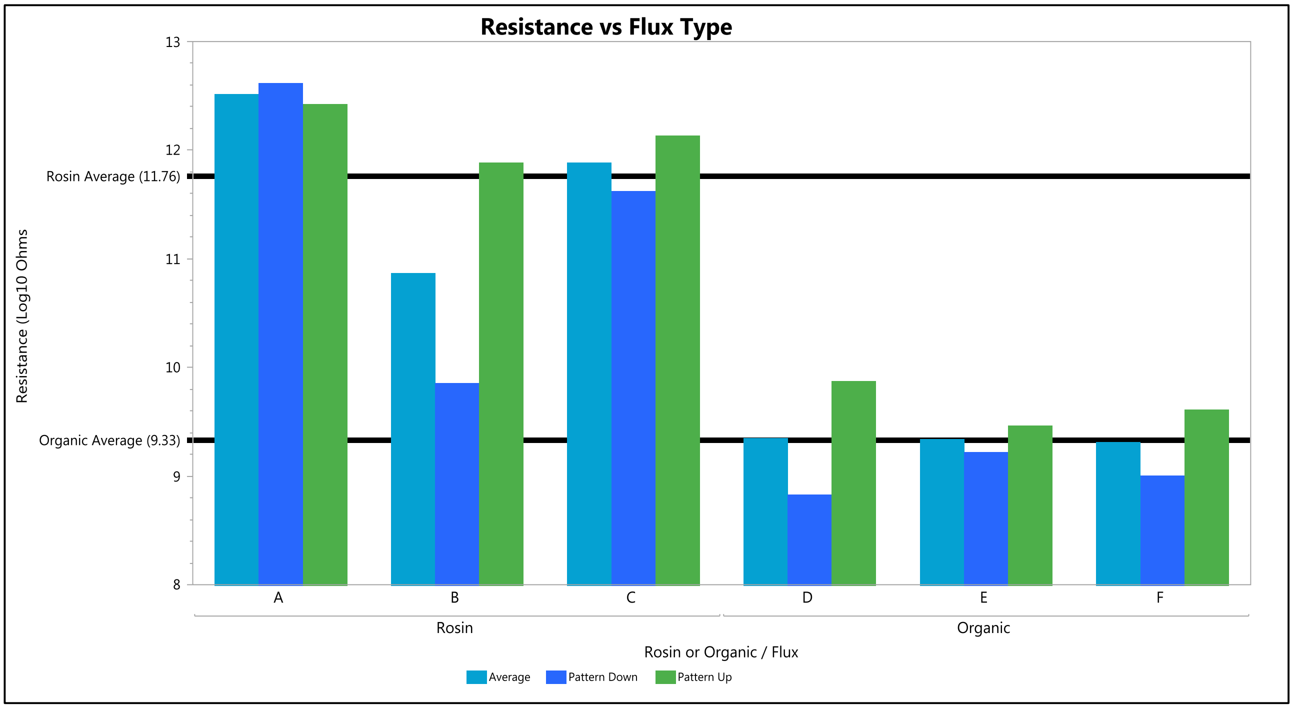

Figure 16. Resistance vs. Flux Type (Ohms). Note that although all fluxes pass the minimum requirement ($\log_{10}$ R= 8), rosin fluxes had a resistance two orders of magnitude better than organic fluxes