Engineered Cleaning Agent Study as a Function of Rinsing under Low Profile Components

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ABSTRACT

Best practice for cleaning printed circuit board assemblies (PCBA) uses an aqueous-based process. The engineered aqueous cleaning material uses low vapor pressure oxygenated compounds that combine ethers, glycols, and modified alcohols blended into an aqueous medium. The cleaning fluid is typically diluted in water and delivered to the electronic assembly being cleaned using spray-in-air cleaning tools.

Aqueous cleaning processes are dynamic. Flux and process residues removed from the PCBA's are non-volatile. As the non-volatile residues build up into the wash chemistry, rinsing can be compromised. Additionally, some engineered cleaning agents are harder to rinse than other designs.

The purpose of this research is to study rinsing effects as a function of loading and cleaning agent design. A new type of sensor for non-ionic organic compounds integrated within the machine will be used to monitor both cleaning agent saturation and flux residues within the rinse streams. A custom-designed SIR test board will be used to monitor rinsing effects. Absorbance, conductivity, contact angle measurements, and SIR response will be used to monitor rinse water quality.

Key words: Cleanliness, Rinsing, Electrochemical Reliability

INTRODUCTION

The evolution of electronics has resulted in increased board density. Interconnect solutions are trending toward bottom terminations with tighter pitches between conductors of opposite polarity. Miniaturization requires a higher degree of built-in components and functionalities.

When the device is exposed to environmental climates, moisture can form on the surface of the electronics[1]. This moisture dissolves ionic residue, which forms an acidic electrolyte, and can mobilize metal oxides. When the device is operated, the electrical bias creates the electrical field, which enables these metal oxides to migrate in the form of leakage currents, which results in intermittent and long-term failures.

PCBA cleanliness is one of the more important factors in preventing water build-up onto the assembly. Cleanliness influences humidity-related failures by: [1]

1. Reducing the deliquescent relative humidity level at which residue absorbs moisture
2. Increases the efflorescence relative humidity level at which the water films release the dew formation when ambient humidity level drops
3. Cleanliness reduces the water films since there is no residue present to absorb and trap water next to conductors

The rinse step is critical when cleaning electronic assemblies. Soil build-up in the wash and rinse fluids can trap these fluids under low-profile components.[2] The purpose of this research is to study the function of flux loading and cleaning agent design.

PURPOSE OF THE RESEARCH

1) Test and measure the influence of drag-over of nearly pure cleaner to the response of activated carbon and ion exchanger in cascade rinsing (both 1st and 2nd rinse steps).

2) To compare the response of two different engineered cleaning fluids using the same process conditions. This comparison was performed on two types of solder pastes.

3) Test and measure rinsing response on continuous loading of the cleaning bath with reflowed flux. The

research design allows for a study of the correlation of the quality of rinse baths to SIR values, surface tension with measurable parameters of cleaning and rinsing baths: Loading of wash (OCS, NVR), rinsing (OCS response, conductivity, and COD chemical oxygen demand).

EXPERIMENTAL DESIGN

Test Board

A custom SIR test board was designed with two bottom terminated components referred to as QFP80 and QFP160. The QFP80 represents a big challenge for cleaning because the poles are quite long and wide. i.e. the gaps between poles are long and narrow (Figure 1). In the center of the component is a large SIR comb pattern, which is designed to detect trapped rinse fluids.

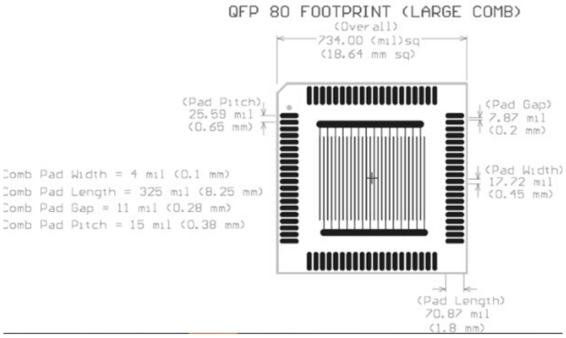


Figure 1: QFP-80 Component Design
(Channel A -between poles; Channel B – SIR comb)

The QFP-160 has a smaller pad design, which makes for an easier-to-clean component (Figure 2). The SIR Comb under the component termination is designed to detect trapped wash fluids that have not been fully rinsed.

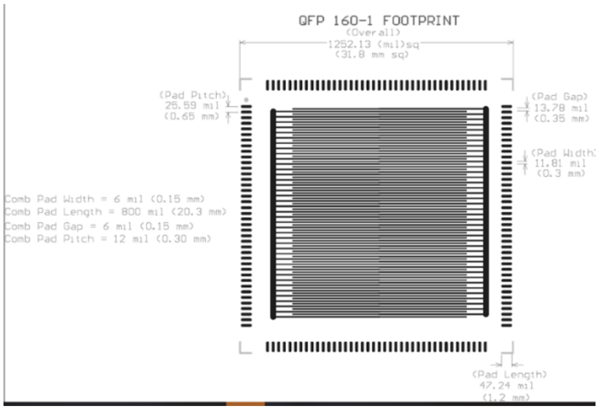


Figure 2: QFP-160 Component Design
(Channel C- between poles; Channel D -SIR comb

The standoff distance between the component and PCB was optically measured at roughly 130µm. The spaces between poles are filled with flux residues; only some bubbles are visible in the residues structure (Figures 3 &4).

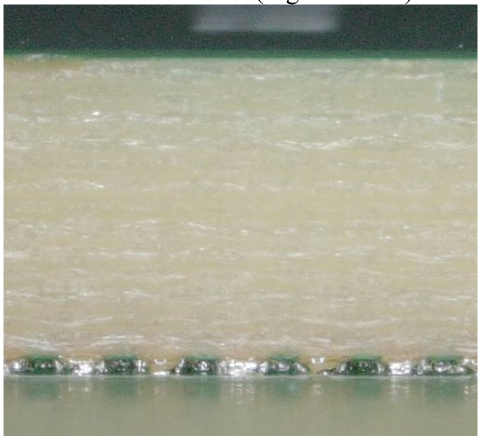


Figure 3: QFP-80 Side View

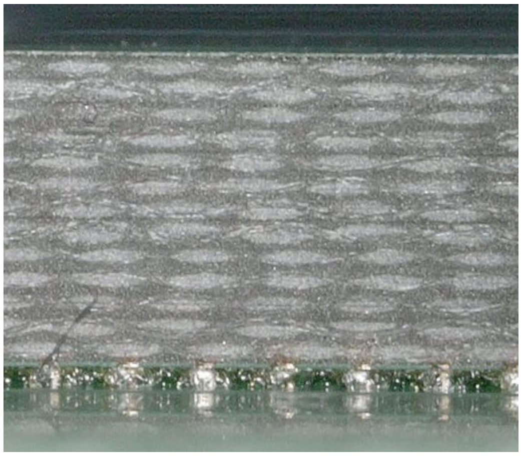
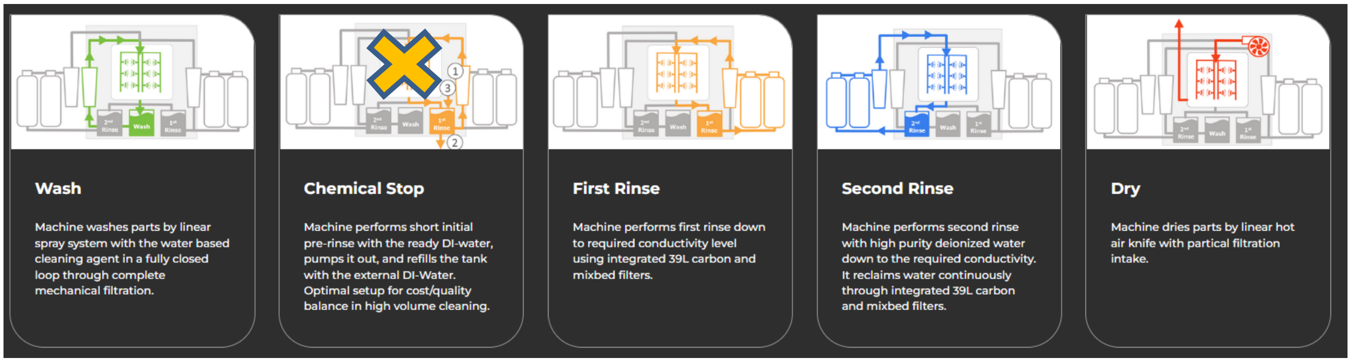


Figure 4: QFP-160 Side View

Cleaning Machine

A stand-alone batch aqueous spray-in-air cleaning machine designed with a separated closed loop using a dedicated pump and water filtration system was selected for this research. The process cycles are shown in Figure 5.[3]



Wash

Machine washes parts by linear spray system with the water based cleaning agent in a fully closed loop through complete mechanical filtration.

Chemical Stop

Machine performs short initial pre-rinse with the ready DI-water, pumps it out, and refills the tank with the external DI-Water. Optimal setup for cost/quality balance in high volume cleaning.

First Rinse

Machine performs first rinse down to required conductivity level using integrated 39L carbon and mixbed filters.

Second Rinse

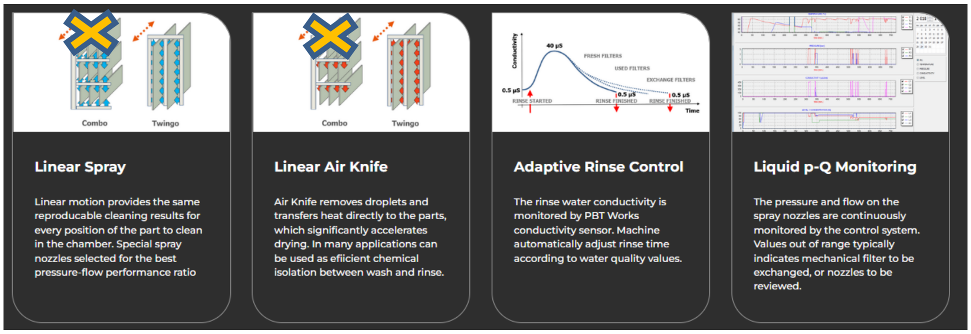
Machine performs second rinse with high purity deionized water down to the required conductivity. It reclaims water continuously through integrated 39L carbon and mixbed filters.

Dry

Machine dries parts by linear hot air knife with partical filtration intake.

Figure 5: Cleaning Machine Design. For the test, we did not use the chemical Stop. Machine was running in 100% close loop

To penetrate and remove flux residues under large area low profile components, a directed spray impingement is required. The closed loop rinse section uses carbon and ion exchange resins to remove wash fluids from the rinse water. A description of the process is shown in Figure 6.



Linear Spray

Linear motion provides the same reproducable cleaning results for every position of the part to clean in the chamber. Special spray nozzles selected for the best pressure-flow performance ratio

Linear Air Knife

Air Knife removes droplets and transfers heat directly to the parts, which significantly accelerates drying. In many applications can be used as efiicient chemical isolation between wash and rinse.

Adaptive Rinse Control

The rinse water conductivity is monitored by PBT Works conductivity sensor. Machine automatically adjust rinse time according to water quality values.

Liquid p-Q Monitoring

The pressure and flow on the spray nozzles are continuously monitored by the control system. Values out of range typically indicates mechanical filter to be exchanged, or nozzles to be reviewed.

Figure 6: Cleaning Process Design. For the test, we used the direct spray tooling configuration of the machine. Some quality parameters was measured and documented with the integrater data Monitoring . Adaptive rinse control was OFF for the purpose of the test

Engineered Cleaning Fluid

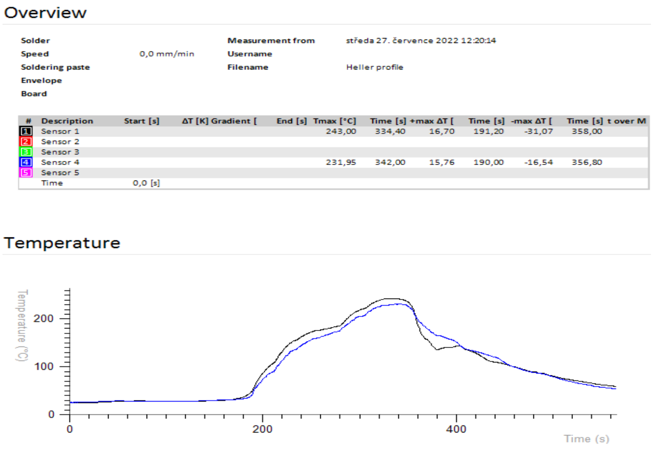
Two commercial cleaning fluids were selected. The first cleaning fluid combines solvency using oxygenated solvents combined with mild reactivity and functional additives. The second cleaning fluid combines solvency using oxygenated solvents combined with low reactivity and functional additives. Both cleaning agents are designed to form a solvent /water interface to achieve maximum cleaning performance.

Solder Paste

Two different low-residue solder pastes were selected for this study. The halogen-free pastes form a clear, probe-testable flux residue.

Flux Residue Loading into the Wash Fluid

Unpopulated blank boards were loaded with solder paste and reflowed. Six of these flux-loaded boards were added to each cleaning cycle to simulate the load from real assemblies. Each board was deposited with 33,3 grams of solder paste followed by reflow. So, total load per cycle was 200 grams. The temperature profile completely melted the paste using a peak temperature of 245-255°C for about 40 seconds.



Overview

Solder		Measurement from	středa 27. července 2022 12:20:14
Speed	0,0 mm/min	Username	
Soldering paste		Filename	Heller profile
Envelope			
Board			

#	Description	Start [s]	ΔT [K]	Gradient [	End [s]	Tmax [°C]	Time [s]	+max ΔT [	Time [s]	-max ΔT [	Time [s]	t over M
1	Sensor 1					243,00	334,40	16,70	191,20	-31,07	358,00	
2	Sensor 2											
3	Sensor 3											
4	Sensor 4					231,95	342,00	15,76	190,00	-16,54	356,80	
5	Sensor 5											
	Time	0,0 [s]										

Temperature

Figure 7: Reflow Profile

Figure 8: Solder Paste Loading board for profilling

Figure 9: Flux Residue Post Reflow

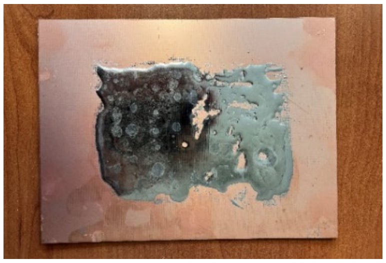


Figure 10: Flux Removed during the Cleaning Cycle

Wash Optimization

To investigate the rinsing quality, the wash time needed to fully remove the flux residues under the component termination was tested. Inspecting PCB and component after removal is very important in such cases. As the components were large, with many terminals, a mechanically rigid tool was used to shear the component from the circuit card. We placed the board on the milling machine table and shared chips by support (Very slow, manual feed).

Figure 11: Shearing the Component

The wash parameters settled on are shown in Table 1.

Table 1: Wash Conditions

Process	Medium	Temp [°C]	Time [min]	Pressure [Bar]	Agitation
Washing	According to the trial, 15%	60	30	3.2	Spray in Air
Rinsing	DI water	40	15	1.4	Spray in Air
Rinsing	DI water	40	7,5	2.4	Spray in Air
Drying	Hot Air	110	200	-	Hot Air Knife

Rinse Optimization

The proper setting of rinsing time is a matter of experience and feedback from the external measuring of PCB cleanliness. In this case, a recently developed Organic Carbon Sensor[4] was used to monitor both rinsing steps (Figure 12). In addition to measuring the resistivity of rinse water, the Organic Carbon Sensor allows for the measurement of non-ionic (or weak-ionic) residues and their absorption rate.

Figure 12: Organic Carbon Sensor (OCS)

Some test cycles were run to measure the response of rinsing water quality to the pollution from the drag-over from the wash step. The Organic Carbon Sensor data and conductivity data are shown in Figure 13. The plot shows the contact time required for the carbon and ion exchange resins to absorb the wash fluids from the rinse water.

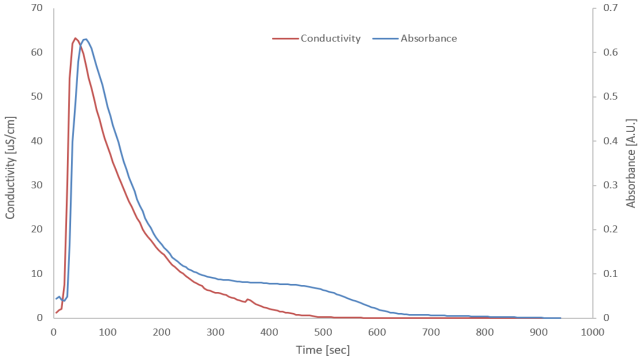


Figure 13: Contact time to Absorb Wash Fluids into Media

The shape of the conductivity and absorbance lines are similar. The initial shock of wash fluids from dragged-over cleaner to almost zero concentration took roughly 600 seconds (10 minutes).

When operating a cleaning process, it is important to monitor the absorption time. Otherwise, the non-absorbed residues stay in the rinse bath, and the next cycle starts from the higher level. Repeating this procedure leads to insufficient rinsing quality even when the activated carbon filters are not exhausted.

The record from the machine shows that 900 sec (15 min) to complete the absorption of both ionic and non-ionic contamination.

The Organic Carbon Sensor monitors and establishes the time to completely absorb the wash fluids in the first Rinse. Once the wash fluids are completely absorbed, the system starts the second Rinse, also known as a safety rinse, to ensure that the assemblies are free of any wash fluids. The time in the second Rinse is shorter, nominally 7.5 minutes.

Suppose during the test, the chemical filters become partially saturated. In that case, we cannot return to the original “zero” concentration in the first Rinse. The value of the Organic Carbon Sensor is to see and measure the influence of such a not ideal rinsing on SIR and the possible surface tension of samples.

TEST CONDITIONS AND RESULTS

The first set of tests was to clean SIR test boards using a fresh wash bath. Drag-over of the measured cleaning system was 0.8 liter/cycle. To test worst-case conditions, an artificial increasing of drag out was provided by installing the 200 mL pan. The total drag-over was therefore 1liter/cycle. The level of flux was negligible. Each cycle had only one test board and no loading boards.

Drag-over was measured volumetrically (from 10 subsequent cycles) and confirmed by measuring non–ionic contamination of a very clean first rinse using the following procedure.

1. Defined volume of cleaner was diluted in the 1st rinsing tank and measured by OCS (the absorbance).
2. The chemical filters were monitored to ensure total absorbance.
3. Volumetric concentration was compared with absorbance
4. The absorbance was measured by OCS after each wash cycle to calculate the actual drag-over. Within this range, the absorbance is linearly proportional to the amount of non–ionic contamination. Therefore, the drag-over can be accurately calculated.

WASH CHEMISTRY #1

Figure 14 plots the conductivity and absorbance in the first rinsing bath over 22 wash cycles using fresh wash chemistry.

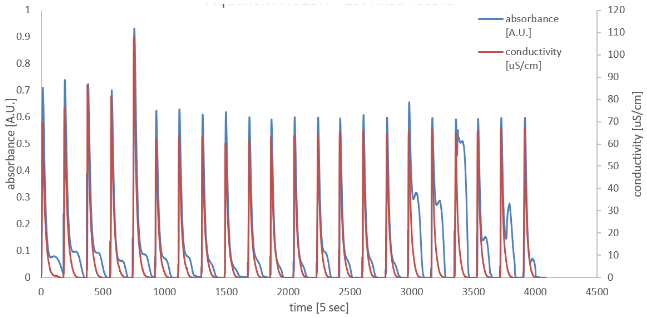


Figure 14: Cleaning fluid conductivity and absorbance plot

The testing revealed two interesting facts.

1. From the beginning, the new, fresh activated carbon absorbs slower. After some time, the absorption runs more quickly.
2. In cycle 17 (and subsequent cycles), some secondary peak is visible on the absorbance records. We assume this may be some releasing of a specific type of absorbed organic from the mixed bed, superseded by more potent ionic active compounds.

The final level of cleanliness remained almost constant. (Near to zero) for both Conductivity and Absorbance. The rinsing cycle time was 15 min. With a shorter rinse time, the rinsing quality would be compromised.

To monitor the activated carbon bed, COD measured on samples rinse water in external laboratory was used to monitor the rate of media depletion. Figure 15 shows the slight penetration of low molecular weight and weak polarity cleaner compounds without the presence of π electron system in their structure. Due to their above-mentioned characteristics, their activated carbon absorption is difficult, and a much longer contact time is required.

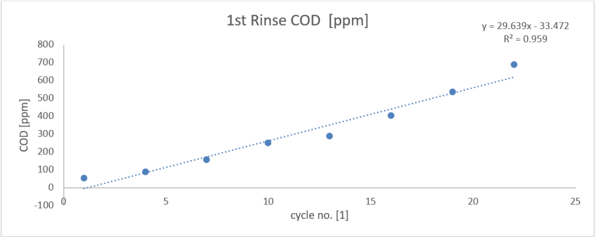


Figure 15: COD in the first Rinse after each Wash Cycle

Figure 16 summarizes the test methods used to monitor the first Rinse.

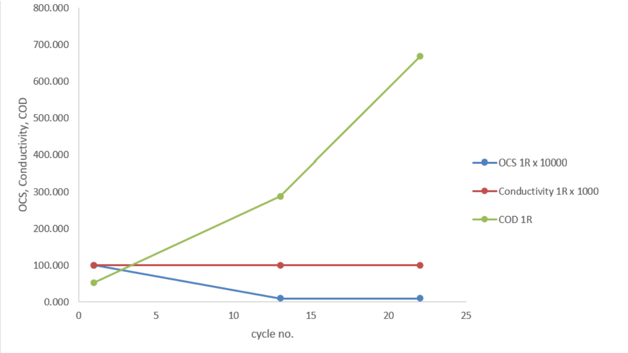


Figure 16: OCS/COD/Conductivity Measurements

The following inferences can be drawn:

- COD, measured at an external laboratory, is the most precise method; it shows a growing content of organic residues at each end of the rinsing cycles. (Samples are taken always in the 15th minute of rinsing)
- The conductivity change was almost no measurable during the entire series of measurements.
- Lowering the OCS reading during the test can be explained as a function of activated carbon filters in the loop. The filters were fresh. Water was deionized only on the machine before the test. The criterium for DI water was only conductivity. Some organics with higher absorbance from tap water used to flush the activated carbon before its installation in the cleaning machine were possibly still in the loop during the first cycle.

Second Rinse

Values from the second Rinse were almost constant (Figure 17).

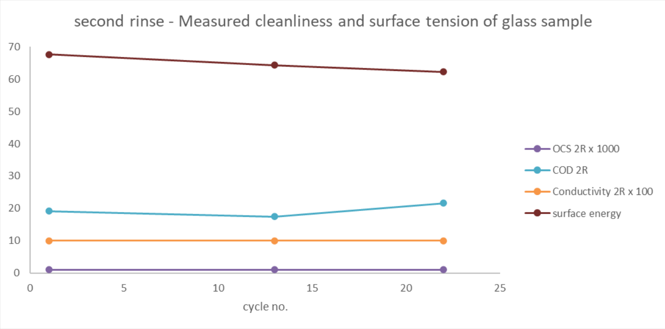


Figure 17: Second Rinse Values

The following inferences can be drawn:

- Conductivity was lower than 0.1 µS/cm and stayed low during the entire test
- OCS values were under the minimum detectable limit (0,001 AU)
- Interesting was the lowering of surface tension (surface free energy – SFE) on the glass test board. The lowering of about 3x more significant than the standard statistical deviation (which was ±1 to ±1,5mN/m)

SIR (Surface Insulation Resistance) of the Comb Pattern

Conductive residues that are not fully rinsed from under the component will lower insulation resistance. The SIR test boards were tested over 168 hours at 40°C / 90% RH / 5 Volt Bias / 5 Volt Measurement.

Eight SIR boards were processed during the 22 wash cycles (Cycles 1, 4, 7, 10, 13, 16, 19, & 22). Minimal values from each sample for both types of pastes and comb patterns under both components (QFP80 – channel B, QFP160-Channel D) are shown in Figure 18.

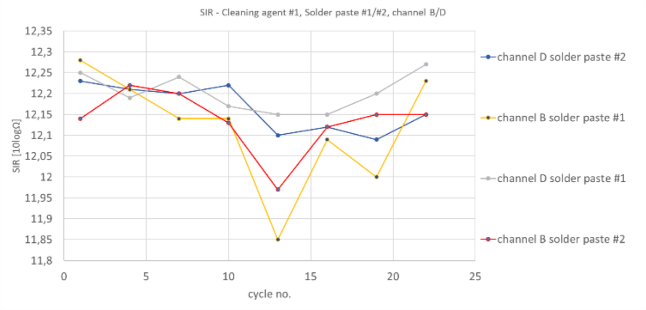


Figure 18: SIR from the Combs under the Component Terminations

The results from both solder pastes are very uniform, except for one sample (Cycle 13, Sample 5 lower SIR value). The relevant SIR record from sample 5 shows a shortage during a test in channel C (between poles of QFP160 - the other channel and component as a comb pattern (channel B). On channel A (belonging to QFP80 - between poles) between poles, no residues were optically documented. Figure 19 shows the image from the shortage on Channel C. There are small residue levels, which could be partially dissolved flux.

Generally we cannot see any tendency of SIR values during the test.

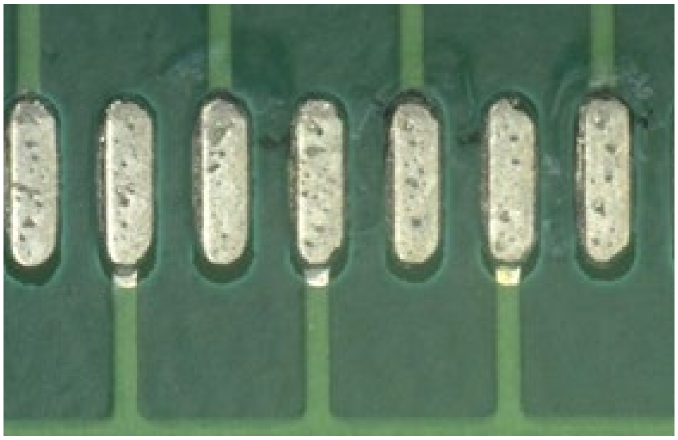


Figure 19: Component shortage example

WASH CHEMISTRY #2

22 cycles of trial cleaning with dummy SIR test boards were performed using wash chemistry #2. No loading boards were inserted – so the dissolving of flux was minimal (only that, which was on test samples.

Measuring rinse quality is on the following graph by conductivity and OCS (absorbance): (records made at the same number of cycles - the same total drag- over to the rinsing bath.)

Comparing the response of conductivity and absorbance in a typical rinse cycle of the first rinse step shows a different intensity of ionic and non-ionic pollution dragged over with the same amount of Wash Chemistry#1 and Wash Chemistry #2.

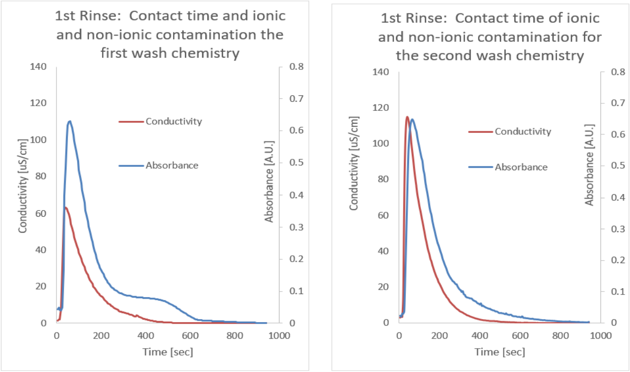


Figure 19: Comparison of the Two Wash Chemistries

Cleaner#1 has about 50% of the influence on the conductivity increase as the cleaner Cleaner#2. The concentration of non-ionic pollution is about the same. However, it is clearly not the same composition of the chemistry because the response of Activated carbon is different. Absorbance of non-ionic residues from Cleaner #1 has a different time response. Generally, the absorption of non-ionic pollution from Cleaner #2 takes longer (as seen on the following record of the complete test (Figure 20 - Compared with Figure 14 Cleaner #1).

Record of conductivity and absorbance from 22 cycles of the test.

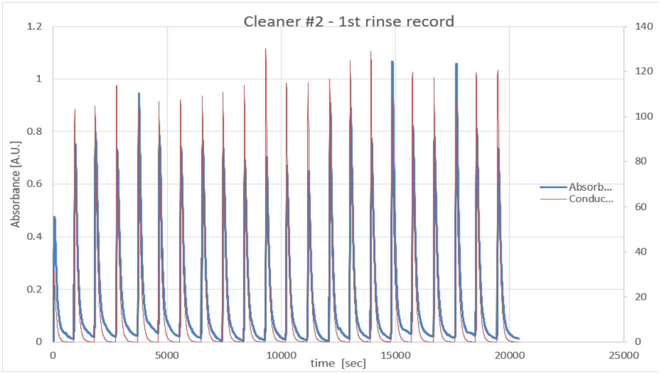


Figure 20: Wash Chemistry #2 Absorbance and Conductivity

Absorbing the entire non-ionic pollution takes longer than the adjusted rinsing cycle time. However, these non-absorbed residues at the end of the cycle are very low because, during the following cycles, we do not see any accumulation of the residue amount.

The following graph shows the growth of residual non-ionic pollution (sampled in the always at the end of the rinsing cycle).

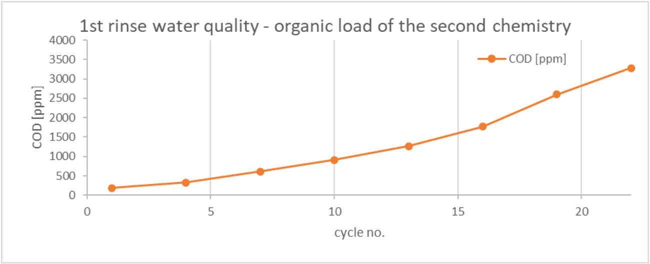


Figure 21: Organic Load of the 1st Rinse Second Chemistry

A precise measurement of COD shows growing organic pollution during subsequent cycles. The values are about 5x higher than the relevant values in the same test of Chemistry #1. (see Figure 15) This is a warning that using this cleaner will have a bigger pollution potential for wastewater.

The following graph shows different parameters of the Rinse #1 quality during the test.

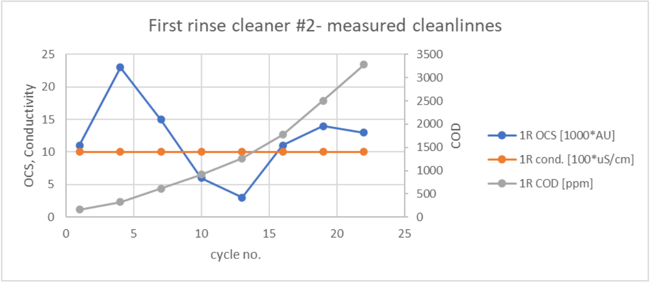


Figure 22: OCS/Conductivity/COD Values for Cleaner #2

- Conductivity was less than 0.1 µS/cm and stayed so low during the entire test
- Values OCS fluctuate (it shows the level of non-ionic residues at the end of each rinsing cycle). If you compare it with the complete record of OCS and conductivity, the record (values at the end of cycle) shows the same tendency. Measured values are low, so some part of the fluctuation was near the limit of quantification. That also can have influence on the fluctuation of QCS values. However, the liquid in first rinse is not homogenous, some residues of emulsion are flowing in the water. The fluctuation can be caused also by detection of these more concentrated parts of the rinsing mixture.

Second Rinse for Cleaner #2

Figure 23: Second Rinse Cleanliness

- Conductivity at the end of the cycle was stable and less than 0.1µS/cm
- Measured non-ionic pollution was almost stable during the entire test
- COD measuring shows a continuous increase during the test. COD test can also see some other organic compounds (those which do not cause UV absorbance). However, we will show a good correlation at higher values in the third part of the test (with loading by dissolved flux)
- Surface tension (surface free energy – SFE) was a little lower than from the rinsing after Cleaner #1; (see Figure 17) however, the difference is very small. Here, it does not show any dropping during the test. This may be caused by the different compositions of Cleaner #2. Also, blowing – off the rest droplets after rinsing during drying may cause a significant reduction in the influence of rinse water contamination

PHASE 2: TESTING OF THE EFFECT OF ***FLUX*** LOADING using the OCS sensor, followed by a series of Responses

The objective is to simulate real-process conditions. To do so, 6 boards loaded with 33.3 grams of solder paste were reflowed (Figures 8, 9, & 10). The flux residue from these 6 pcs loading boards were cleaned in each test cycle. The flux dissolved into the wash bath was measured using NVR (non-volatile residue). The loaded boards were processed over 28 complete cycles. The test procedure is listed below.

- Completed Test Cycles ~ 28
- Wash Chemistry #2
- 6 boards loaded with 33,3 grams (totally 200 grams) of solder paste followed by reflow ~ flux residue was cleaned during each test cycle
- SIR Test boards were processed
    - One with Solder Paste #1
    - One with Solder Paste #2
- One glass test board was processed to take surface tension measurements
- Always one cycle before the test cycle, we ran a cycle with a shorter wash (10 minutes) and cleaned a Glass test board with 200 chips to visually test cleaning performance under leadless components
- Each test cycle, we took samples from the wash bath to measure NVR
- Each test cycle, we took samples from the first and second Rinse to measure COD at the end of the cycle
- Concentration of the wash chemistry was measured using a Chem Control Kit (An accurate measure of wash concentration). Concentration adjusted to be constant – 15%.
- We measured (weighted) exactly each addition of concentrated cleaner. As this was dosed through an automatic mixing device from the cleaning machine to achieve a fixed concentration of 15% - we also monitored and recorded the amount of DI-Water added to make up the wash bath

The response variables were measured as follows:

- We measured the absorbance of the cleaner solution by OCS sensor continuously and compared it with NVR testing of samples.
- We measured the absorbance of the first and second water rinsing by OCS (always at the end of the cycle and compared it with COD measurements from an independent laboratory).
- We measured the rest contamination under components after cleaning on dedicated Glass test boards to compare it with the bath loading.
- We measured the surface tension of the glass test board

Saturation of the Cleaning Bath

Dissolving the flux residue from the loaded boards increased the concentration of flux residues in the cleaner (Figure 24).

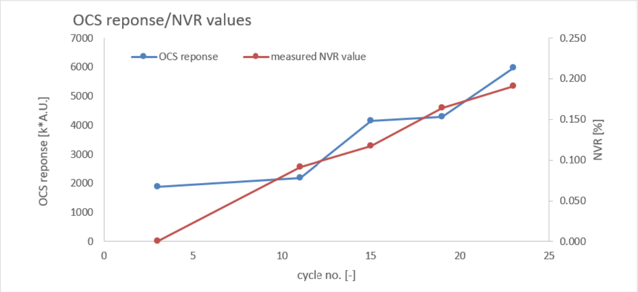


Figure 24: OCS response correlates with NVR

- The graph of absorbance measurement shows a good correlation (0,8982) with the NVR measurement of saturation of the cleaning bath.
- Even though we dissolved the equivalent of 4,4 kg of solder paste (reflowed) during 22 working cycles of the machine, measurements show that we are still at the beginning of the lifetime of the wash bath.

We measured the NVR (non-volatile residues) in the washing solution on the automated evaporation instrument RADWAG 50WH. Test run at 160°C until the weight change during the 2-minute interval is lower than 0,001g.

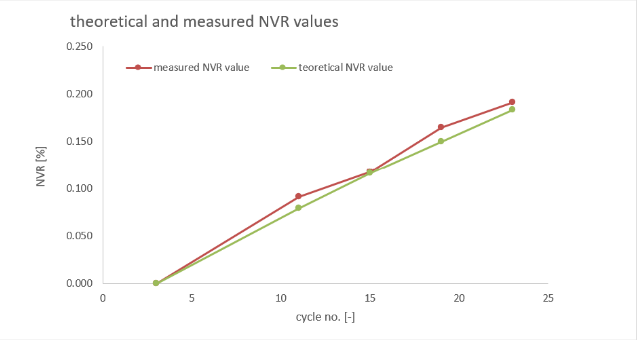
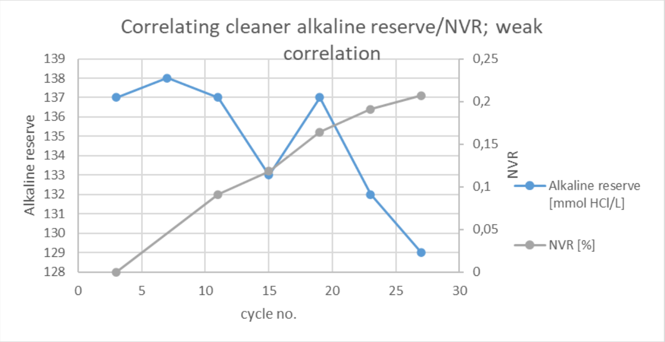


Figure 25: Theoretical versus Measured NVR values

- A graphical comparison of volumetric saturation calculation with the NVR measurement shows a perfect correlation with our NVR test method. (0,9974).

Also, we measured a wash bath saturation by cleaning a PBT Glass Test board loaded with flux residue under the chips.[5]



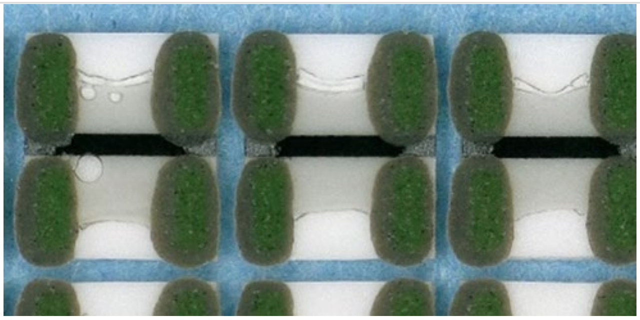
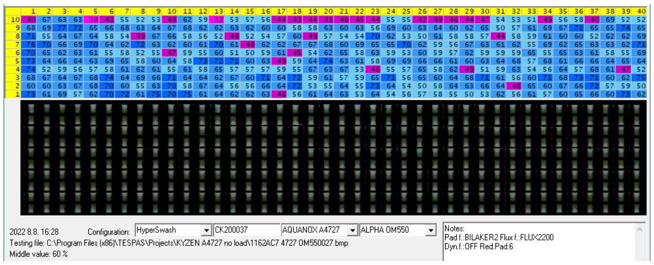


Figure 26: Glass Test Board with 200 Chips for evaluating cleaning after 10 minutes

This board is a precisely made model of PCB with 200 chips in reverse forms (0511). The black strip on the chip bottom is only for testing purposes. Figure 26 illustrates the Glass Test Board that is partially cleaned.

We can automatically evaluate the level of cleaned flux residues by a dedicated AOI. Following records show a consequent regress in cleaning power correlating with the saturation of wash.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10	40	67	63	63	38	43	55	52	53	48	62	59	32	53	57	56	44	43	44	41
9	68	69	77	72	65	66	68	63	64	67	68	62	62	63	62	60	60	58	58	63
8	71	55	64	67	64	58	54	49	67	66	58	56	52	48	52	54	57	60	49	57
7	76	70	66	69	70	64	62	72	63	62	60	61	70	61	48	62	62	67	67	68
6	70	65	62	63	61	55	58	52	55	47	59	55	60	51	50	59	61	45	54	62
5	73	64	66	64	63	69	65	58	60	64	58	73	72	71	60	63	49	59	64	74
4	74	52	59	56	57	58	61	62	61	55	61	58	65	57	57	57	59	55	67	63
3	68	67	64	67	68	74	64	69	66	71	64	64	62	67	60	71	64	72	59	61
2	60	60	63	67	68	70	60	55	63	70	58	67	64	56	56	66	64	72	53	55
1	73	61	69	57	62	70	72	61	75	70	75	61	64	62	62	63	46	56	61	64

	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
10	46	45	44	55	55	42	49	46	44	47	54	53	51	49	56	58	40	69	52	52
9	60	63	56	69	60	63	64	60	62	65	50	57	61	69	67	72	65	65	74	65
8	54	54	70	62	53	50	61	58	58	57	44	58	59	61	60	60	52	62	62	69
7	60	69	65	65	70	62	59	56	67	63	61	62	55	69	62	65	63	63	62	71
6	65	58	63	59	53	60	59	57	62	59	59	59	65	55	65	63	61	58	55	69
5	63	61	58	69	69	66	66	61	60	63	64	68	57	68	61	66	66	64	65	64
4	67	53	46	55	57	65	58	62	49	51	59	63	54	56	64	57	68	61	47	52
3	57	59	65	71	56	65	60	64	68	71	61	56	60	71	68	73	71	60	62	75
2	64	55	73	64	54	50	58	64	63	66	64	48	65	60	67	66	72	57	59	50
1	63	53	64	54	56	57	58	55	50	53	62	56	61	57	60	65	66	60	73	62

2022 8.8. 16:28
Configuration: HyperSwash | CK200037 | AQUANOX A4727 | ALPHA OM550
Testing file: C:\Program Files (x86)\TESPAS\Projects\KYZEN A4727 no load\1162AC7 4727 OM550027.bmp
Middle value: 60 %
Notes:
Pad f.:BILAKER2 Flux f.:FLUX2200
Dyn.f.:OFF Red.Pad:6

Figure 27: Area Percentage of Flux Residue left the 200 chips on the Glass Test Board (test protocol from AOI)

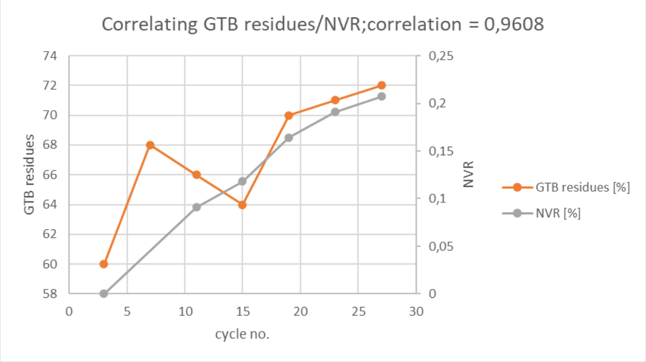


Figure 28: Cleaning of Glass Test Board as a Function of NVR (flux loading in the wash bath)

- The graph in figure 28 shows the subsequent saturation measured as NVR and tested by Glass test boards cleaning as a dropping efficiency of dissolving flux residues in the wash.
- Even though we dissolved the equivalent of flux residues to 4,4 kg of printed solder paste, the NVR was measured as 0,22 % Cleaner is not exhausted. Still, saturation is detectable in the rinsing on the final cleanliness.

We also tested the alkaline reserve. The graph in Figure 29 shows subsequent changes in the alkaline reserve

Figure 29: Free Alkalinity Reserve as a function of flux loading (NVR)

- Higher saturation (NVR) may relate to the lowering of the alkaline reserve because of acidic activators in the flux.
- The correlation is weak because the values dropping is about 7%, while the measuring accuracy of this measurement was ±12%. So, the fluctuation of that data is within the test accuracy.

First Rinse Water Quality

The conductivity and absorbance record shows a significant absorbance increase during the test.

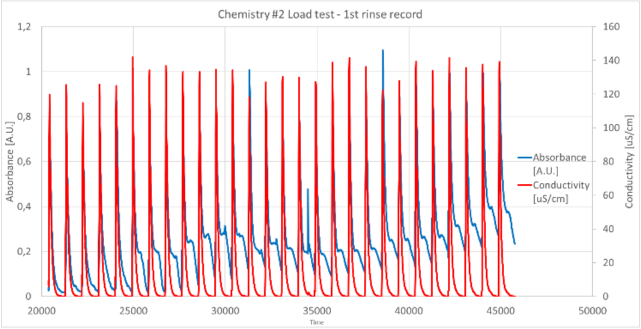


Figure 30: Absorbance vs. Conductivity for the 1st Rinse

- Increasing the final rest contamination of the first Rinse at the end of the cycle is a signal of continuous saturation of the activated carbon filter in the close loop rinsing system.
- On the contrary, the final conductivity was not changed measurably during the 22 working cycles. For a standard user of a cleaning system that does not have an OCS sensor is still "everything OK."

Comparison of records from test w/o flux loading and with flux residues and corresponding COD values can be interpreted strictly as the penetration of the wash bath containing flux components through the depleted activated carbon. Flux residues can be measured in the Rinse with high sensitivity.

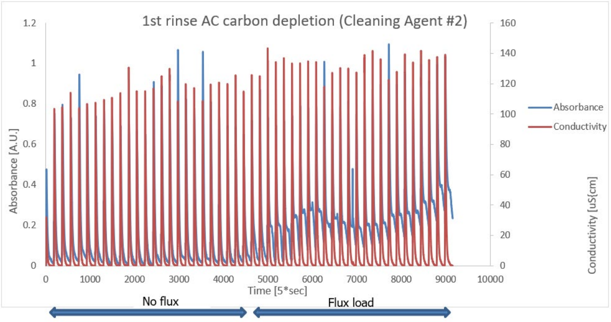


Figure 31: Sensitivity of Flux Load

- The record shows an almost continuous increase of the peak conductivity at the beginning of each rinsing cycle
- Ion exchangers can process even the growing pollution during the complete test.
- The activated carbon filter can no longer absorb the organic load in the preset time of 15 min. The absorbance at the end of the cycle is significantly growing. This is a sign of continuous depletion of the Activated carbon absorption ability.

The following graph shows data from the COD test compared with the OCS measurement. Data are for both parts of the test with Chemistry #2 (no flux load and flux load). It is measured in the first Rinse.

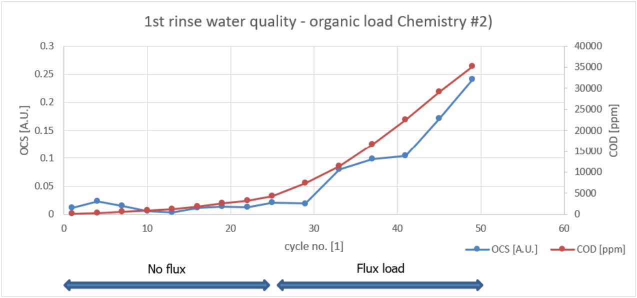


Figure 32: COD and absorbance of the 1st Rinse

- The graph shows a good correlation (0,9753) between the OCS measuring and COD analysis.
- Practical limits of COD in the wastewater for public clearing stations differ but are generally between 150 to 700 ppm. Even the water without flux load cannot be drained into public sewage.
- Conductivity was constant in all cycles – 0.1µS/cm

Second Rinse of Cleaning Agent #2 Water Quality

Because of the very low exhaustion of both activated carbon and mixed bed filters in the second loop, we did not exchange those filters between the test with Cleaning Agent #1 and Cleaning Agent #2 no flux test as well as Cleaning Agent #2 flux loaded test. Therefore, the chemical filters at the beginning of the Cleaning Agent #2 flux loaded test already have some loads from previous tests.

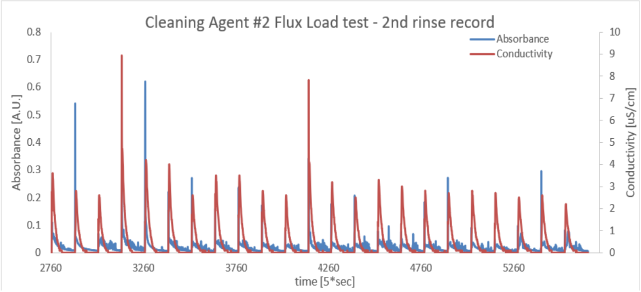


Figure 33: Absorbance and Conductivity of the Second Rinse

- The peak absorbance does not grow cycle by cycle, like in the first Rinse. We can only see some random peaks. Also, the peaks are very low. That signified a meager level of non-ionic residues that remained after the first rinsing step.
- Final absorbance (end of the cycle is near zero but not zero)
- Conductivity peaks are higher than in the test w/o load of flux residues. (W/o residues (2-3) µS/cm, with residues (2-9) µS/cm.
- Final conductivity is below the detection limit of the measuring instrument on the machine (<0.1µS/cm)

We used another glass test board to get values of surface tension (Surface Free Energy - SFE).

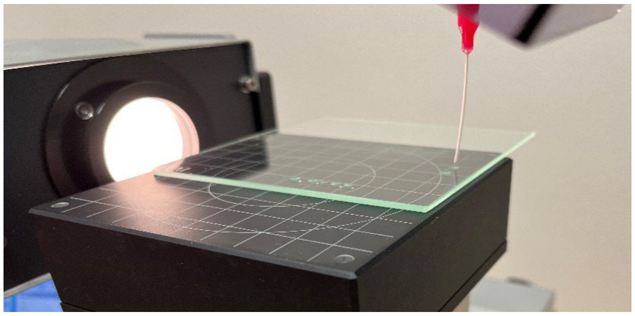


Figure 34: Glass test board for surface tension measurement on the table of an automatic surface free energy test system

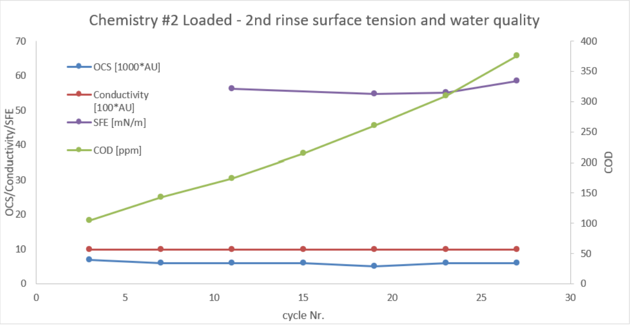


Figure 35: Comparison of the surface tension with cleanliness parameters for second rinse conductivity, OCS, and COD.

- Surprisingly, the surface tension does not substantially change with growing organic content in the rinse water. This could indicates that the flux in wash chemistry has reacted with the builder in the cleaning agent. This reaction forms a water-soluble soil that rinses freely
- The average value is, however, lower than in the test's w/o flux load (see Figures 17 and 23)
- We observed some irregularities across the test glass area. Data on surface energy are processed with several drop tests with a polar and non-polar liquid. Thus, in different places. Such readings differ according to place. We assume that the value of the surface tension at a point depends on the level of organic residues in the unblown rinse water droplets.
- Still, the conductivity is constant and lower than 0.1µS/cm

SIR (Surface Insulation Resistance) Observation

SIR is a STRESS test method that exposes the test boards to 40°C, Relative Humidity of 90%, Bias Voltage of 5 volts, Measurement Voltage of 5 volts, and 168-Hours of test time[2]. The test boards are designed with comb patterns across conductors of opposite polarity. The test detects problematic residues:

- Ionic Residues within the flux residue
- Non-Ionic constituents within the flux residue
- Wash fluid build-up in the closed loop rinse sections

Figure 37 shows the SIR data for the number of wash process cycles. The data shows three failures for Solder Paste #1. Channel A is the QFP-80 signal pins, and Channel C is the QFP-160 signal pins. These failures were due to partially cleaned flux residues that were located next to the signal pins of opposite polarity. SIR drops for Channel A in cycle 23 and Channel C in cycles 15 and 23.

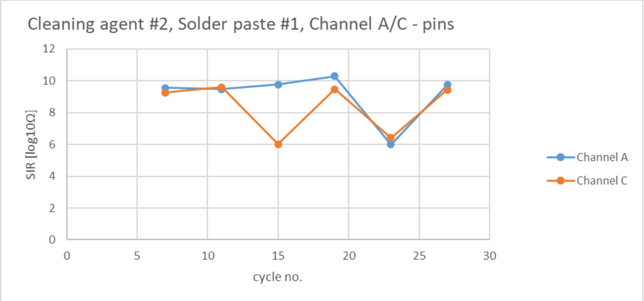


Figure 37: SIR Results from Pin-to-Pin on the QFP-80 and QFP-160 for Solder Paste #1

The SIR comb patterns under the QFP-80 and QFP-160 are designed to measure the insulation resistance after the rinse. Figure 38 shows a small decline in insulation resistance from the slow organic non-ionic build-up in the closed loop rinse reservoirs during the test. The SIR values are held within the desired performance zones.

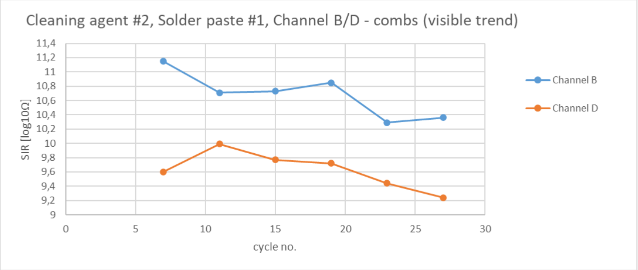


Figure 38: SIR results from the Comb patterns under the body of the QFP-80 and QFP-160 for Solder Paste #1

Figure 39 data shows two failures for Solder Paste #2, both occurring on cycle 23. Channel A is the QFP-80 signal pins, and Channel C is the QFP-160 signal pins. These failures were most likely due to partially cleaned flux residues that were located next to the signal pins of opposite polarity.

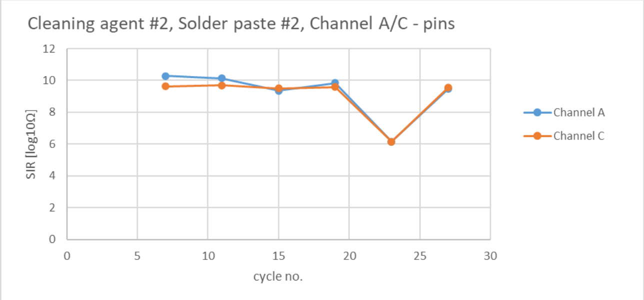


Figure 39: SIR Results from Pin-to-Pin on the QFP-80 and QFP-160 for Solder Paste #2

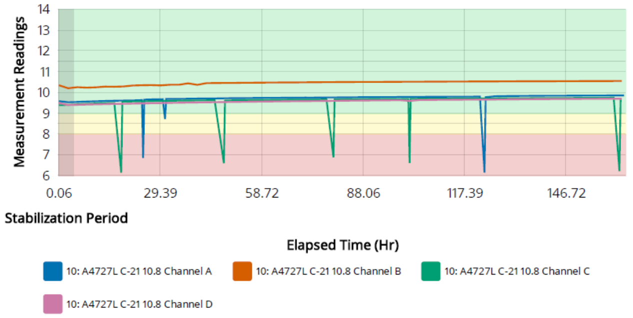


Figure 40: SIR Data over the 168-Hour Test for sample 2/ Cycle23

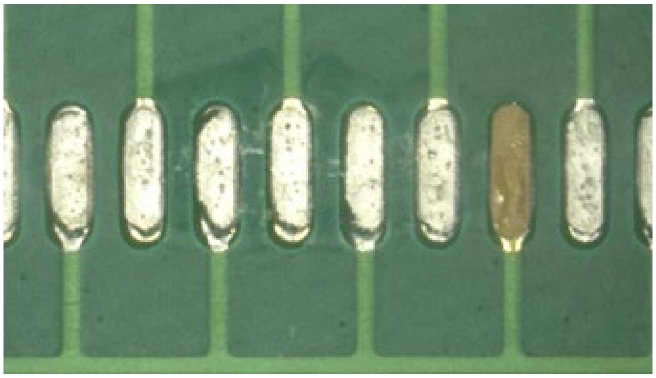


Figure 41: Optical evaluation of channel C (cycle 23, sample 21) with visible flux residues and dendrites formations

Figure 42 shows a small decline in insulation resistance from the slow organic build-up in the closed loop rinse reservoirs. The SIR values are held within the desired performance zones.

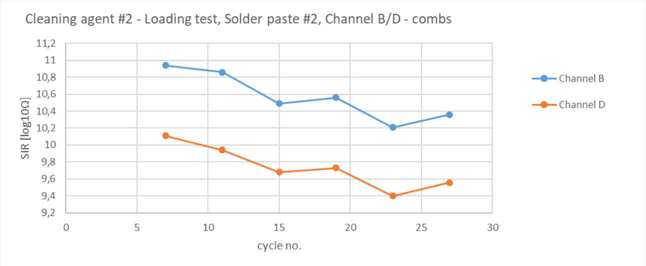


Figure 42: SIR results from the Comb patterns under the body of the QFP-80 and QFP-160 for Solder Paste #2

The following inferences can be drawn from the test results.

- At the moment of activated carbon depletion, the amount of organic matter in the rinse, expressed by the COD/Absorbance parameters, increases significantly.
- From the SIR plots for Cleaning Agent #2 with no flux load (activated carbon still not depleted), the SIR values of channels B and D are constant. When activated carbon is depleted, and there is a significant increase of organics in the rinse water, the SIR values for channels B and D are in a trend relationship (decreasing trend).
- The conductivity of the rinse water was less than 0.1 µS/cm at the end of each loading cycle.
- Based on the above-mentioned, this trend change can only be attributed to the organic loadings in the rinse water.

Conclusions

It is well known that properly cleaned circuit assemblies exhibit improved climatic reliability.

Cleaning is a process that encompasses many variables. Proper control of the process variable equates to a process that is in control.

Assuming that the flux residues are removed, cleanliness is a function of the final rinse. Many cleaning processes close loop the rinse streams. A system that monitors the wash fluid drag out into the rinse streams is needed.

This research introduced two meters that are useful in monitoring the rinse streams. The first meter is the Organic Carbon Sensor (OCS). As organics build up into the rinse water reservoirs, the OCS tracks the absorbance. An increase in absorbance means that the organics from the rinse fluids increase in the rinse reservoirs. This indicates that the carbon resin is nearing a saturation point and must be regenerated. This research validated the OCS meter using COD, Surface Tension, Glass Slide Cleanliness, and SIR.

The second meter was the use of SIR. As flux residue dissolves and builds up in the rinse fluids, there is a slow decline in cleaning performance. As the number of cycles grows, there may be instances where partially cleaned flux residues are left next to the conductors of opposite polarity. When this occurs, SIR detects a drop in insulation resistance. Secondly, when wash fluids build up in the rinse reservoirs, there is a build-up of organic pollution. The test data find that a build-up of organics in the rinse will slowly drop insulation resistance.

Due to the time and cost consuming nature of the experiment we could not make the experiment longer and get the system to less optimal values. Based on real-life experience, we know that the mixed ion exchange bed of equivalent machine configuration and load can last up to 140 cycles on the first rinse. As can be seen from the measured data, activated carbon depletion occurs much earlier. Let us continue with a simple mind experiment at the end. From the graph below (Figure 43), it is clear that in the geometry of this experiment, the drop in SIR values below 8 [log10Ω] for channels B and D would likely occur somewhere after 80 cycles.

Figure 43: SIR Decline as a function of Loading

The purity of the final rinse water is currently monitored using conductivity. The conductivity values range from 1 to 5 µS/cm, which is 50 times higher than the results reported in this study. The OCS sensor data reported in this paper indicate organics will be present in the final rinse water. For processes that are currently closed-looped, the level of organics dissolved in the rinse reservoirs will be many times greater than what we have achieved in this study. The presence of organics in the rinse water represents a risk to the reliability of electronic assemblies cleaned today and in the future.

Implementing these two meters (OCS and SIR) at the assembly site allows the operator to monitor and control the cleaning process.

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