How to fullfill reliability demands for future electronic assemblies

- Vladimír Sítko
- Short CV of presenting author

Vladimír Sítko is a founder and managing director of PBT Works s.r.o, a recognized manufacturer of cleaning systems for electronic assemblies, stencil, and microelectronic applications.

In 90-ties, he founded an SMT process machines and materials supply and consulting service company. At the same time, he was starting the business with development, design, and manufacturing machines for PCBA and maintenance cleaning, which is now running under PBT Works s.r.o.

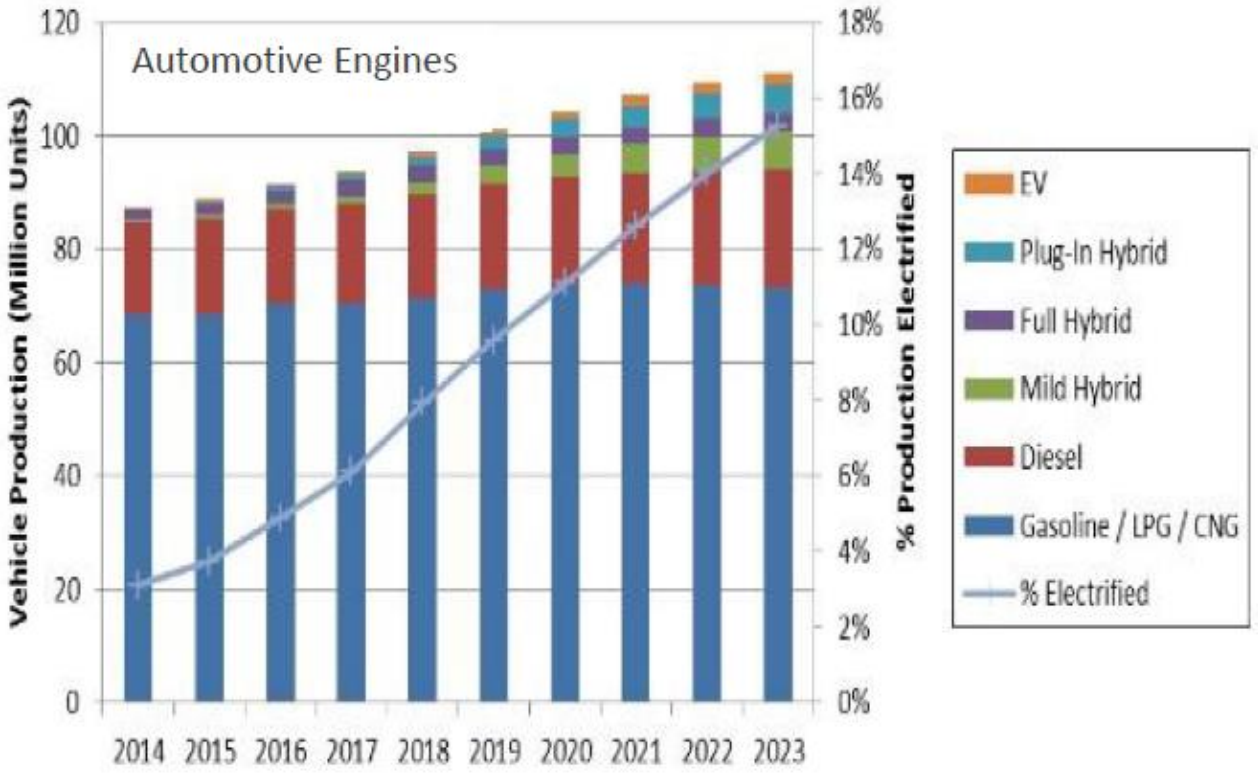
He sets concepts of PBT cleaning machines and process optimization methods. He is also working on the development of new measuring instruments for cleaning parameters monitoring and performance enhancements. He is an owner or co-owner of several patents.

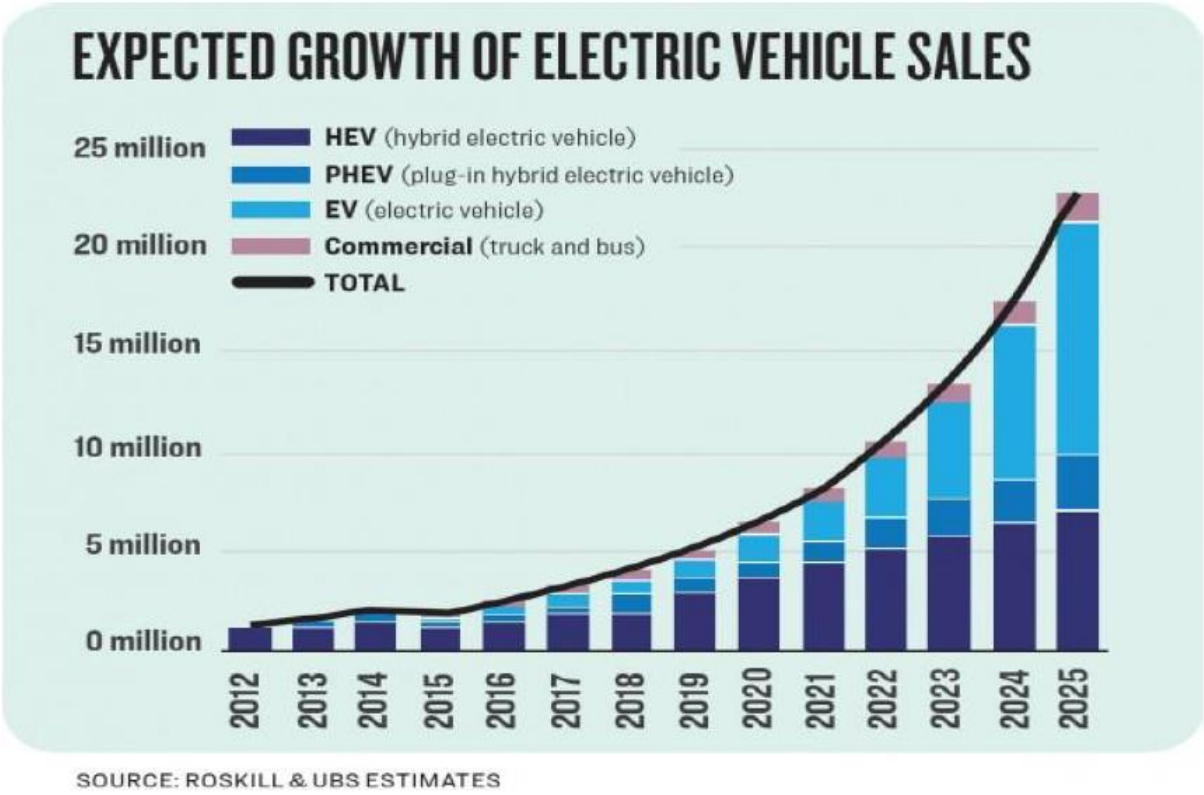
Agenda

- Quo vadis microelectronic ?
- What does mean a NO clean soldering for reliability ?
- How clean is clean ? Qualification of cleaning process
- Optical visualisation of cleaning – powerful tool for process development
- Requirements on cleaning process equipment today and in the future

Main development tendencies in electronics - automotive revolution

- Electro- mobility
- Autonomous vehicles





Reliability and lifetime requirements

Automotive Lifetime Requirements Today		
Lifetime	15 Years	
Operation Time	10.000 Hours	
Mileage	300.000 km	
E-Mobility and Lifetime Requirements		
Driving Operation	~8.000 Hours	1.5 hrs / day, 15 years
Charging Operation	~30.000 Hours	
Off-Grid Parking	~92.000 Hours	
Autonomous Driving		
Driving Operation	**121.000 Hours**	**22.5 hrs / day, 15 years**

Test conditions today:

car mission profiles are statistically measured (family, taxi, business,etc.)

testing according to mission profiles with all measurements

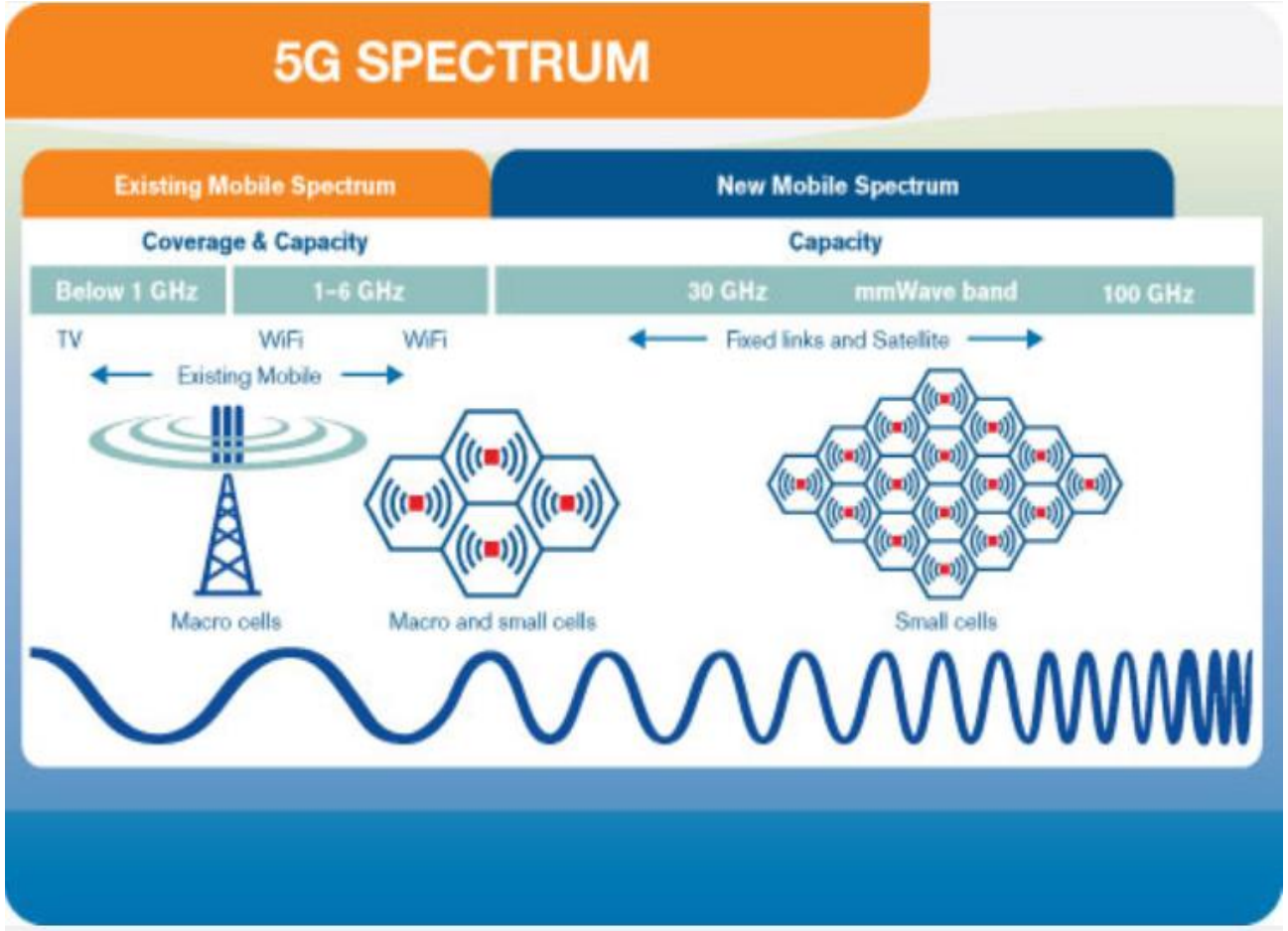
Qualification takes several months (ussualy 6-9 months)

Long lifetimes & high reliability requires CLEANING

Main development tendencies in electronics - communication revolution

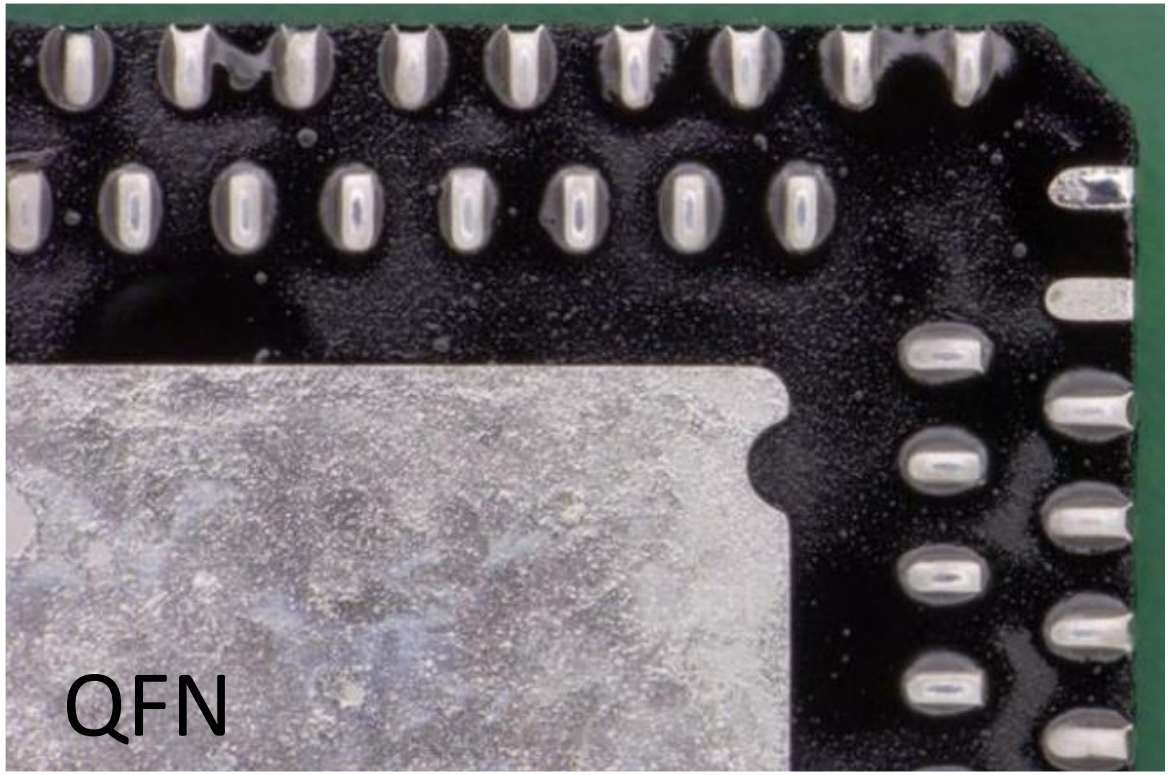
- **5G communcation**
- **IoT**

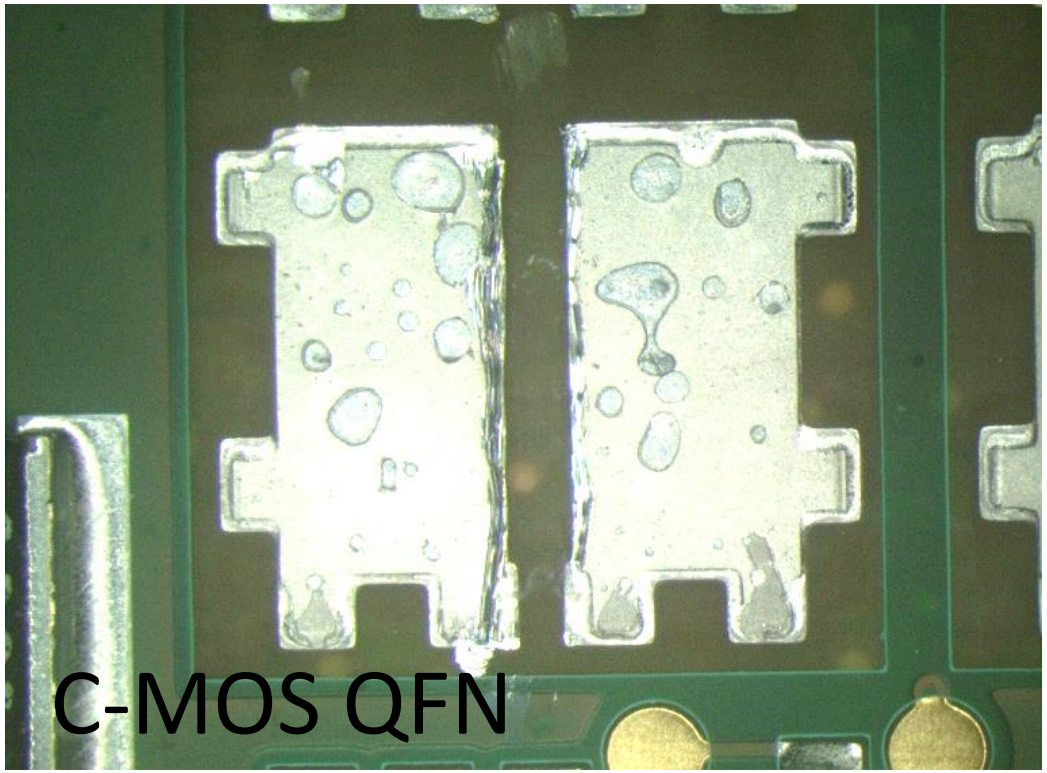
- Requirements on short response time – using high frequencies
- 4G 20-30ms
- 5G 4-5ms



- Compact HF assemblies
- BTC components, very small chips
- **High signal fidelity requires CLEANING**

Leadless components challenges

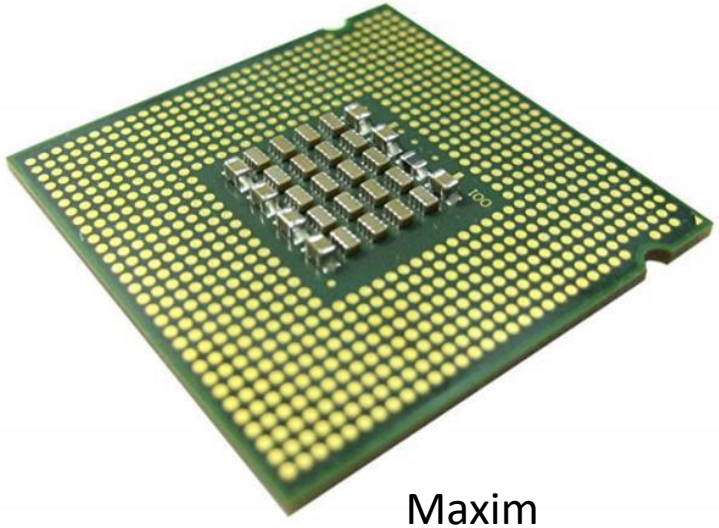




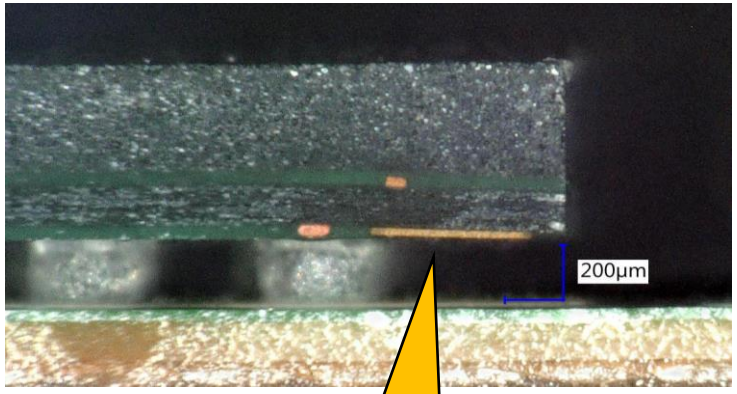
- Low cost packages , but used for high reliable applications
- Short signal paths – Bottom terminations - bad degassing of flux residues
- Saving on component bring extra costs at assembly

Combination of chips under BGA

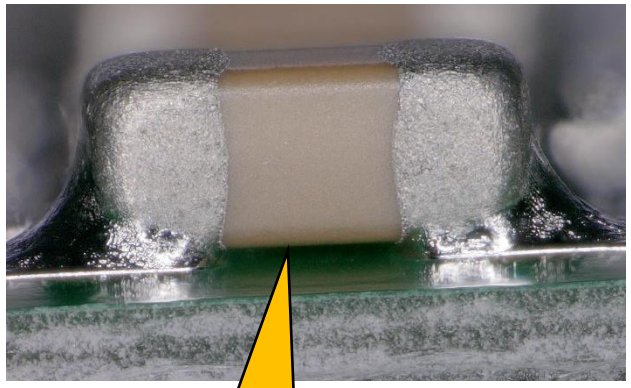
- **High frequency**
  - Low inductance capacitors
  - Low inductance chip periphery
  - Bad for cleaning !



Maxim



220um



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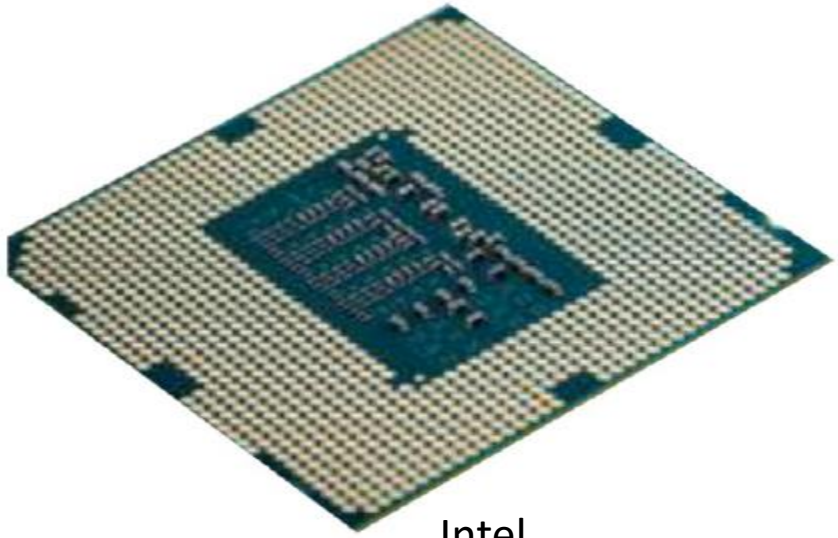
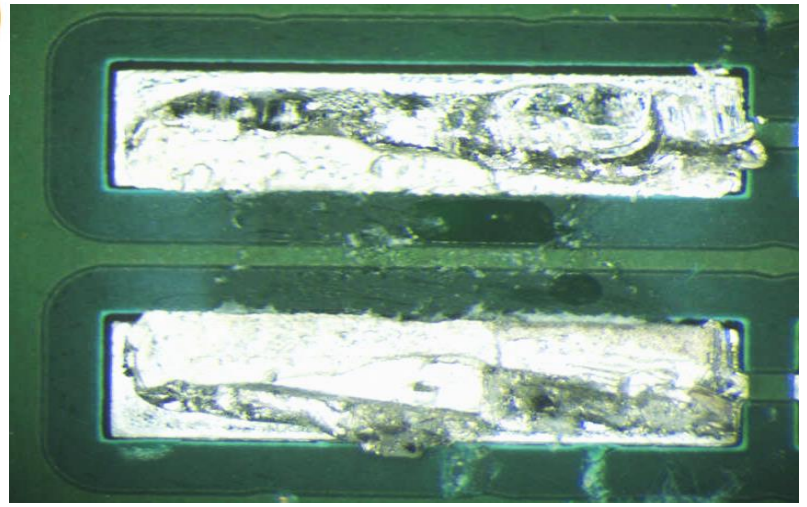


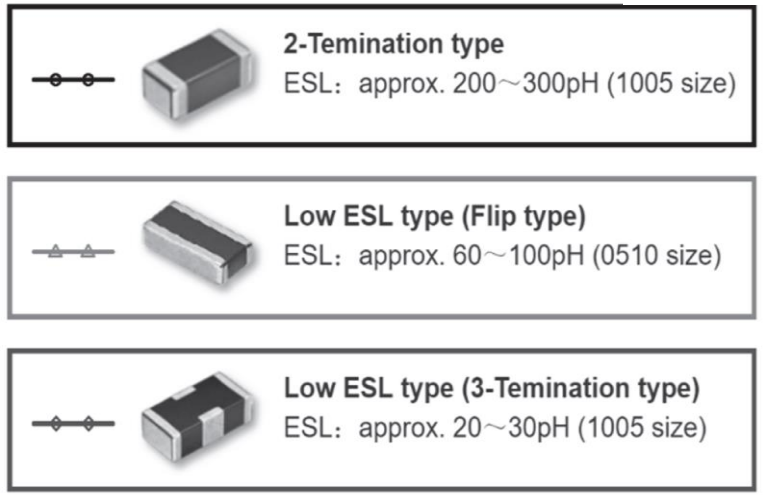
Intel

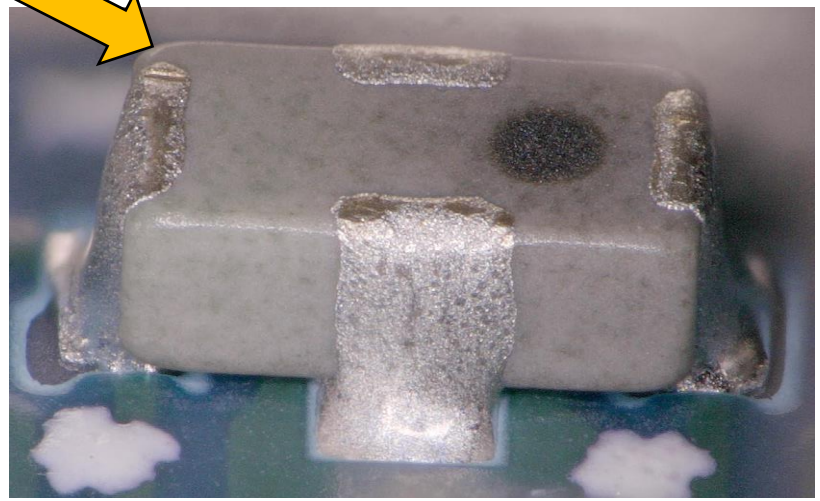
New forms of chips are comming

- **Inverse chip format resistors**
  - Good for heat disspation
  - Challenge for cleaning !



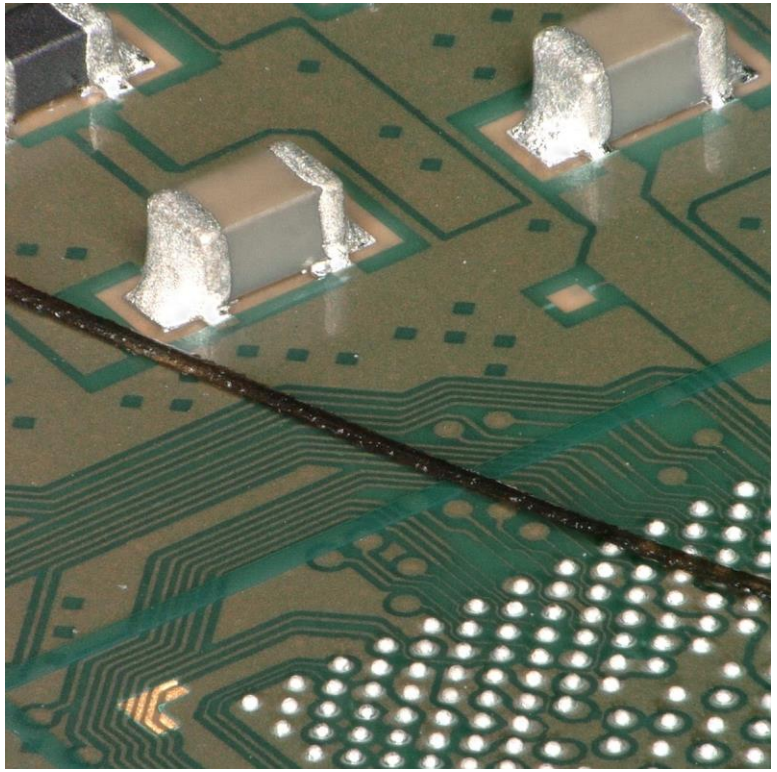
- **Three-terminal MLCC**
  - Low inductance capacitors
  - Good for noise suppression
  - Challenge for cleaning !

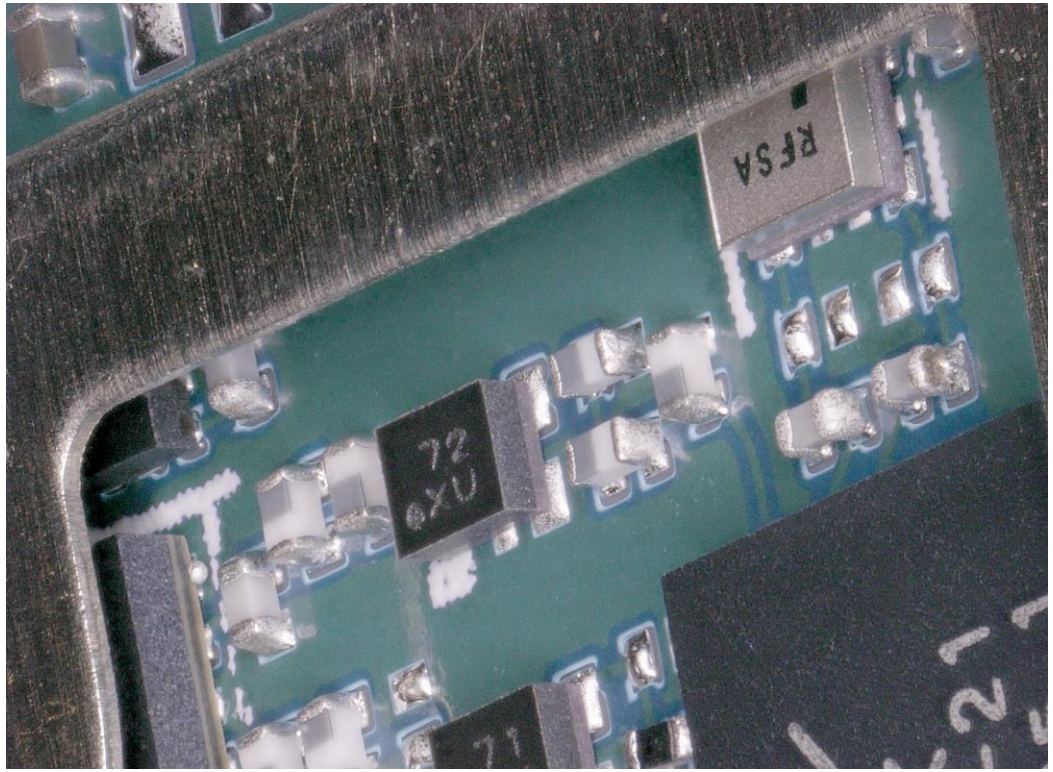


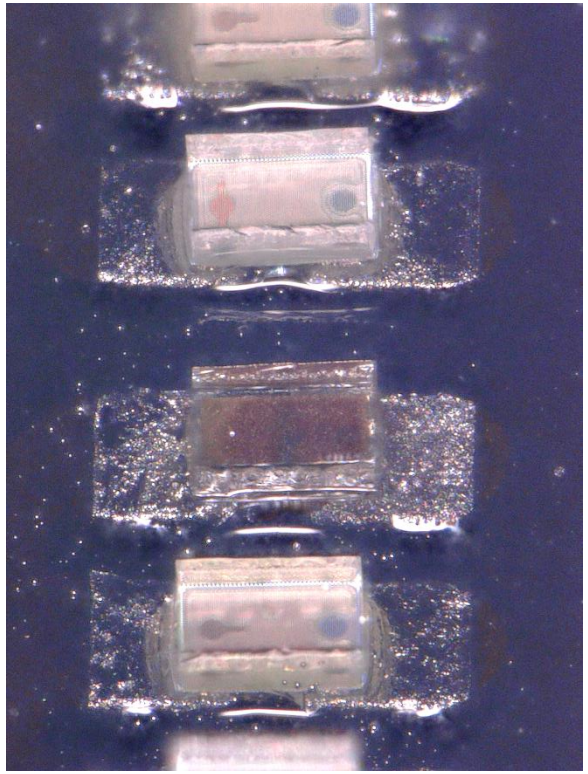


Main development tendencies in electronics - niniaturization

- Sensors, medical implantable electronics, modules
- Assembly before assembly on boards !



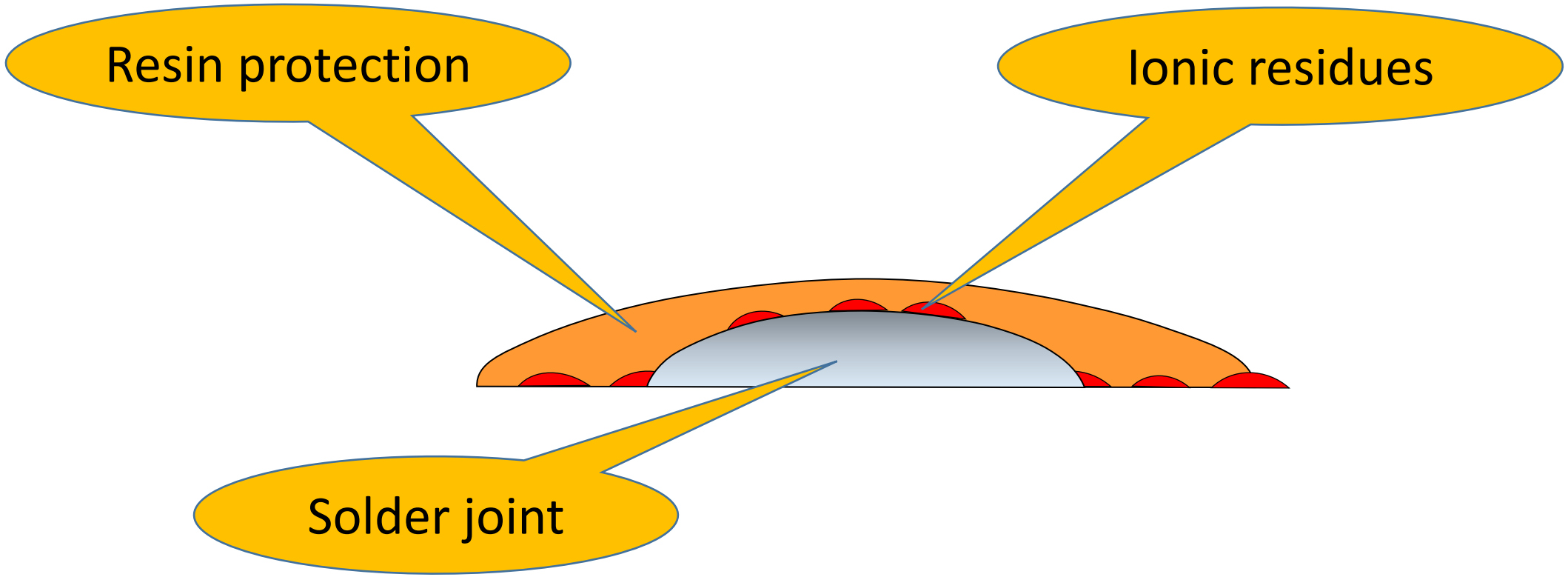




All these assemblies must be cleaned (before packaging)

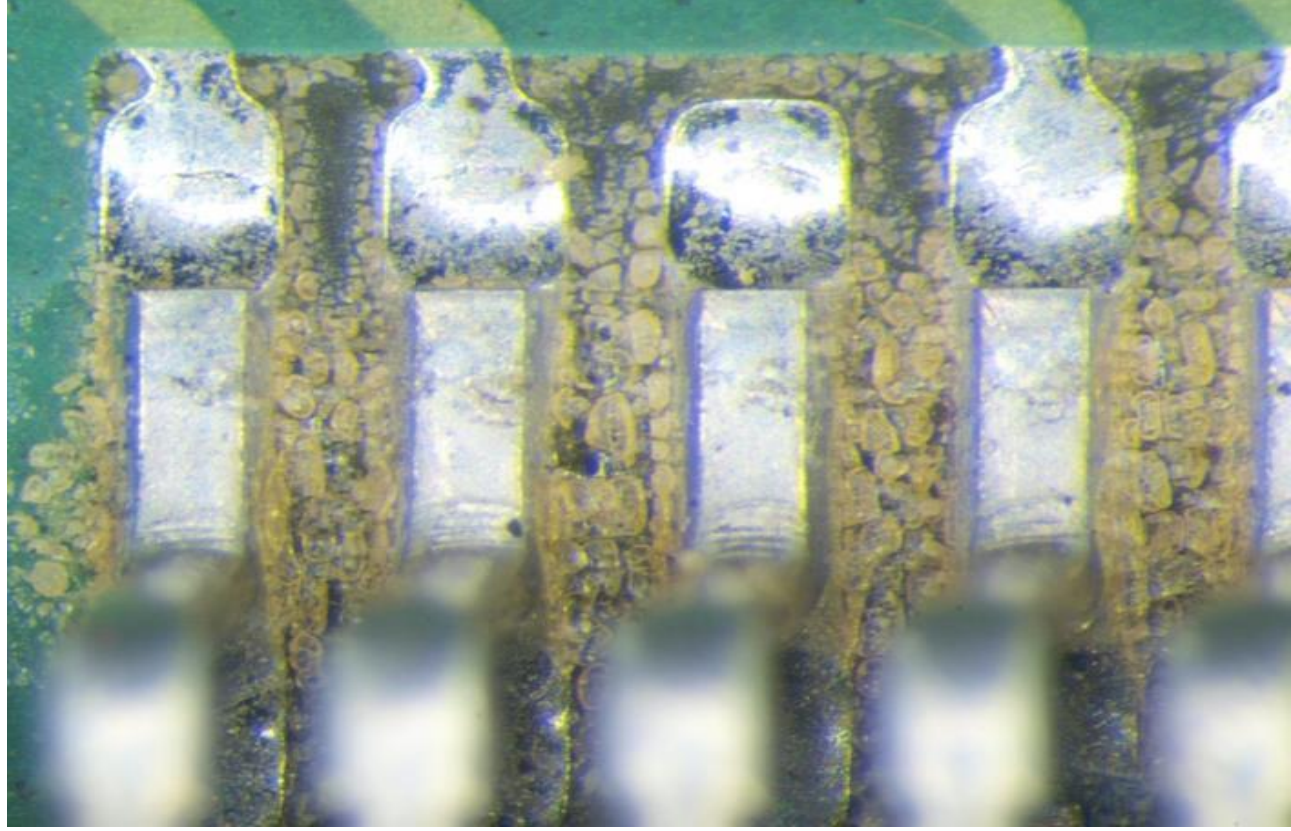
NO clean technology

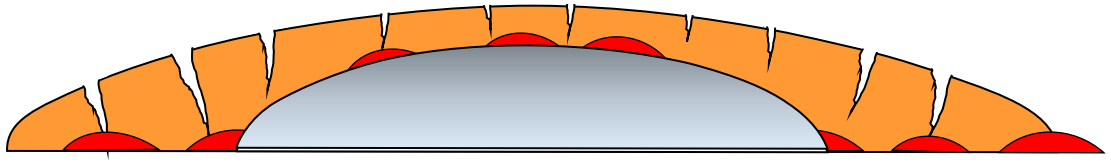
Best resin - highly dense (low vapor penetration)
But: hard, brittle (easy to crack with temperature changes)



NO clean

After 5 year operation

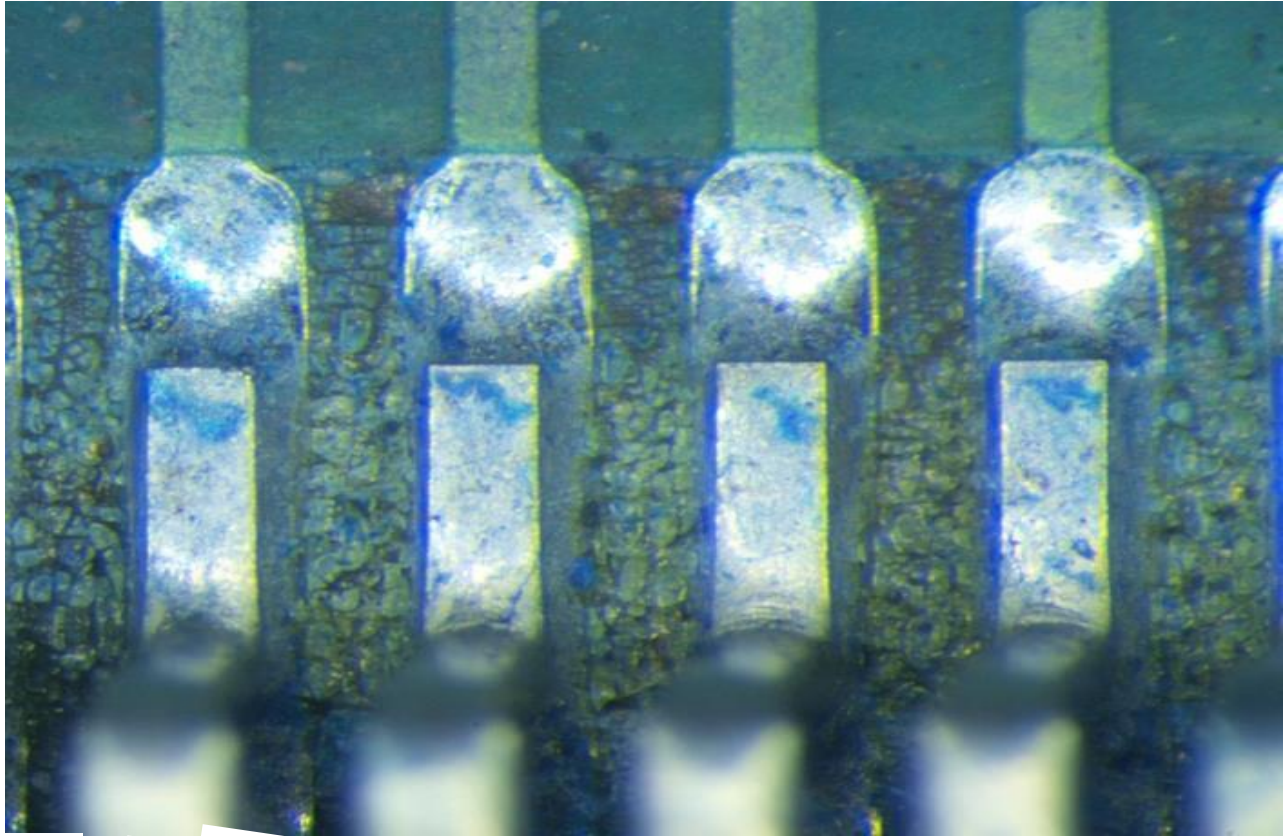


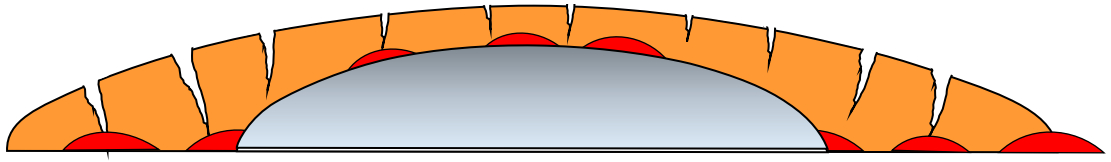


Releases active ionic contamination

NO clean

After 5 year operation





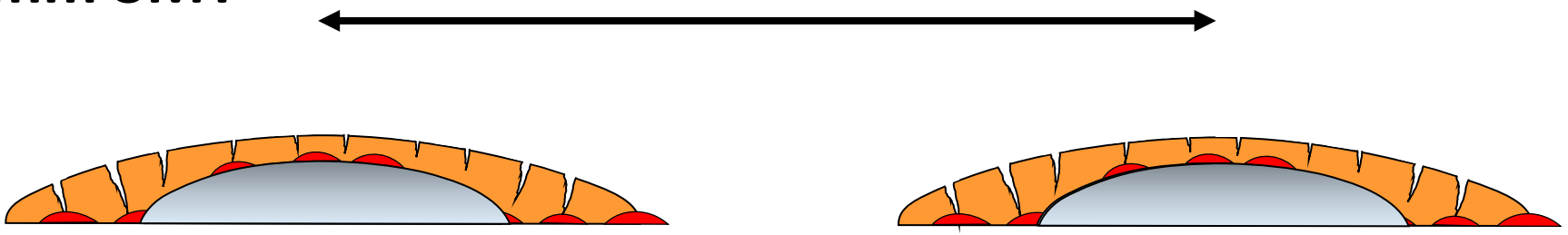
Positive test on carboxylic radicals with ZESTRON Flux Test (blue discoloration)

NO clean

In Nineties (~ 1990)

2,54mm THT

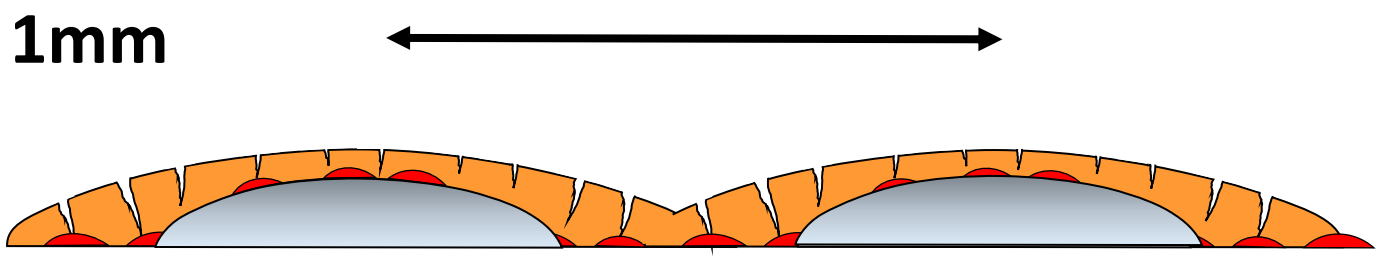
1,27mm SMT



NO clean

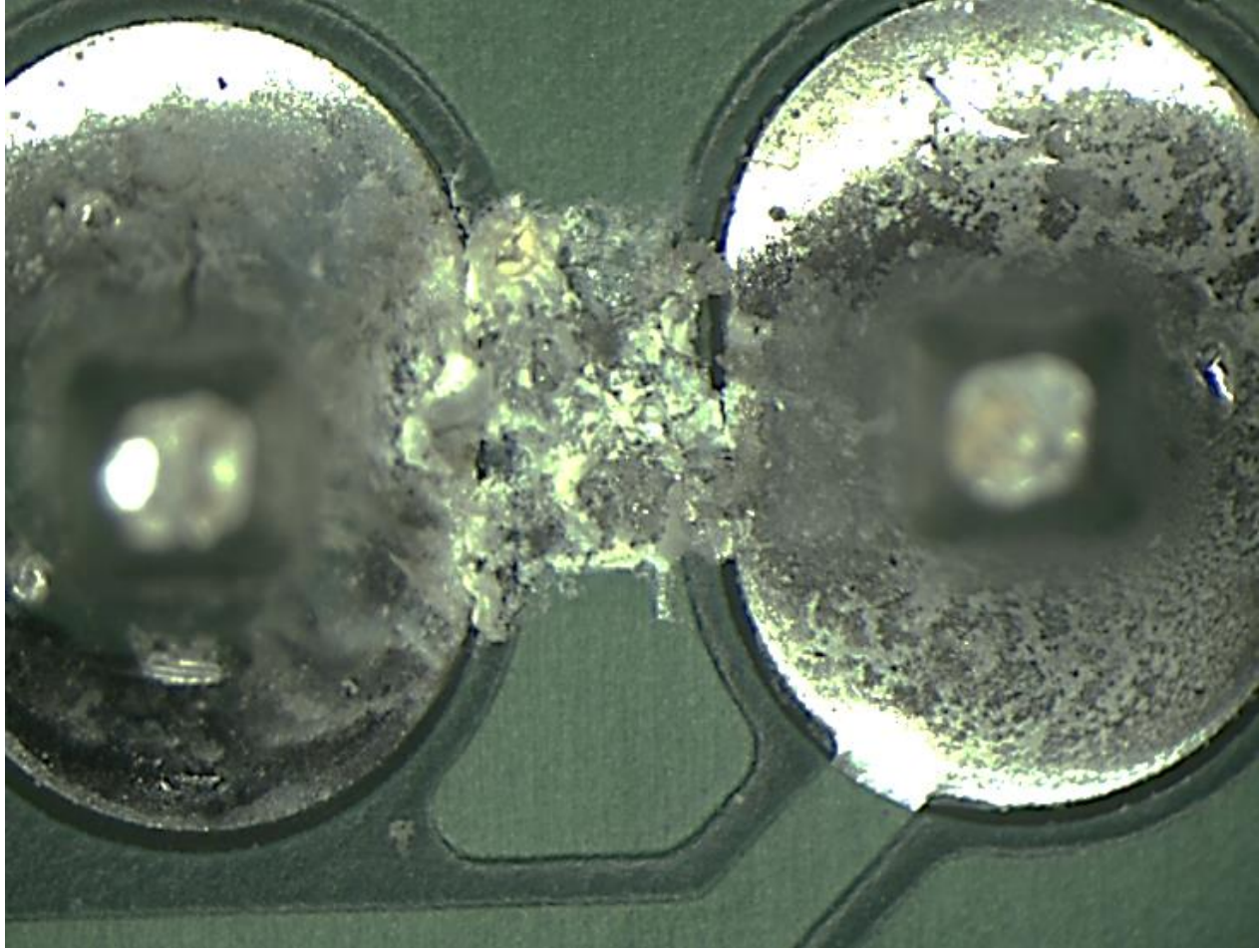
2010 (Today)

< 1mm

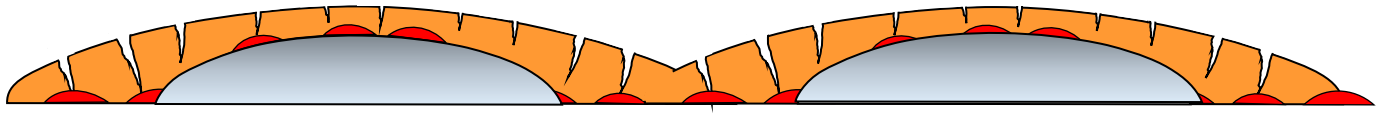


NO clean

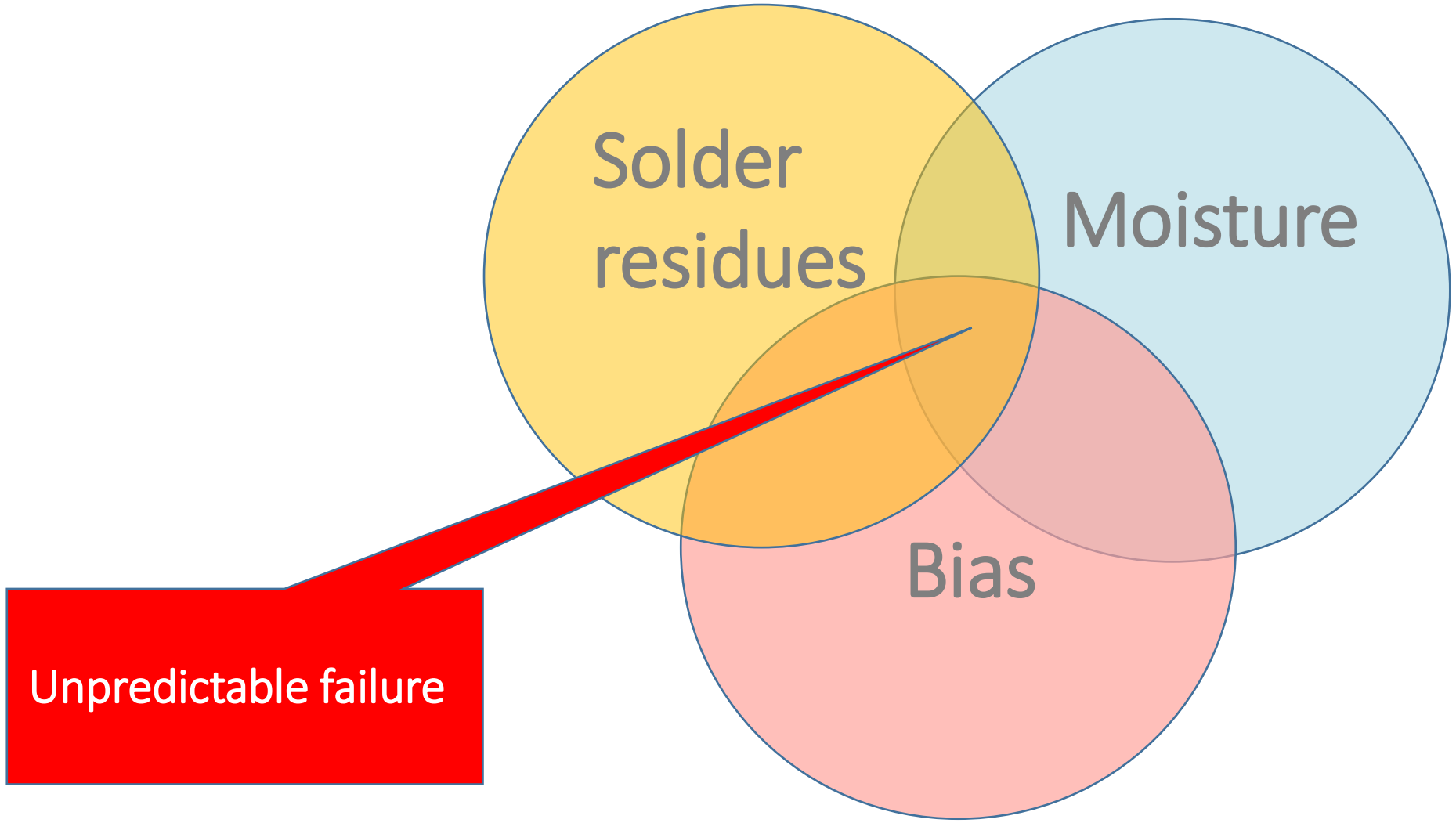
Today

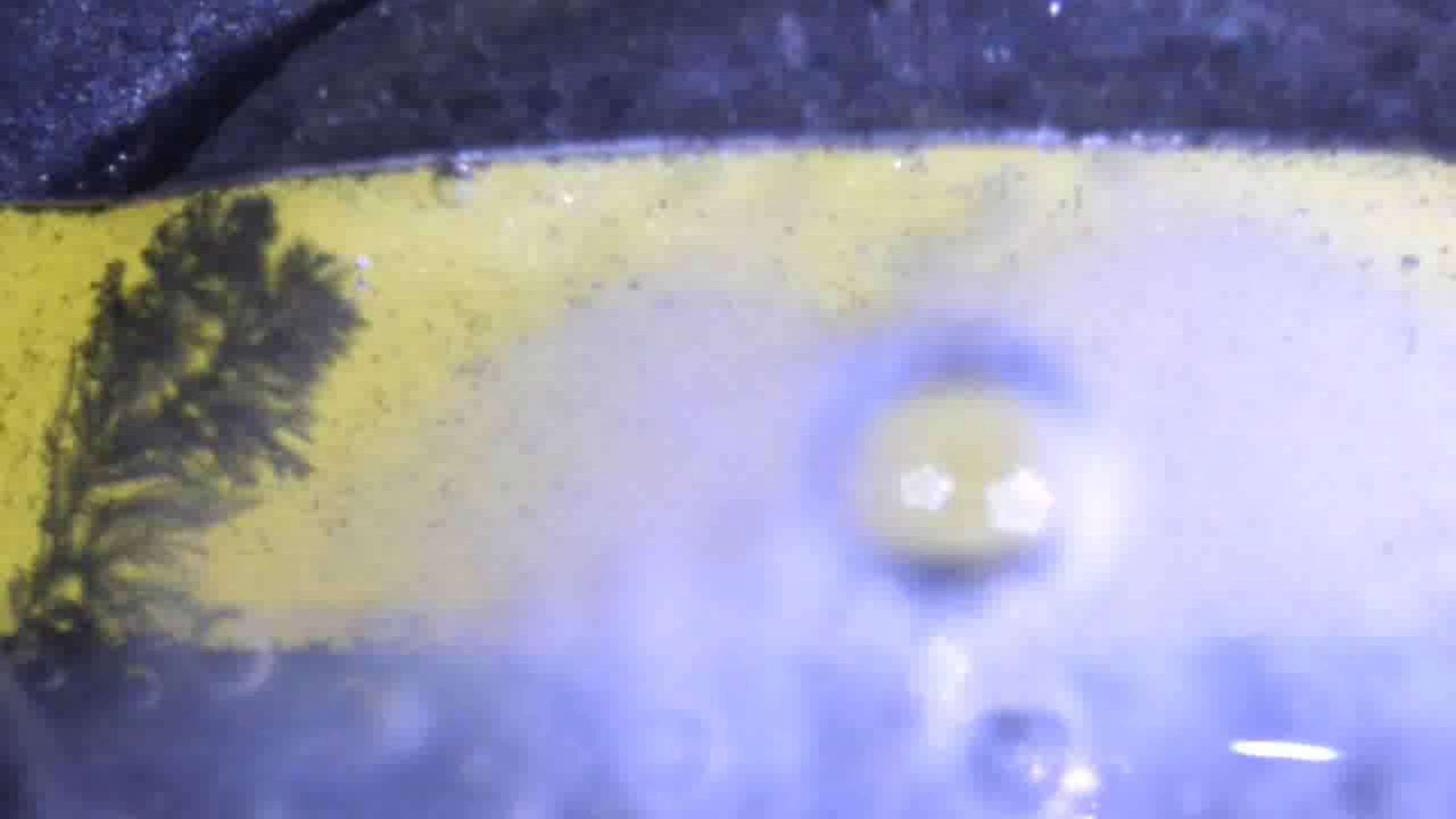


< 1mm

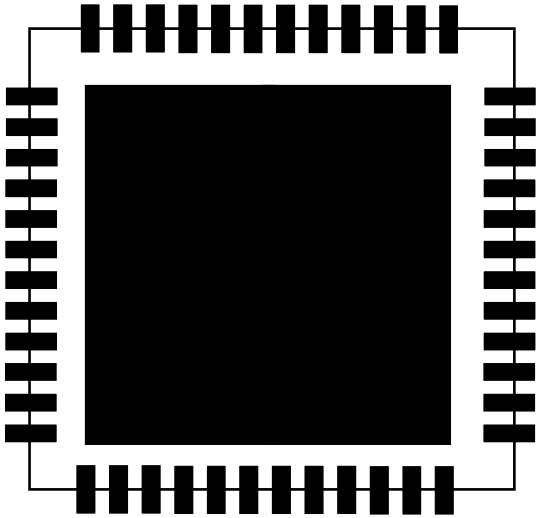


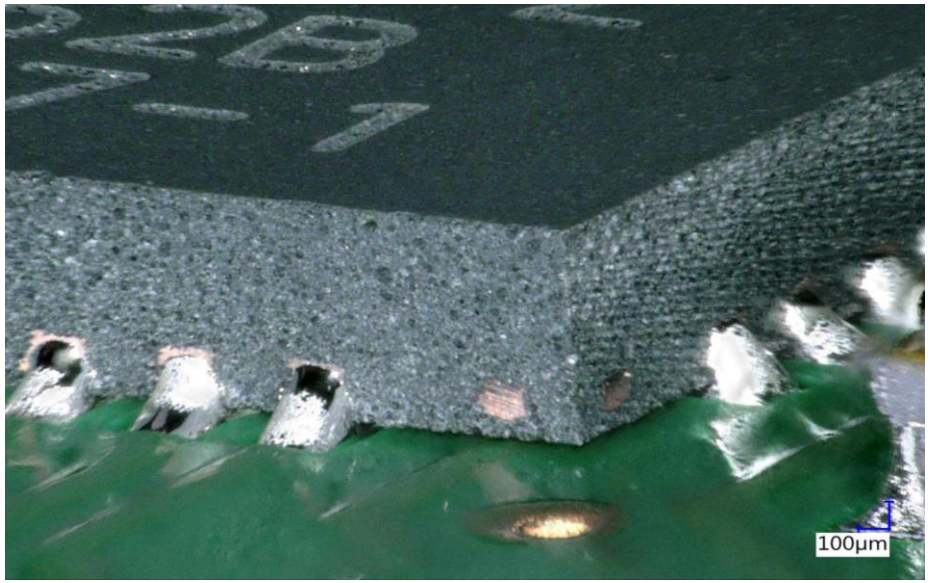
Electrochemical corrosion



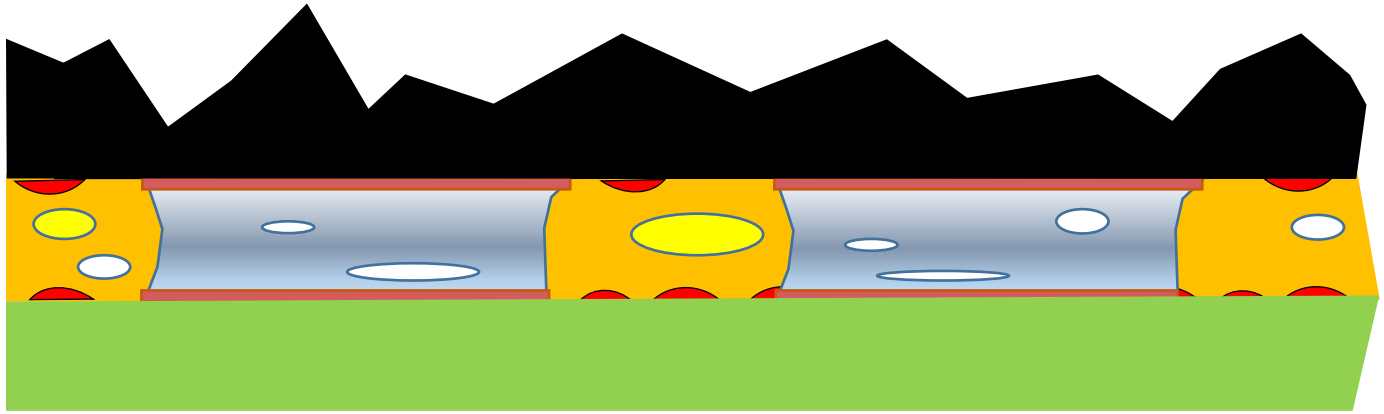


Bottom terminated components – cubic flux volumes





The termal lug contains surpluss organic material
Outgassing is difficult
Mobility of ions under BTC is higher!



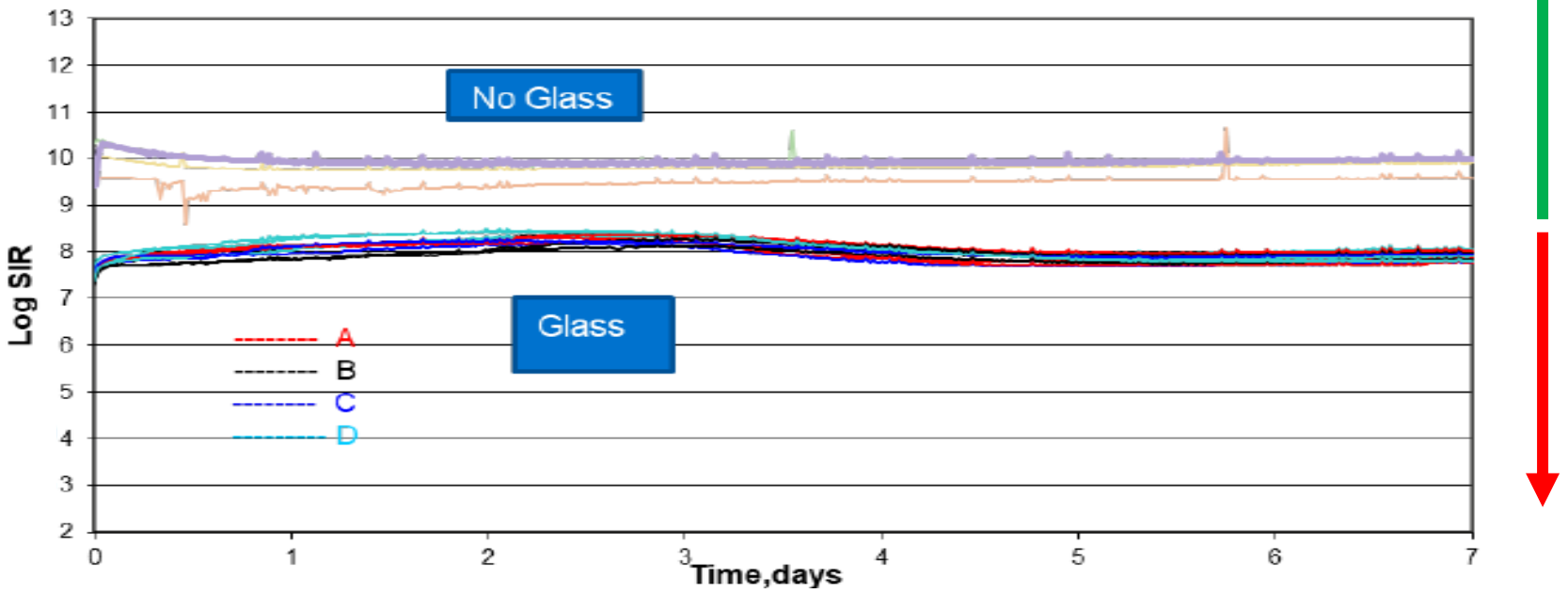
Good Outgasing is a key for good cleanability

Obstacles in outgasing lowers the insulation resistance. Reason is higher ion mobility in such residues

Solder joint covered by Glass

Free surface of Solder joint

SIR test of samples

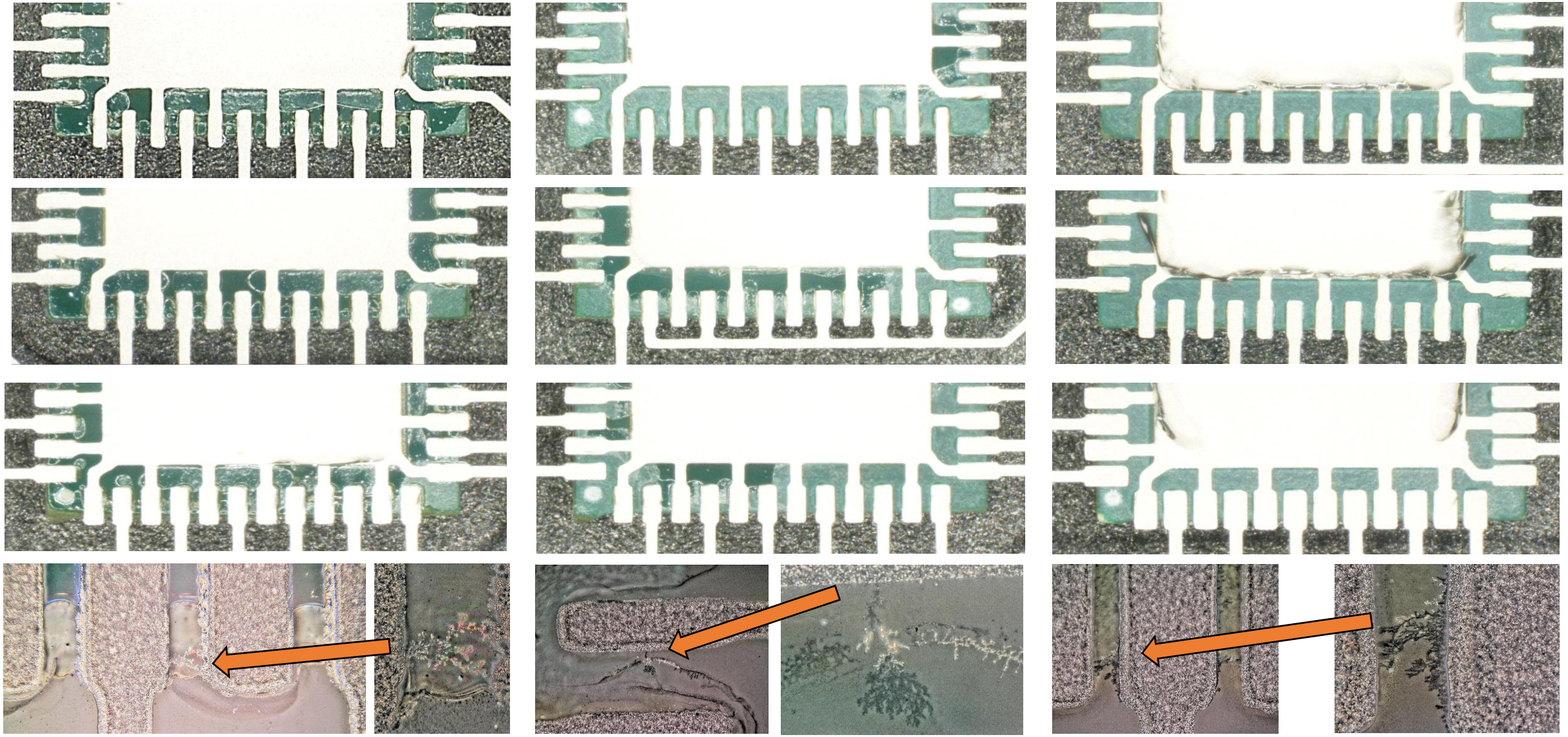


Outgasing under QFN and SIR test

No clean after reflow

Partialy cleaned

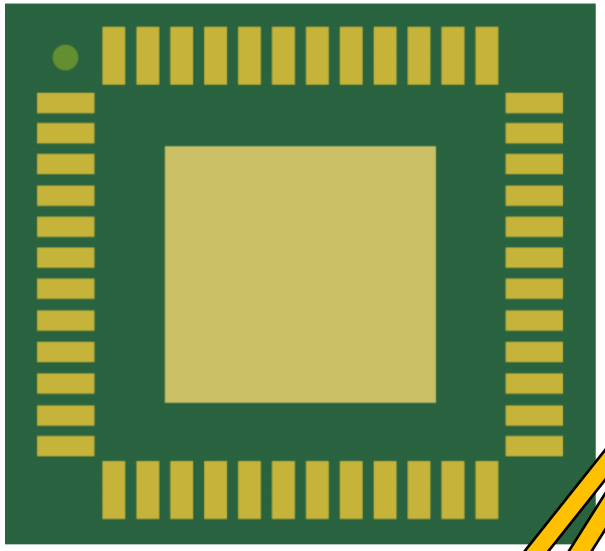
„Completelly“ cleaned



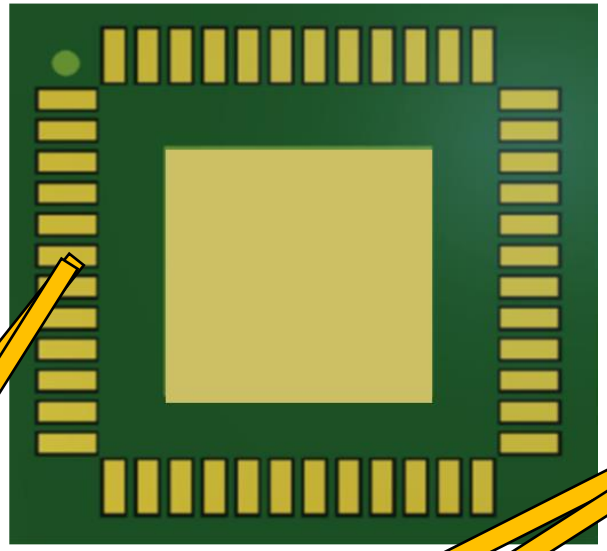
(By Mark Mc Mean Magnalytics USA – STI substrates by PBT Works CZ October 2020)

How to increase outgasing QFN - NO CLEAN

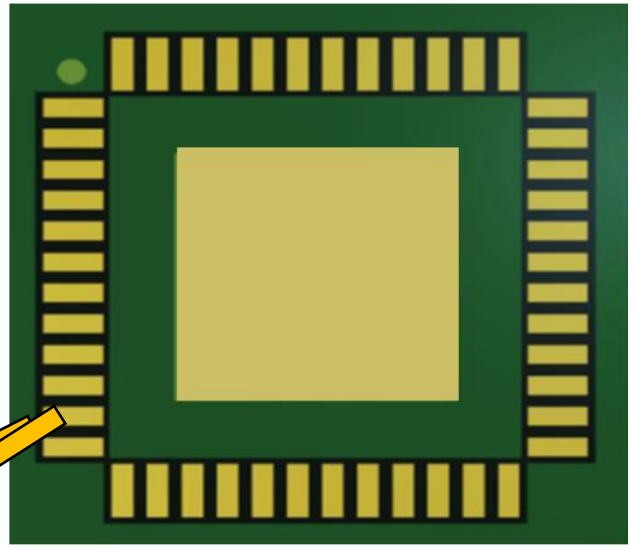
Solder Mask Defined pads

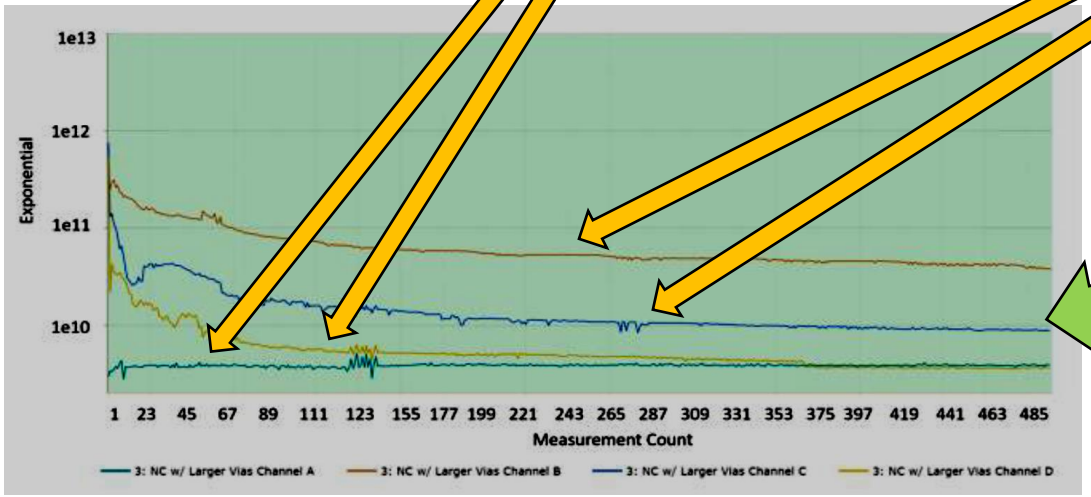


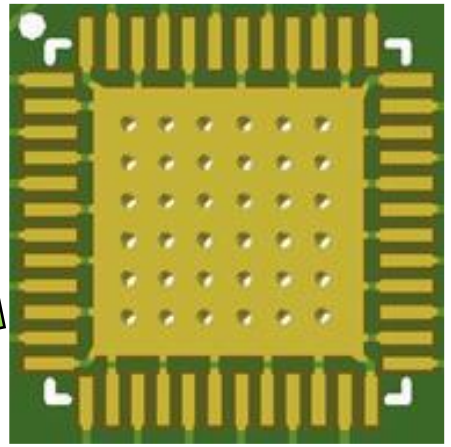
Non Solder Mask Defined pads



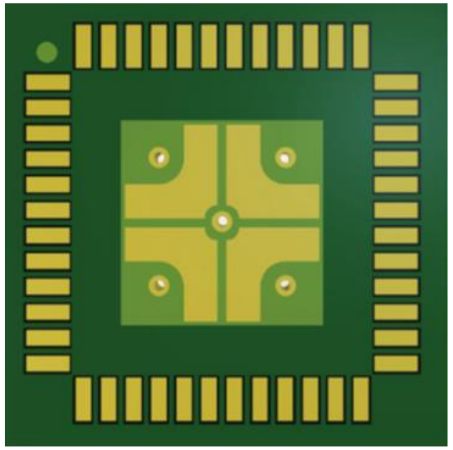
Ganged pads







Termal vias



Solder mask windows + Encroached pads

(By Mike Bixenmann Magnalytics USA October 2020)

Cleaning for reliability
how to judge the ballance cost/ profit

- **Reasons for cleaning**
  - **Real:** assuring reliability – ionic, organic cleanlinnes – high SIR
    - Proces uniformity and repeatibility
    - Logging process parameters, traceability
    - „ expensive“ and „ complex“ equipment
    - Need of permanent process validation tool
    - Process qualification before real start
  - **Cosmetic**: optical cleanlinnes – to make product nice
    - Process uniformity and repeatibility not very important
    - Cheap equipment
    - Process „ validation“ by naked eye
    - Process qualification normally not performed

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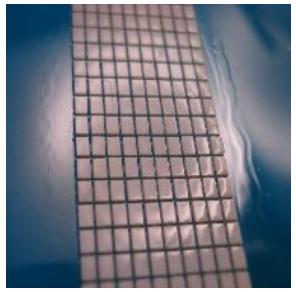
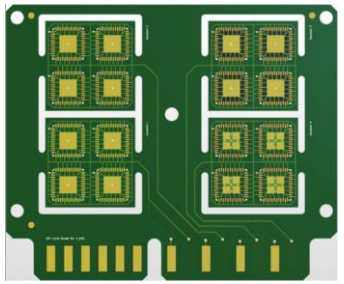
Producing scrap for money

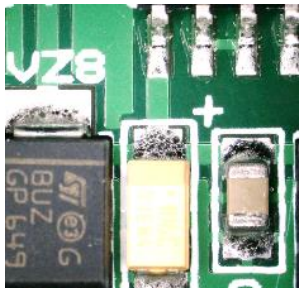
Cleaning process Qualification
IPC J- STD 001H 8.1 (Oct.2020)

- **Objective evidence**
  - **Historically proved reliability** is a valid evidence
  - **Shortened function test** in harsh conditions
    - (moisture, salt, water, heat cycling etc.)
  - **Non direct evidence** (not only one method is enough)
    - SIR measuring *electrochemistry*
    - IC (Ion Chromatography) *chemistry*
    - Optical (check of residues , inclusive under components) *optics*

Cleaning Process qualification







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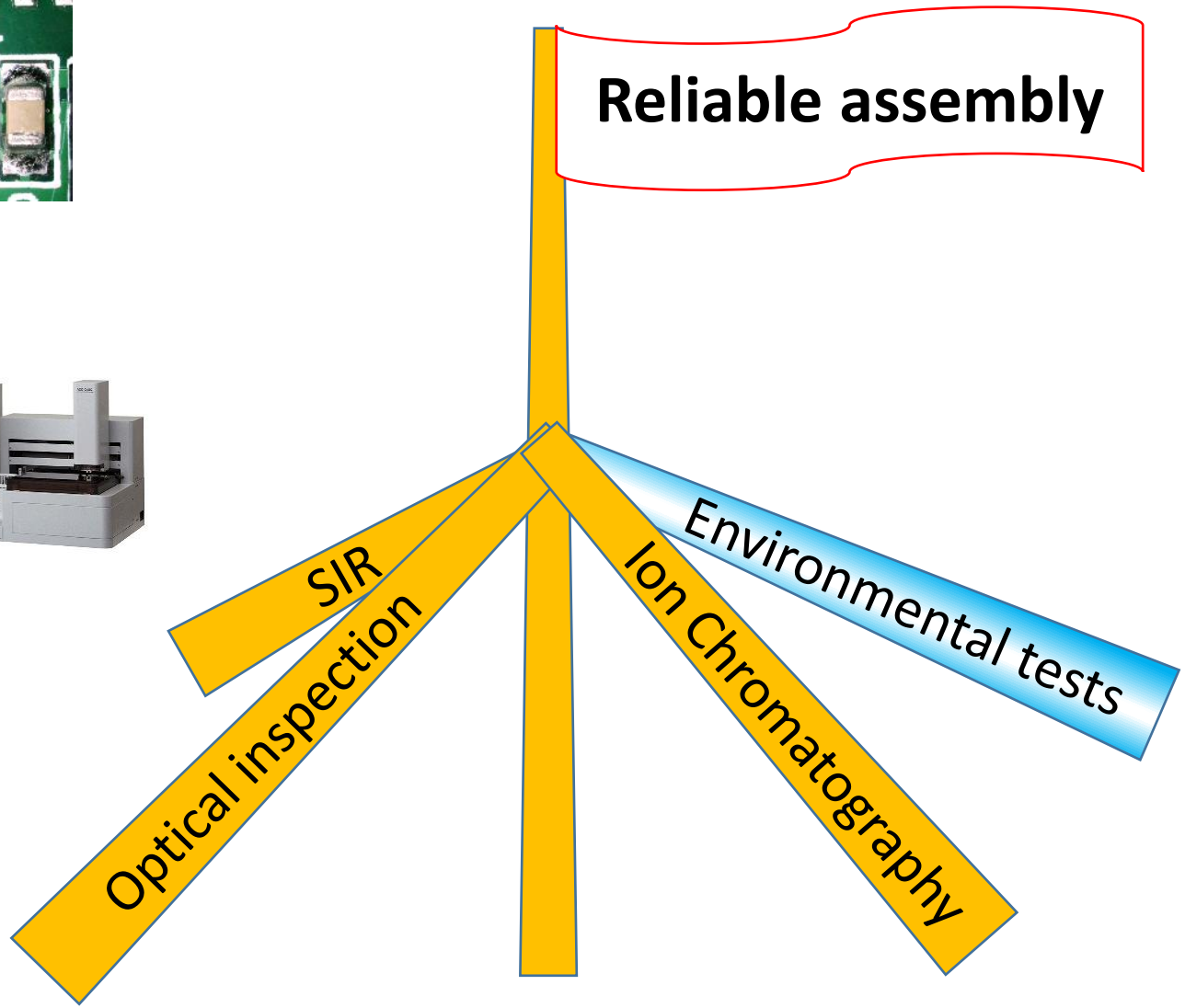
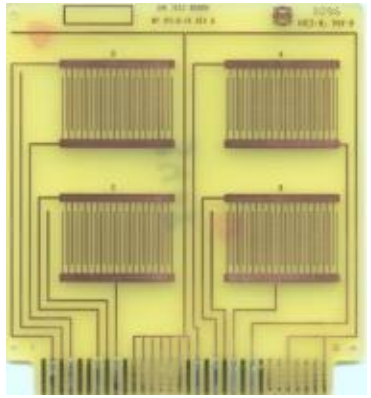


SIR testing – J- STD 004

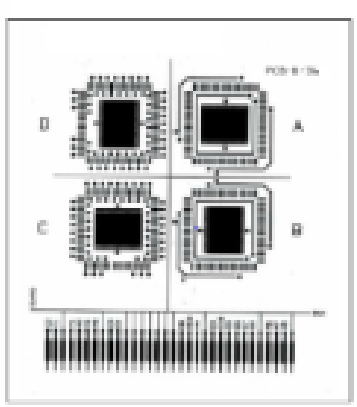
	SIR	
s	J-STD-004A	J-STD-004B
Temp/Humidity	85°C, 85%RH, 168 hours	40C, 90%RH, 168 hours
Stress Bias	45 - 50 Volts DC	5V (8 mil spacing) or 25V/mm
Pre-Bias Stabilization Period	3 hours at T&H	1 hour at T&H
Measurement Bias	-100 Volts DC	5V (8 mil spacing) or 25V/mm
Time of Readings	24, 96, 168 hours	At least once every 20 minutes
Control	>1E9 Ohms, 96 hours to end	>1E9 Ohms, 96 hours to end
SIR data	>1E8 Ohms @ 96, 168 hours	>1E8 Ohms @ All Measurments
Dendrites/Corrosion	None > 25% of spacing	None > 20% of spacing

SIR test coupons

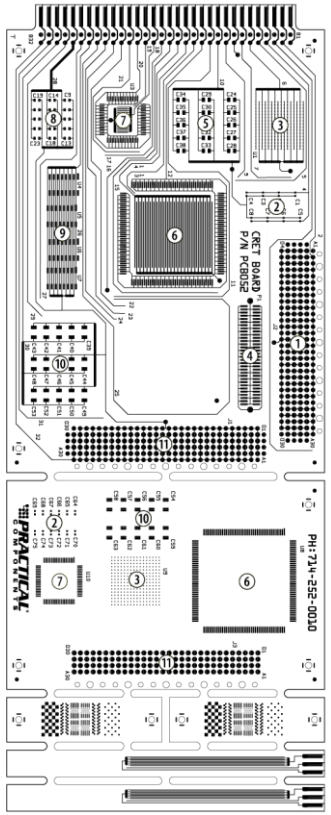
B24

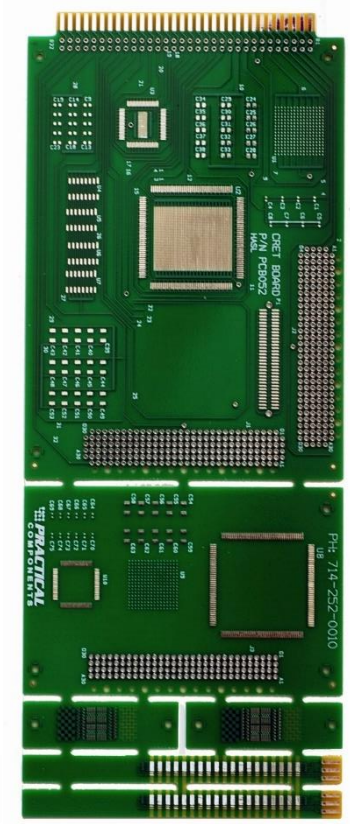


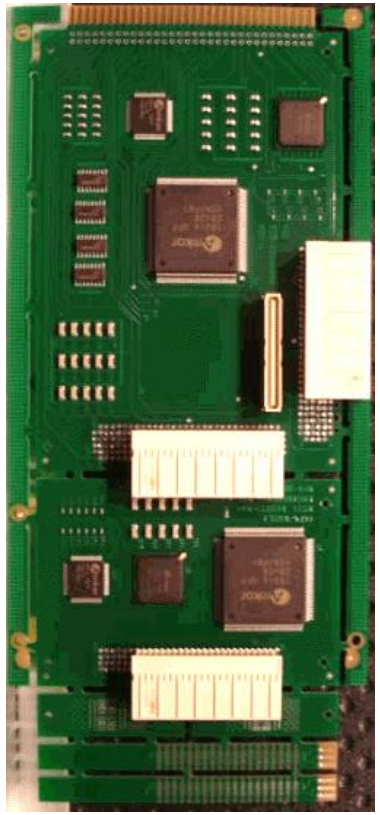
B36



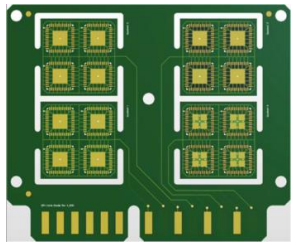
B52 (BY IPC 9201 1996, rev. 2007)

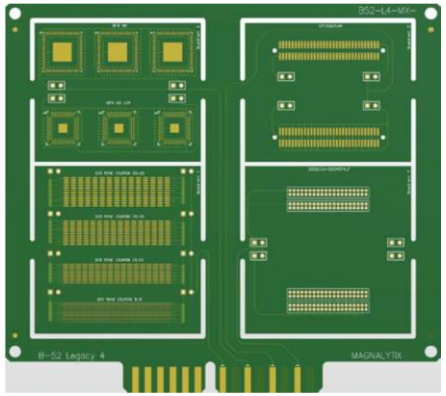


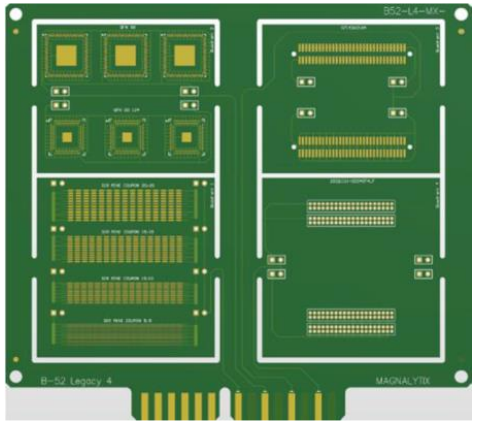


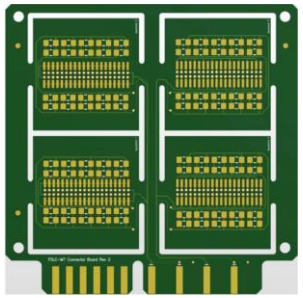


B52 Legacy boards (STI, Magnalytics - closer to customer´s situation today)



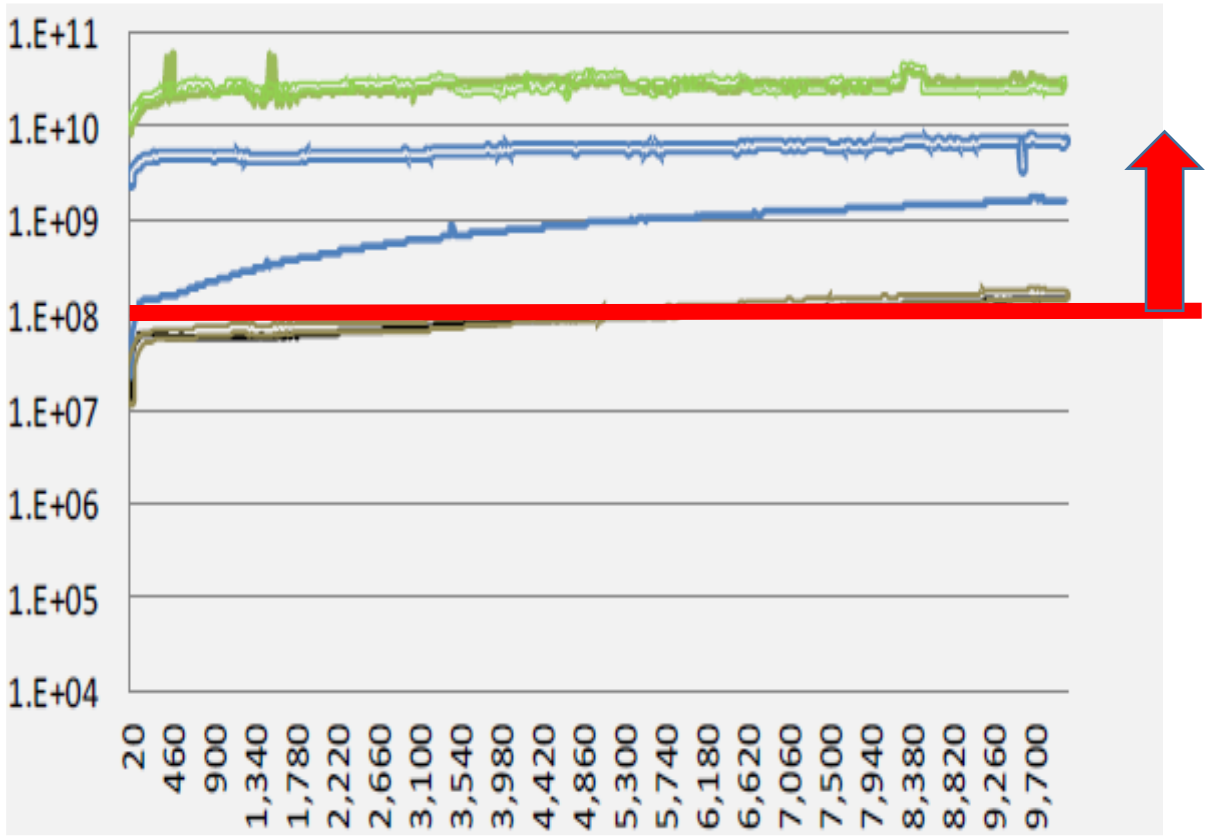




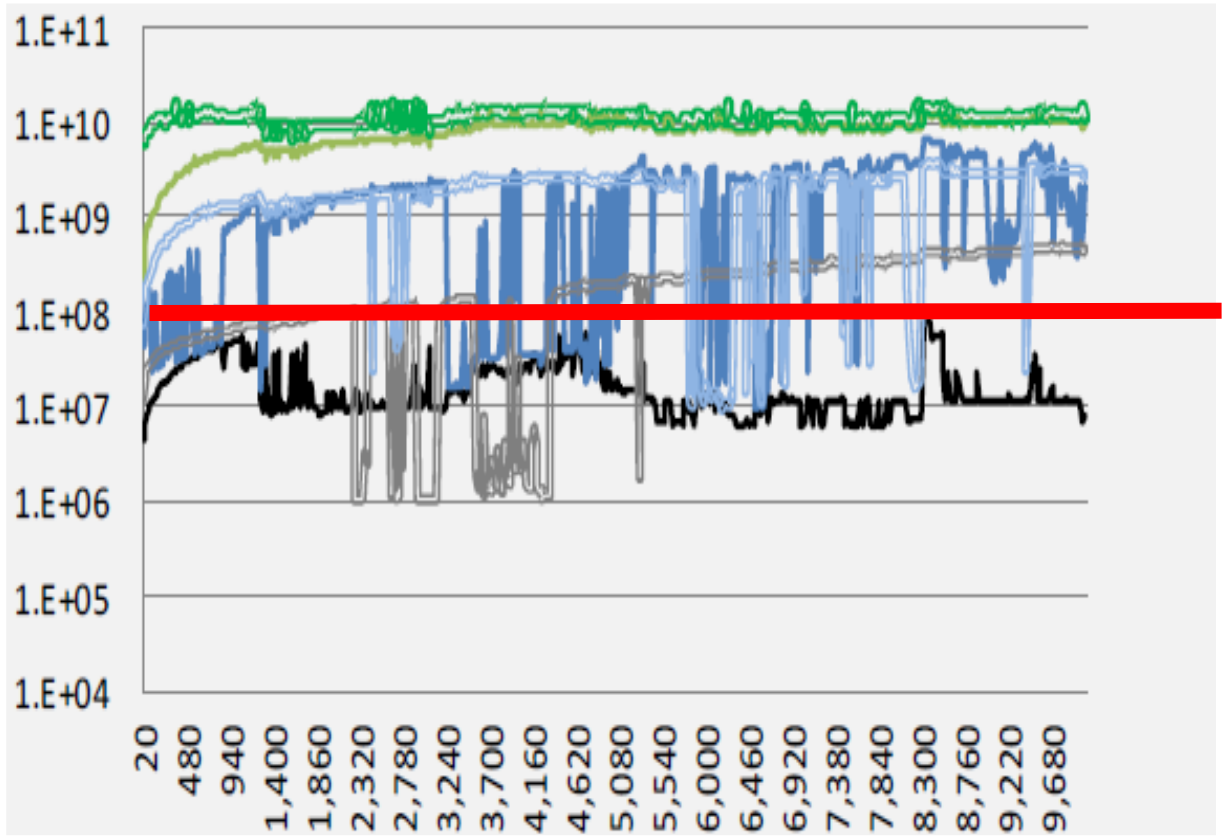


Limit for SIR

B52 cleaned

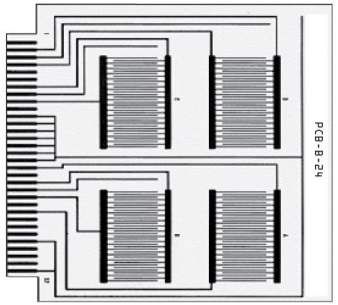


B52 half cleaned

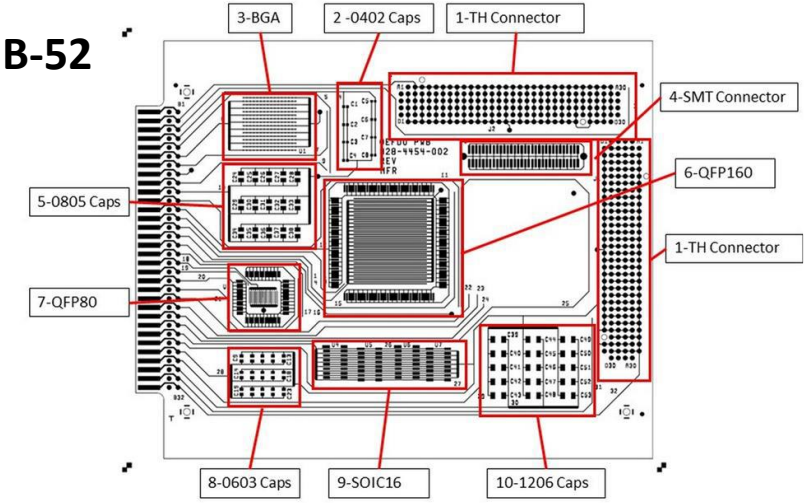


Automotive- driven approach to SIR

B-24



B-52



SIR tests	Enhanced	J-STD 004 A,B
Minimum SIR requirement	5,000MOhms 5*E+10	100MOhms 1*E+9
Time	1,000 hours	168 hours
Spacing	0.2mm	0.5mm
Voltage	10V, 50V	5V
SIR coupon	B52	B24

Enhanced SIR testing requirements – high voltage

Automotive	500V

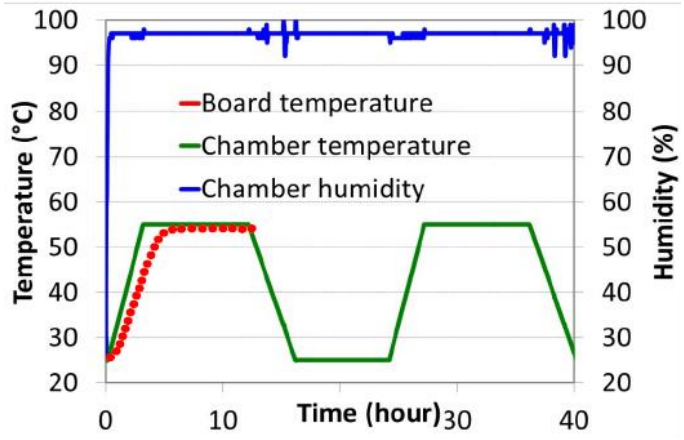
SIR after termal cycling

Temperature Cycling Parameters		
Profile	Dwell (Minutes)	Cycles Completed
-40°C to +125°C	5	~153
-55°C to +175°C	10	~535

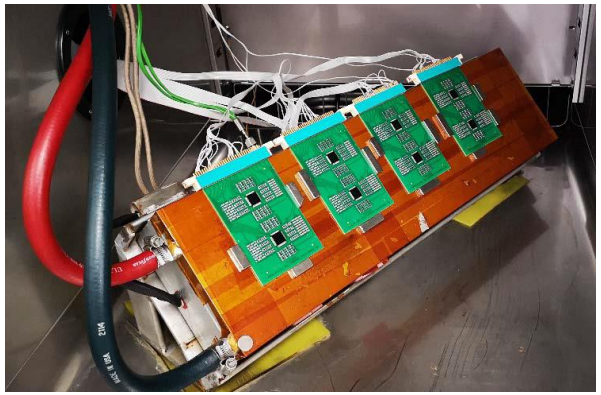
New methods to verify reliability

Conventional Condensation testing

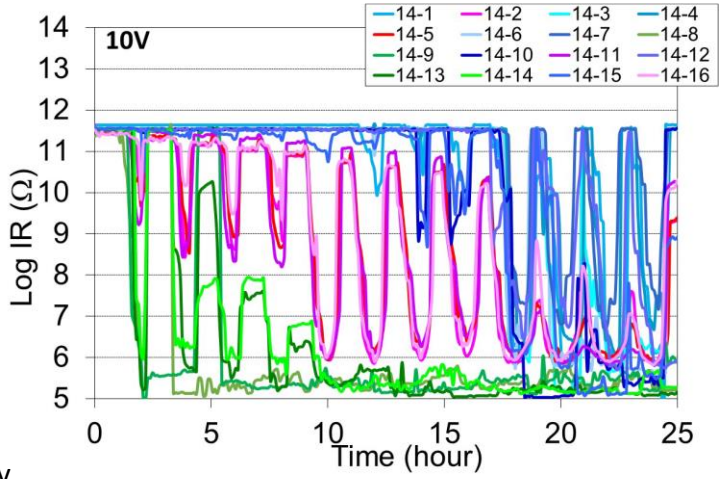
Dependent on mass of subject
Not repeatable , weak definition
Less dynamic



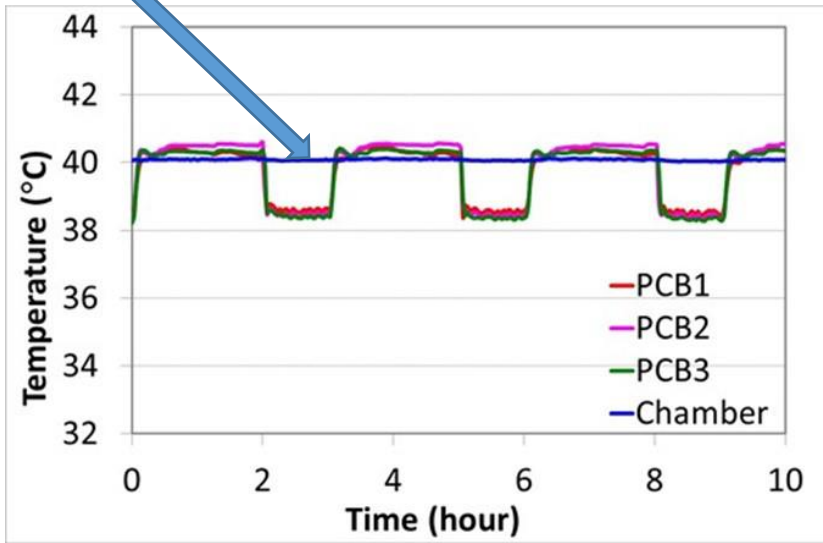
New – precise condensation test (NPL)



Pictures from National Physical Laboratory

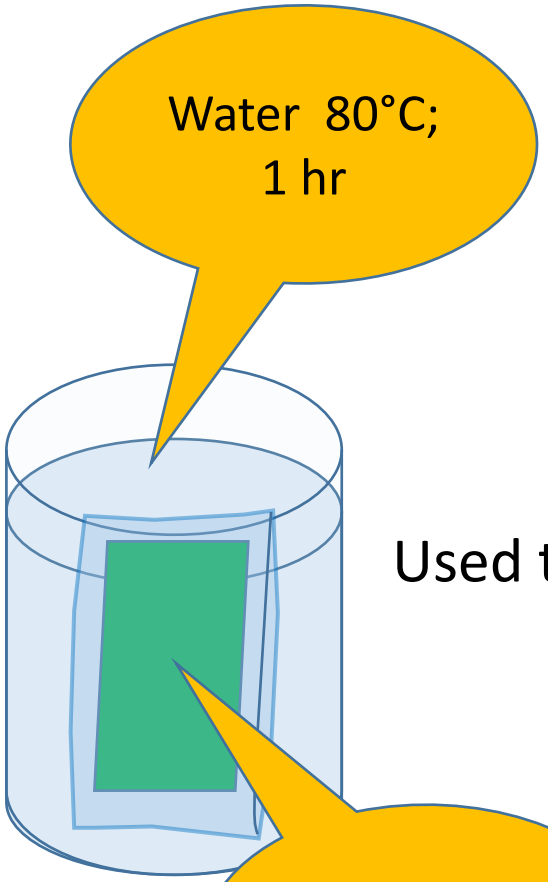


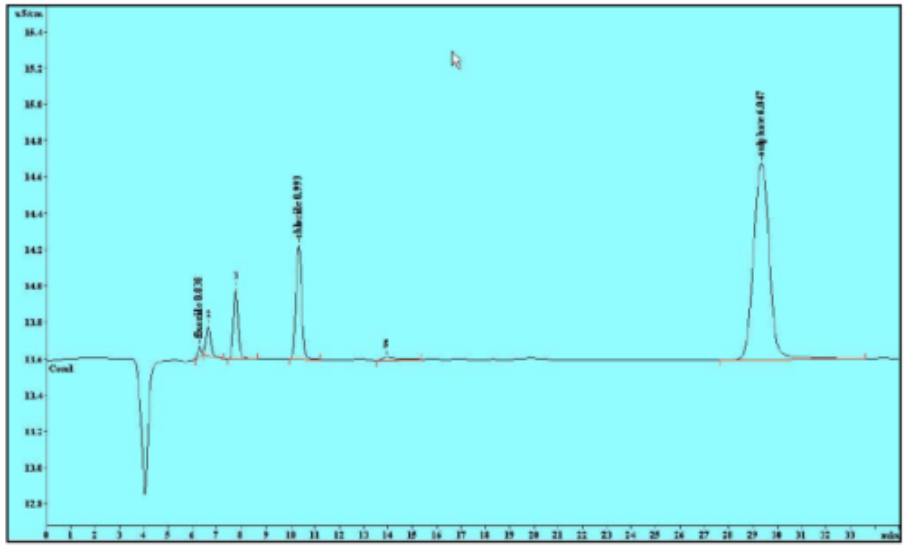
DEW POINT



Electro- chemical testing

Ion Chromatography IPC TM650 2.3.28





Used thresholds (IPC 5704) these are not a universally valid common values !!!

Minimum Ionic Species	Micro Grams/Square inch	Micrograms/Square Centimeter
Bromide	<10 µg/in^2	<1.55 µg/cm^2
Chloride	<6 µg/in^2	<93 µg/cm^2
Fluoride	<3 µg/in^2	<47 µg/cm^2
Sulfate	<3 µg/in^2	<47 µg/cm^2
Phosphates	<7 µg/in^2	<1.09 µg/cm^2
Nitrates	<3 µg/in^2	<47 µg/cm^2
Weak Organic Acids	<25 µg/in^2	<3.88 µg/cm^2

Anions – not specified in this standard

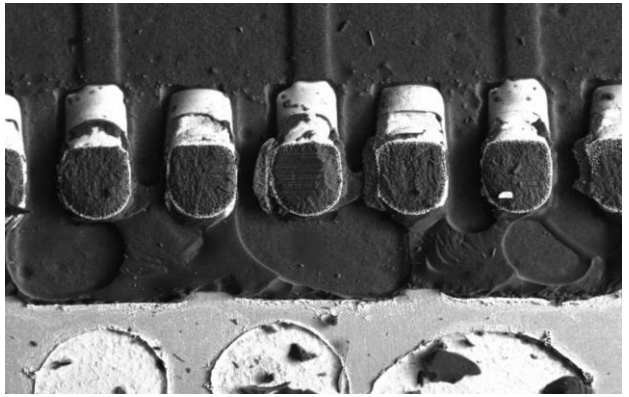
Other methods used today

- FTIR – indication of known material residues. Must be „ teached“.

- C3 – (Critical cleanlinnes Control)
  - Local ionic contamionation analysis
  - Ion chromatography

Foresite Inc.

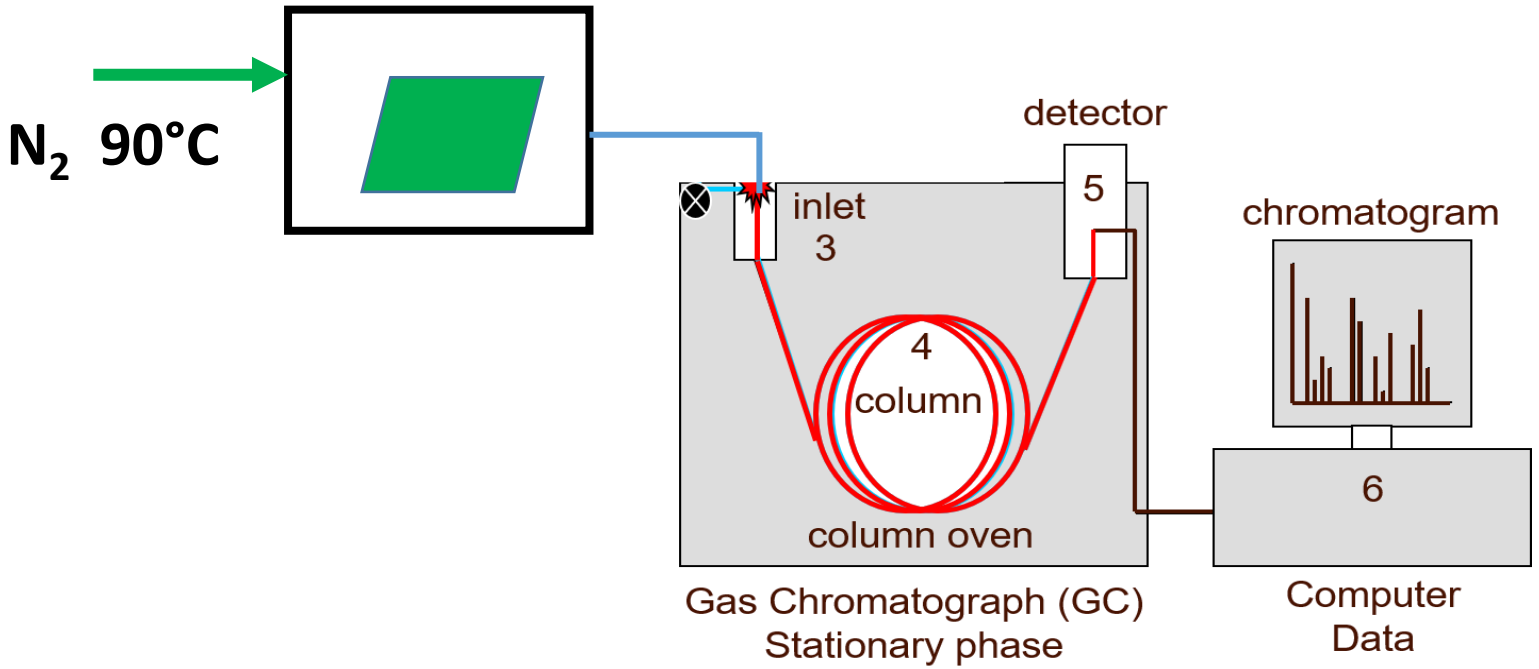
- SEM + EDAX analysis
  - For very high magnification
  - Analysis of elements , not molecules



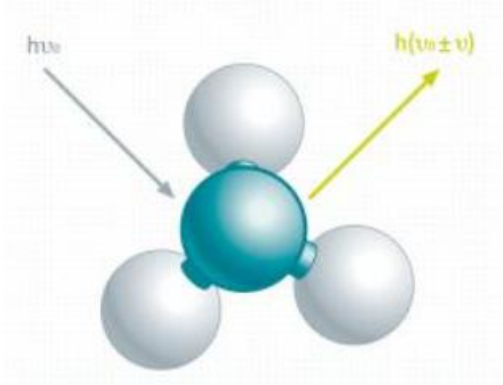
STI inc.

Other methods used today

- Gas Chromatography.

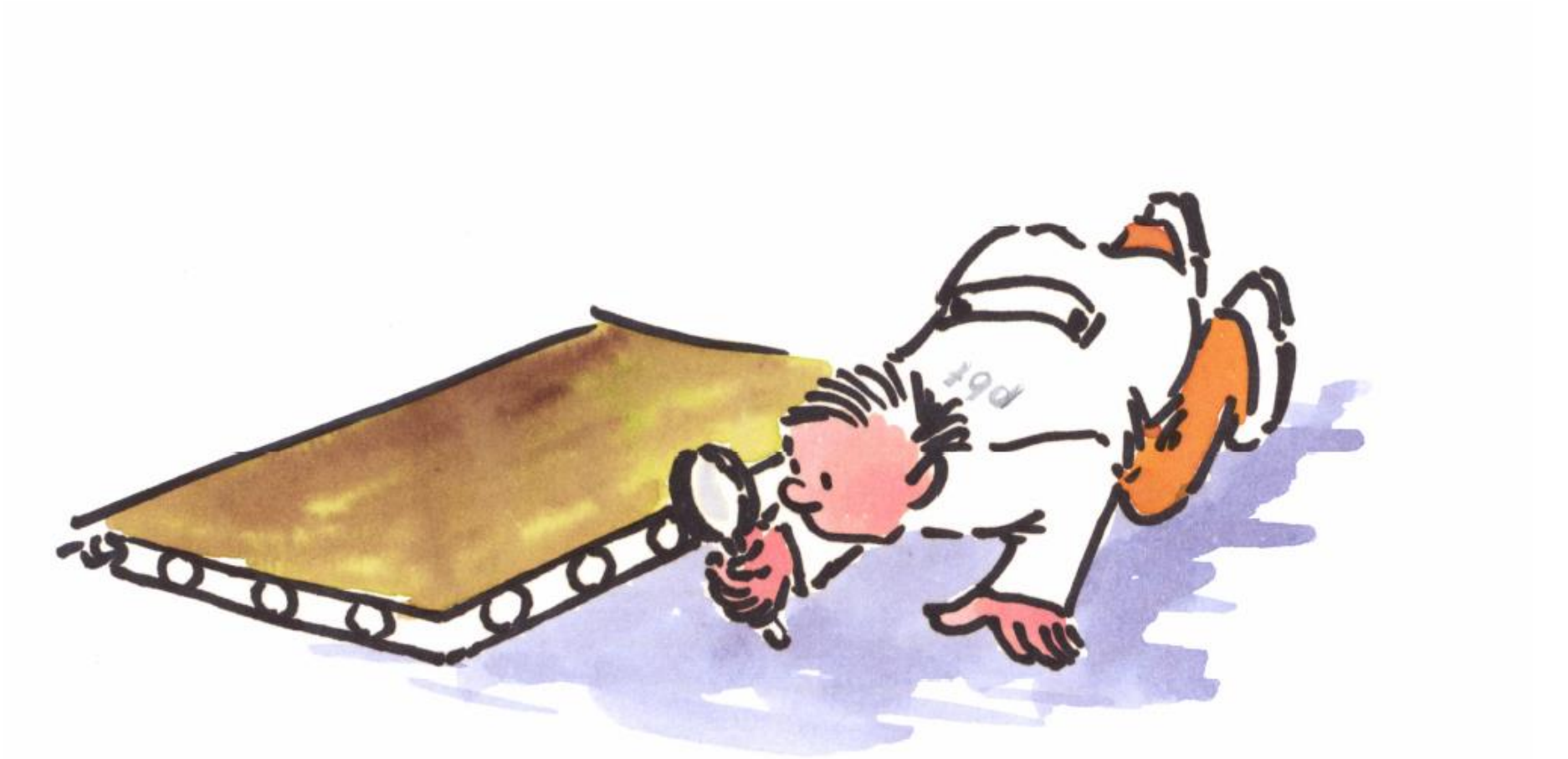


- Raman spectroscopy



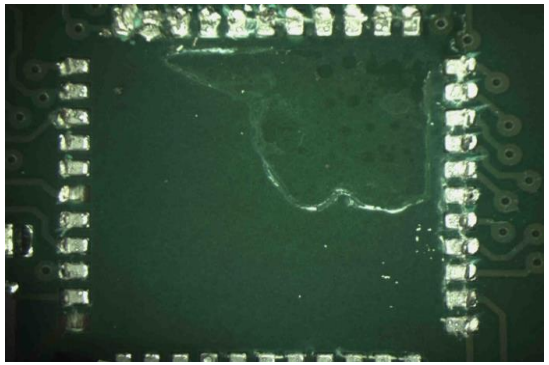
Photon scattering due to absorbtion or energy transfer from the molecules gives information about molecule structure

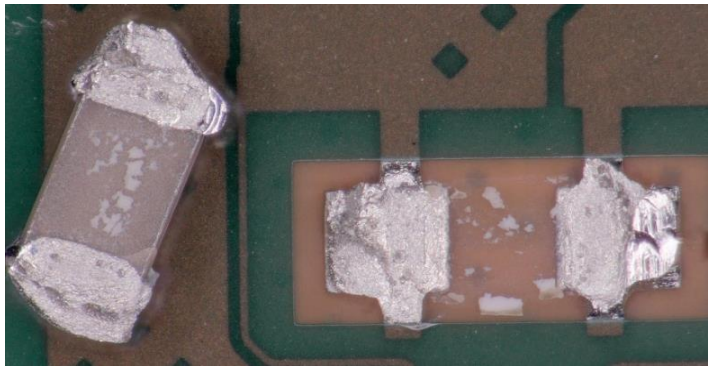
Optical inspection of cleaned assemblies



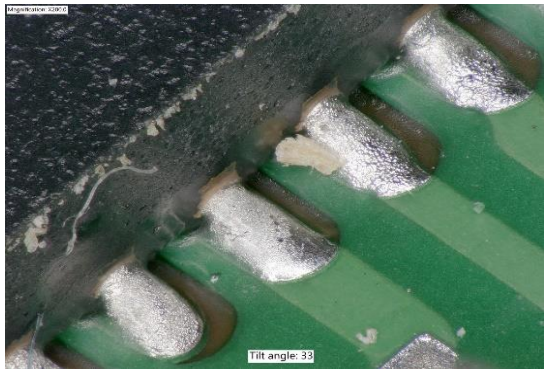
How to look under components

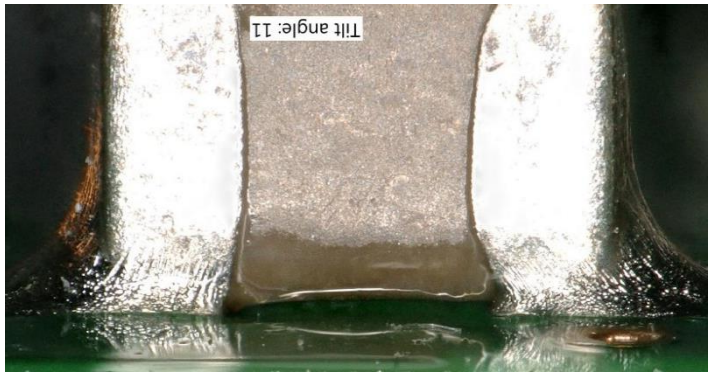
- Components tearing



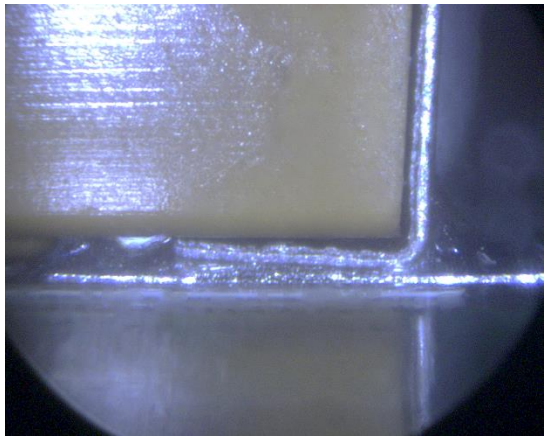


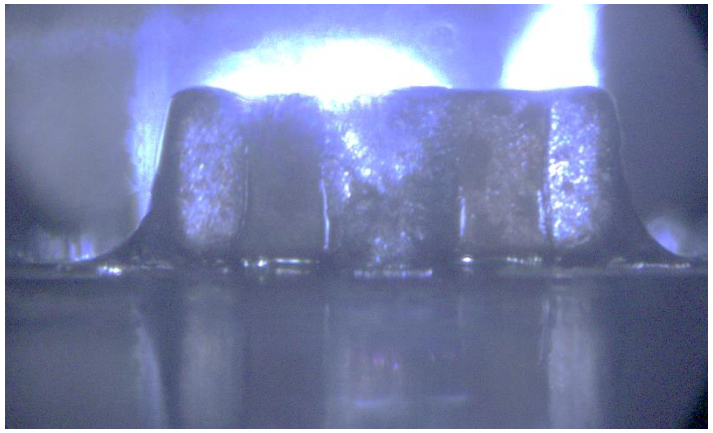
- Tilted wiew

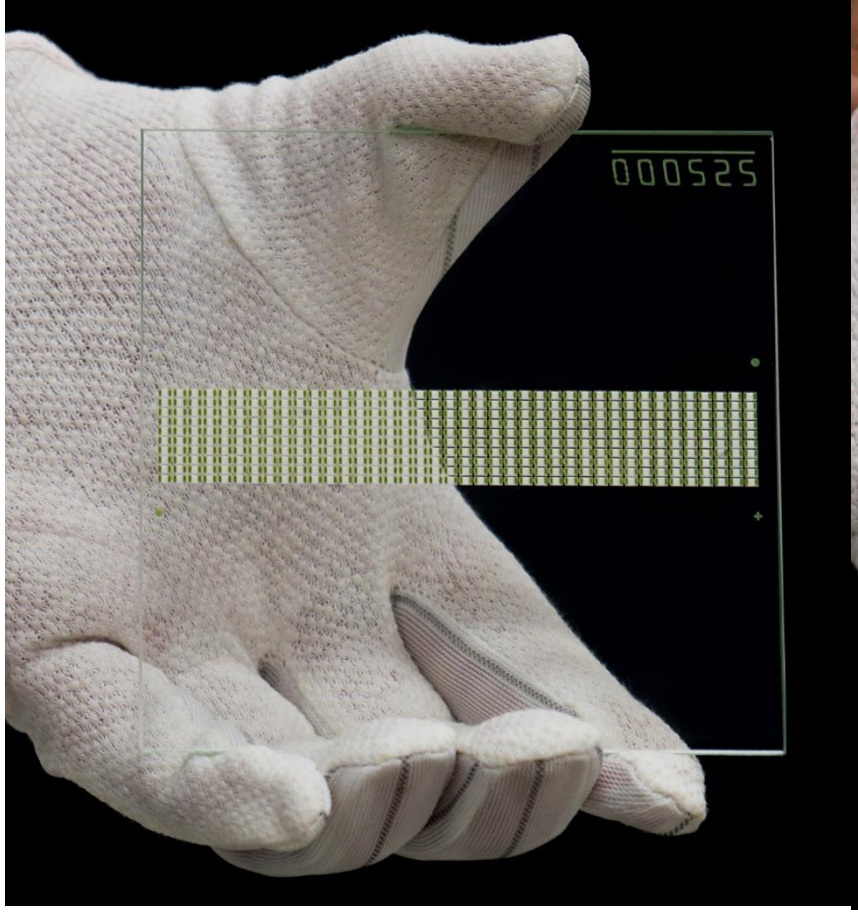


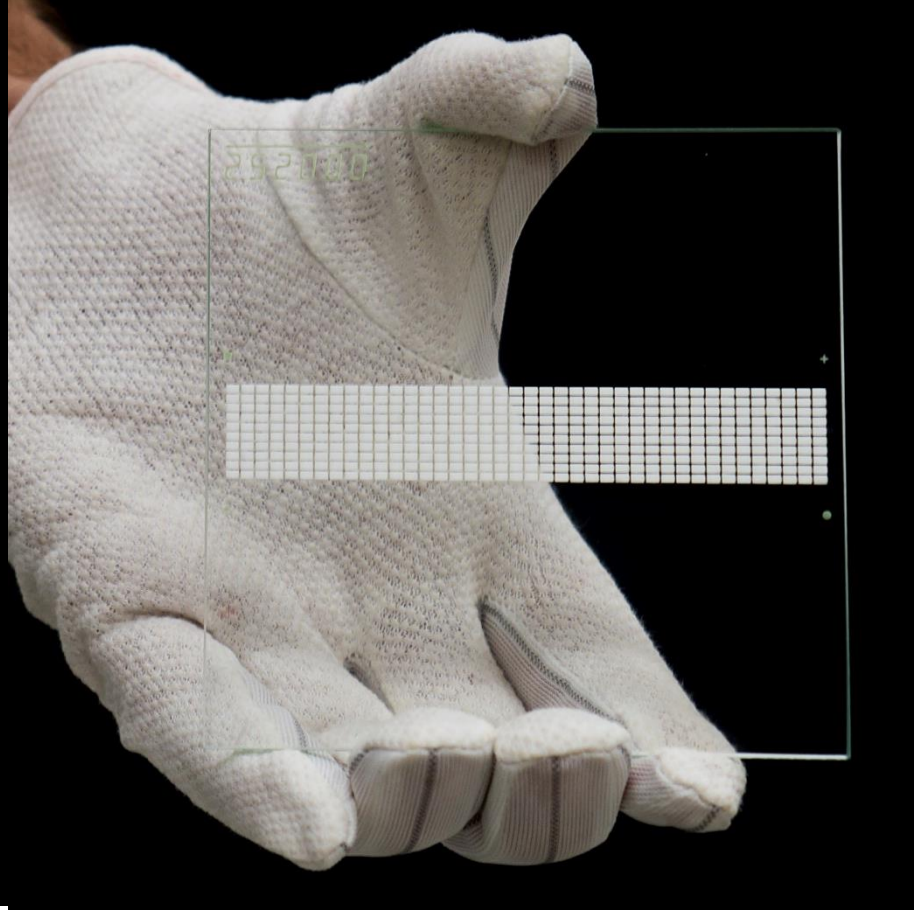


- 90°wiew – endoscope

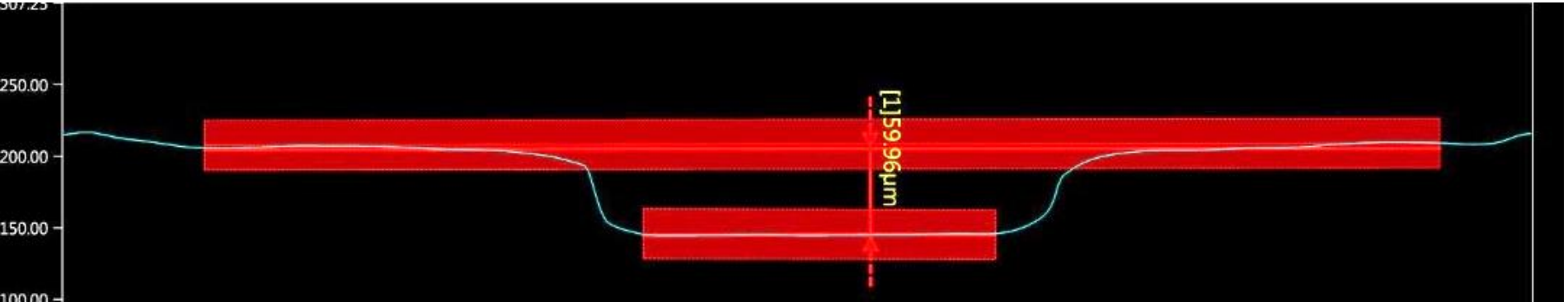


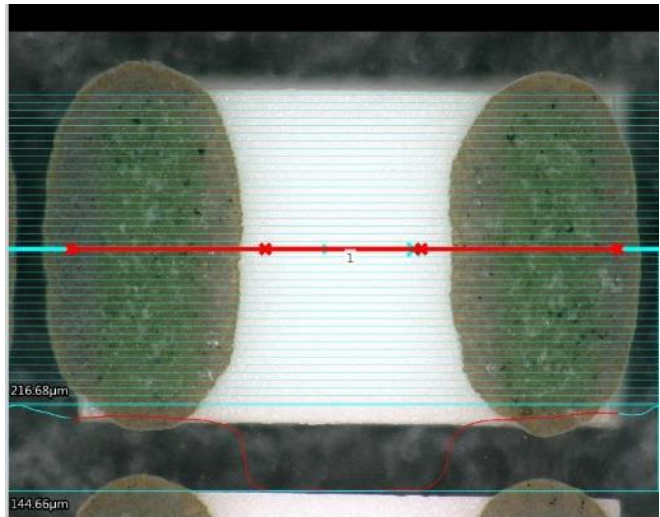




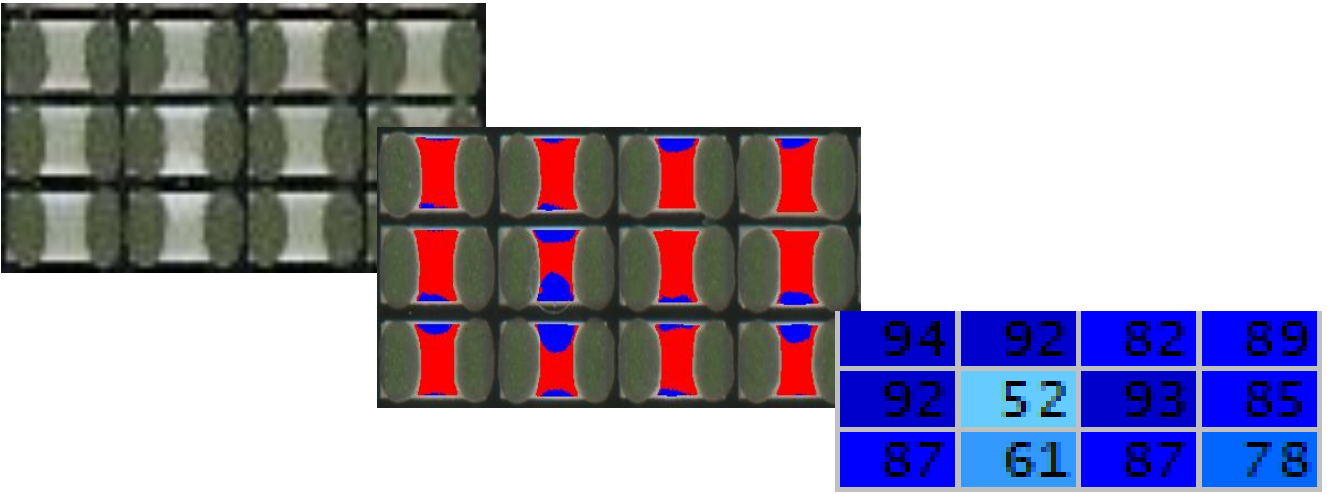


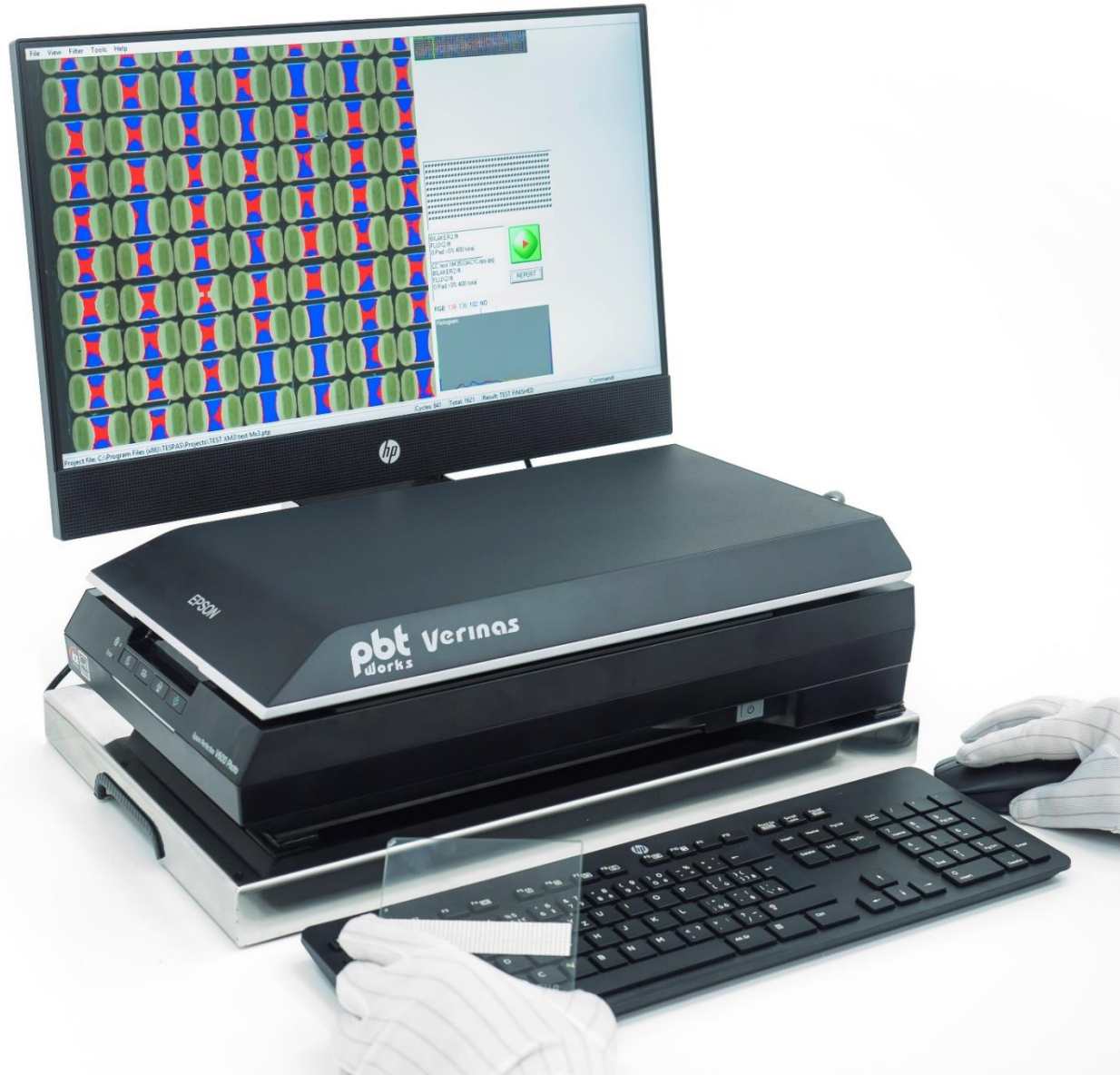
PBT Glass Test Board





PBT Glass Test Board optical tester





- Flux residues solubility testing
- SPC of cleaning process according to J-STD-001 Am.1, par. 8
- Validation of changes instead of ionic contamination measuring
- Cleaning process optimization
- Cleaning machine capability studies
- Cleaning process capability studies

GTB – test protocol

Report

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
10	62	84	66	59	48	51	58	48	70	54	52	46	52	64	66	54	55	48	38	38	47	67	78	45	70	66	52	49	64	60	65	59	51	65	54	60	82	97	58	67
9	99	65	73	99	59	67	79	74	77	78	63	46	81	79	80	72	60	83	55	70	79	99	70	78	82	71	81	83	82	93	74	88	64	86	88	75	88	86	96	94
8	91	69	80	99	66	75	77	79	65	64	87	57	72	69	69	80	85	72	57	69	63	80	78	87	89	65	84	63	71	91	68	70	55	84	84	94	92	82	89	98
7	87	86	74	84	81	83	75	74	67	68	75	57	71	60	62	75	48	68	74	84	76	89	61	86	67	92	78	51	72	77	83	74	79	71	69	92	52	93	85	91
6	100	92	75	77	87	69	87	81	71	61	63	58	79	76	57	78	56	67	63	75	78	84	84	82	73	80	63	72	68	80	60	71	86	74	79	87	61	87	78	98
5	100	78	85	76	95	94	74	75	69	69	77	70	77	90	57	84	63	70	81	77	59	89	68	75	87	77	72	69	73	70	84	73	66	69	81	78	91	89	93	100
4	98	97	97	90	82	88	83	90	88	80	63	75	74	80	86	64	83	85	72	79	60	77	74	77	83	65	85	84	95	61	78	54	84	74	74	82	76	94	92	99
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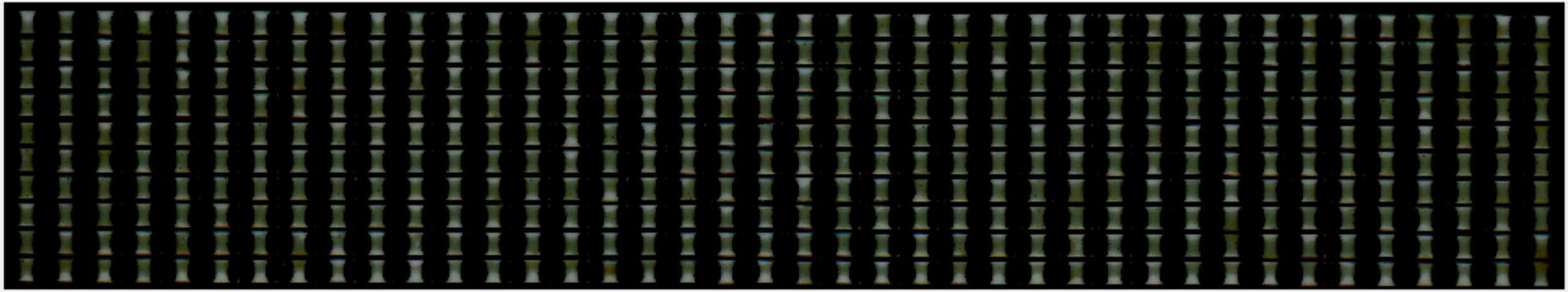
2	100	82	69	68	98	83	80	78	62	58	67	69	68	77	74	66	81	58	60	59	66	76	74	59	81	71	69	69	61	77	79	88	85	72	81	73	77	84	84	82
1	79	67	63	78	60	57	54	57	46	48	19	43	55	56	58	65	62	54	46	40	80	54	43	47	60	46	41	66	54	42	62	54	58	69	55	55	53	53	57	87



2019 4.17. 10:10 Configuration: SuperSwash | S.N.:170294 | AQUANOX A4727 | 1RS 446 AC8

Testing file: C:\Program Files (x86)\TESPAS\Projects\SMTA19 2Ra\000501 AC2.bmp

Middle value: 73 %

X=0.729 StDevRR=0.136 N=400 XLit=1.168 StdErrPR=0.0068 StdErrLit=0.0345

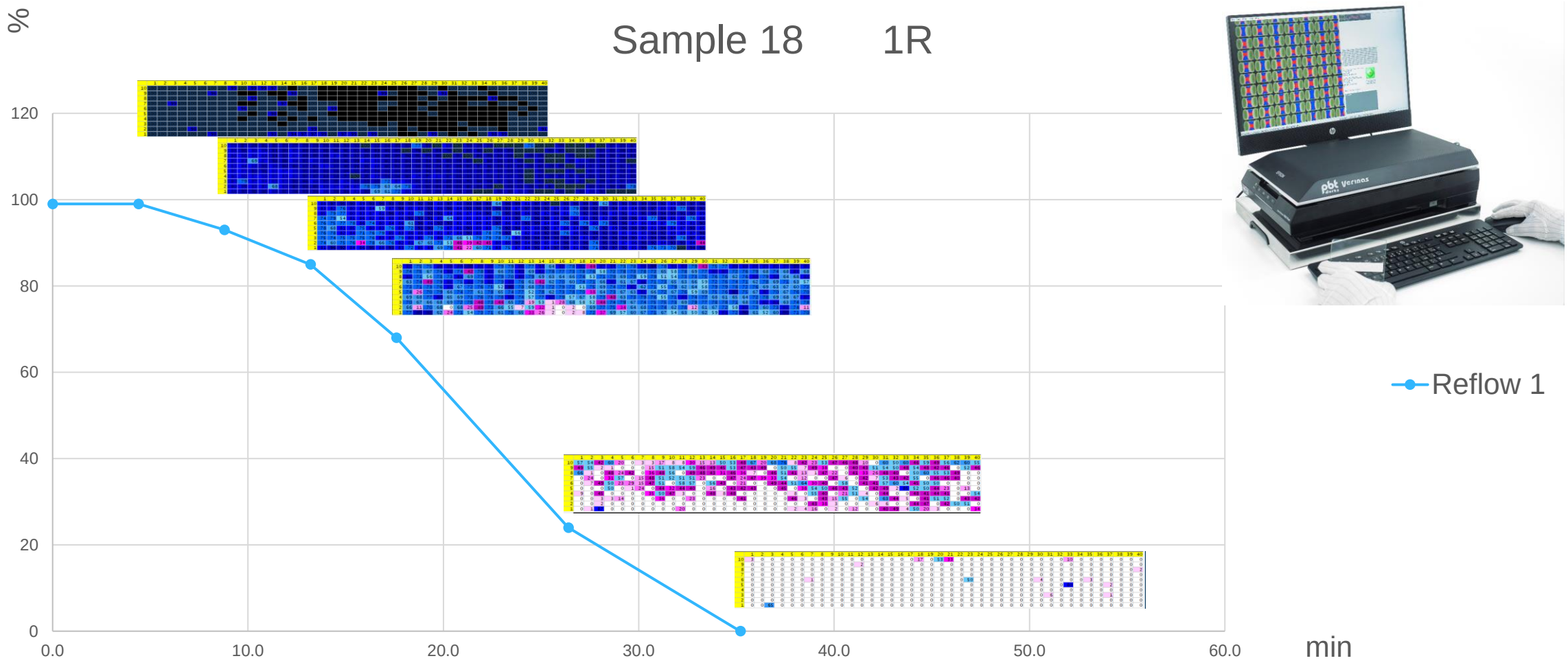
LoCILit=1.0994 HiCILit=1.2373 LoCI=75.01 HiCI=77.51 MeanResp=76.28

T:

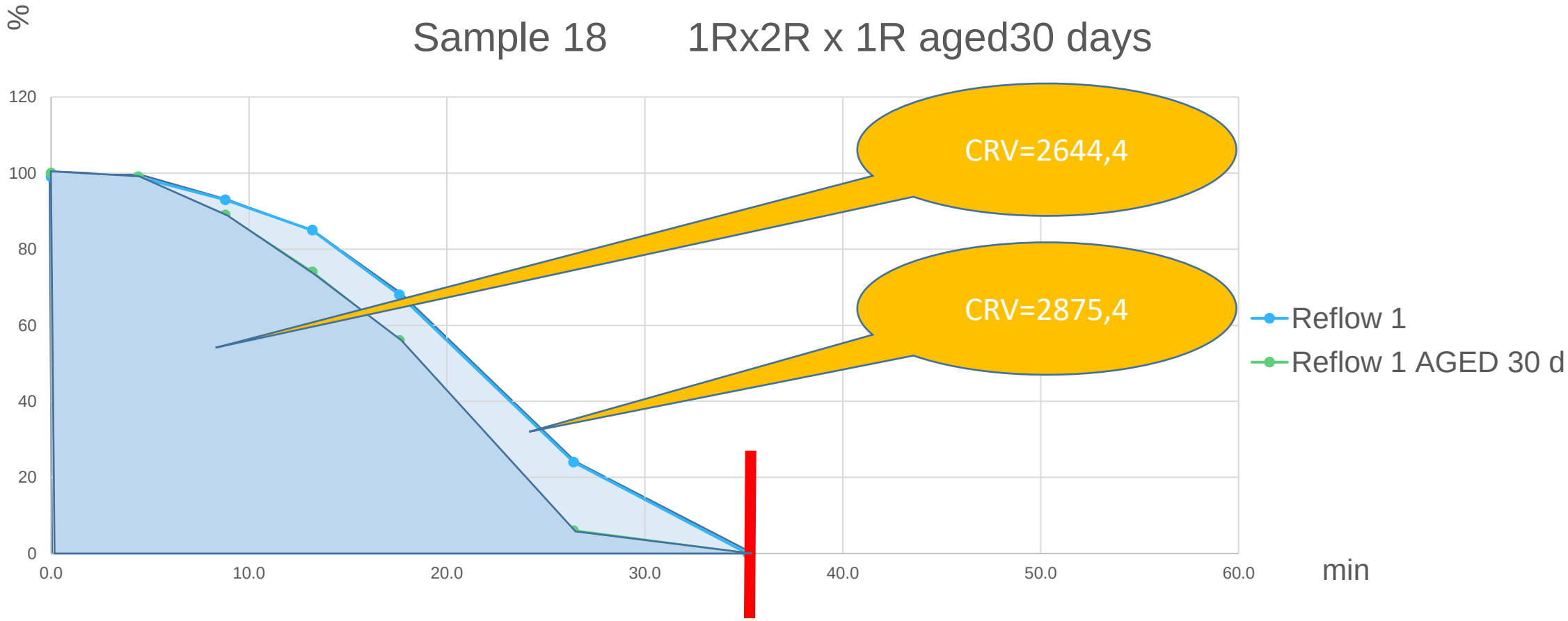
Save View

Notes:
Pad f.:BILAKER2 Flux f.:FLUX2
Dyn.f.:OFF Red.Pad:2

Washing response measurement

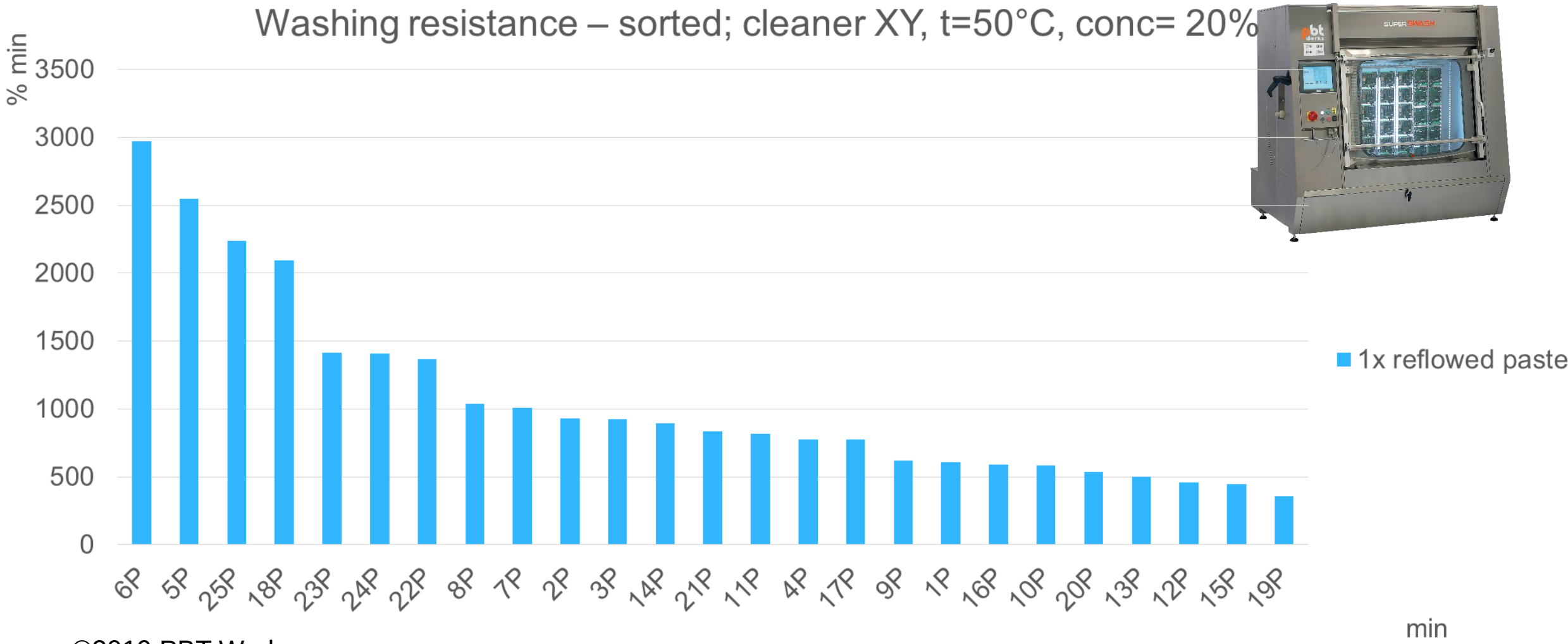


Washing response measurement
Cleanability Resistance Value (CRV) definition



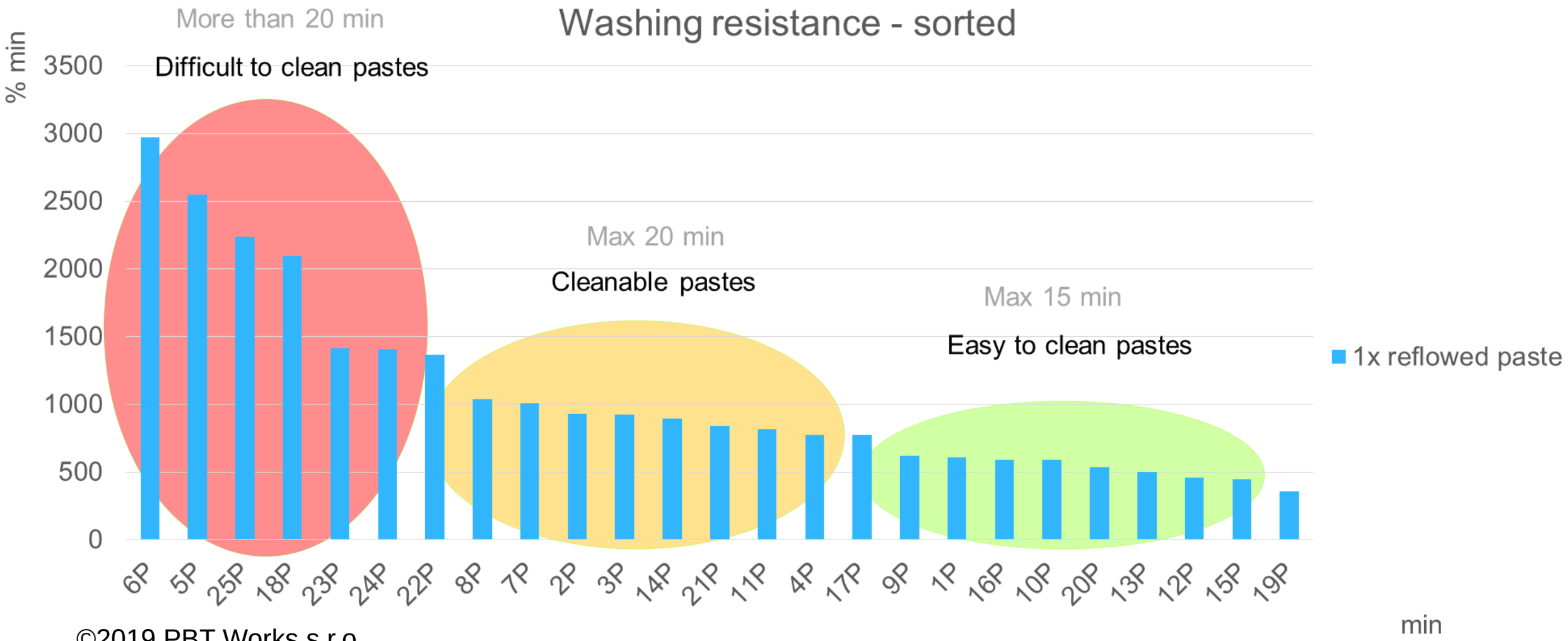
Cleaning of different solder pastes

- All pastes are cleanable,but big differencies in cleanability

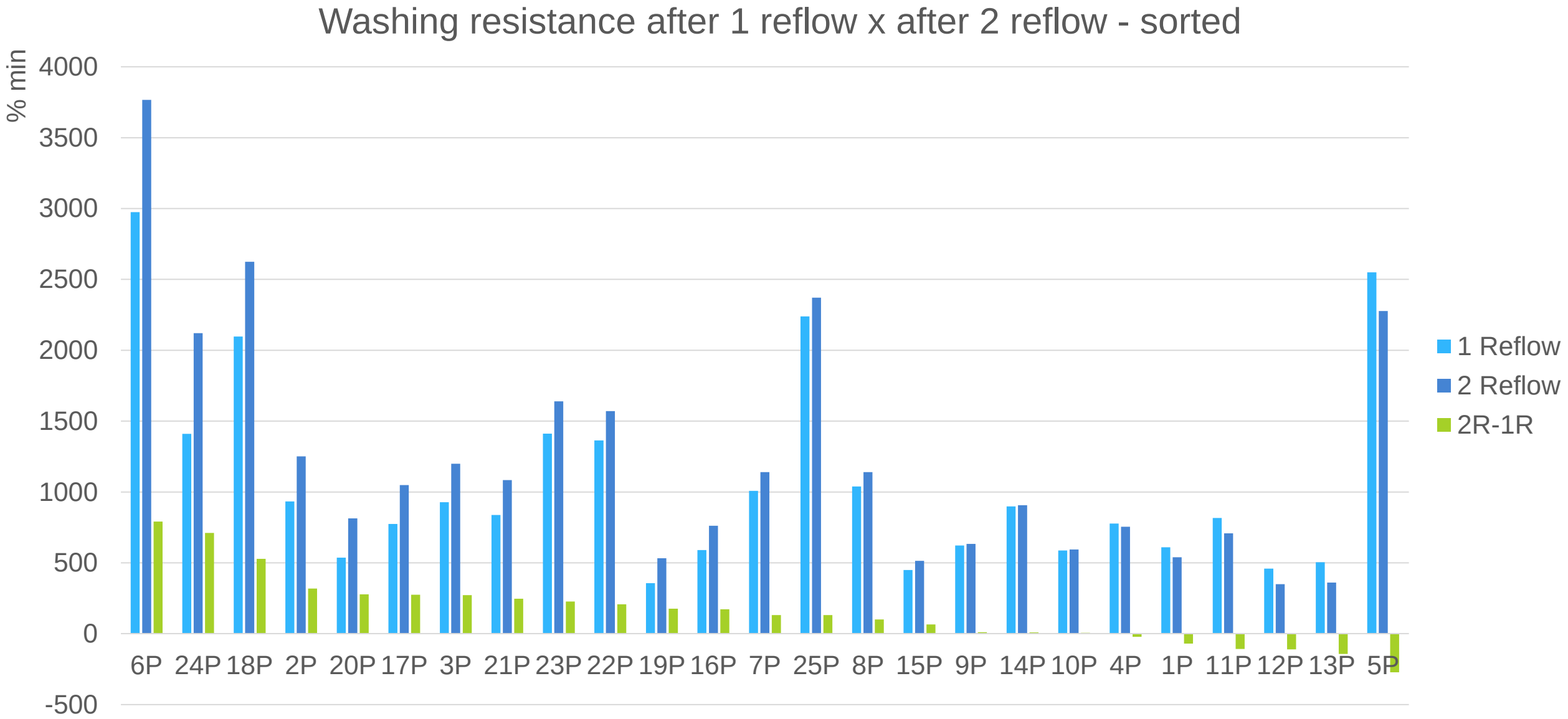


Cleaning of different solder pastes

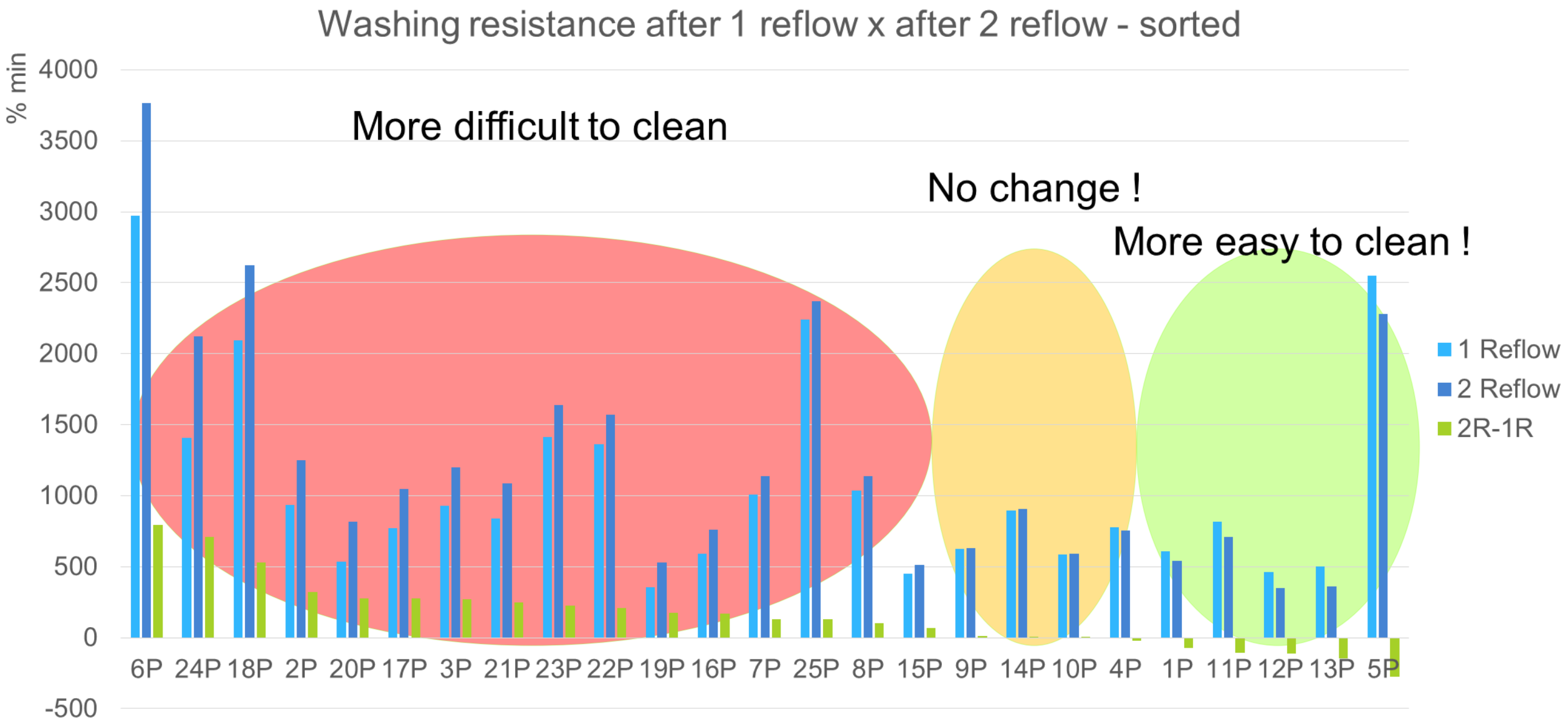
- All pastes are cleanable,but with big differencies



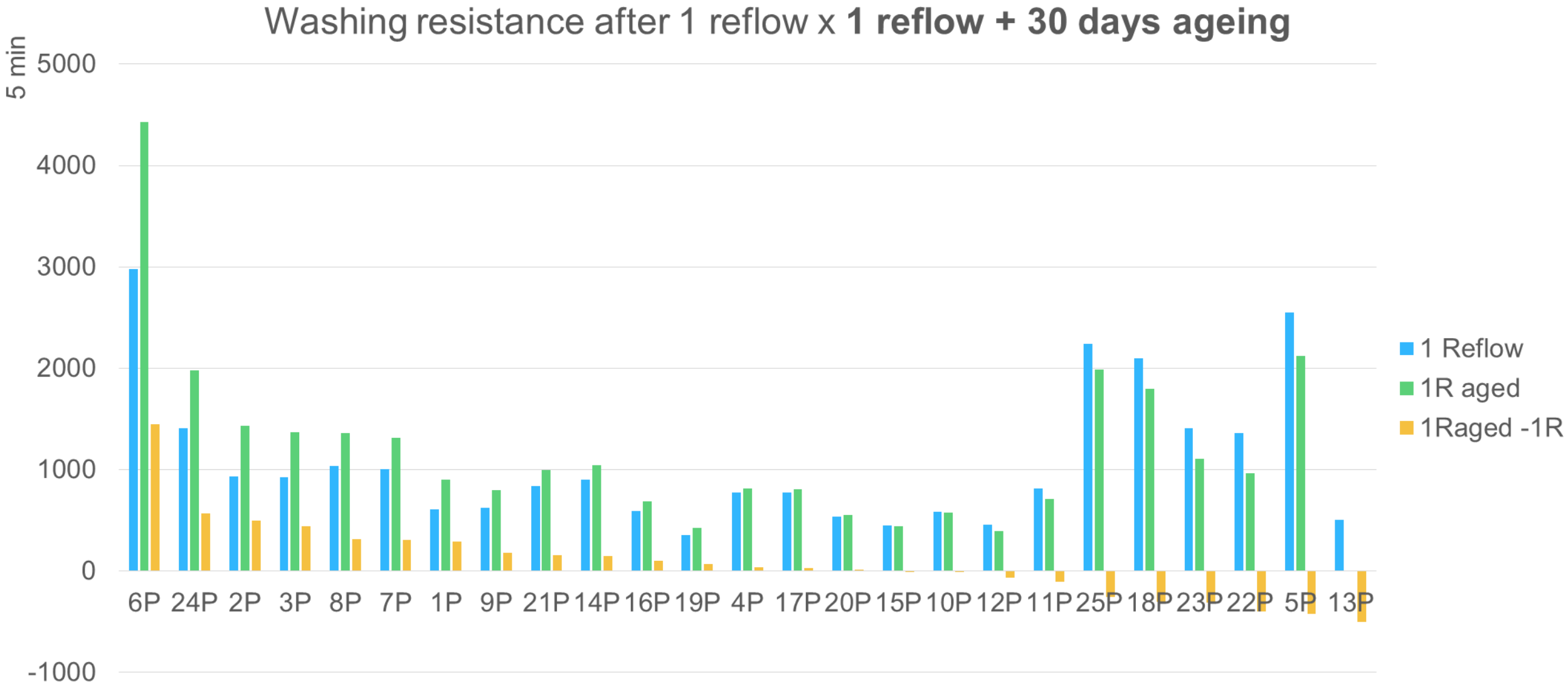
Difference between 1 and 2x reflow exposure



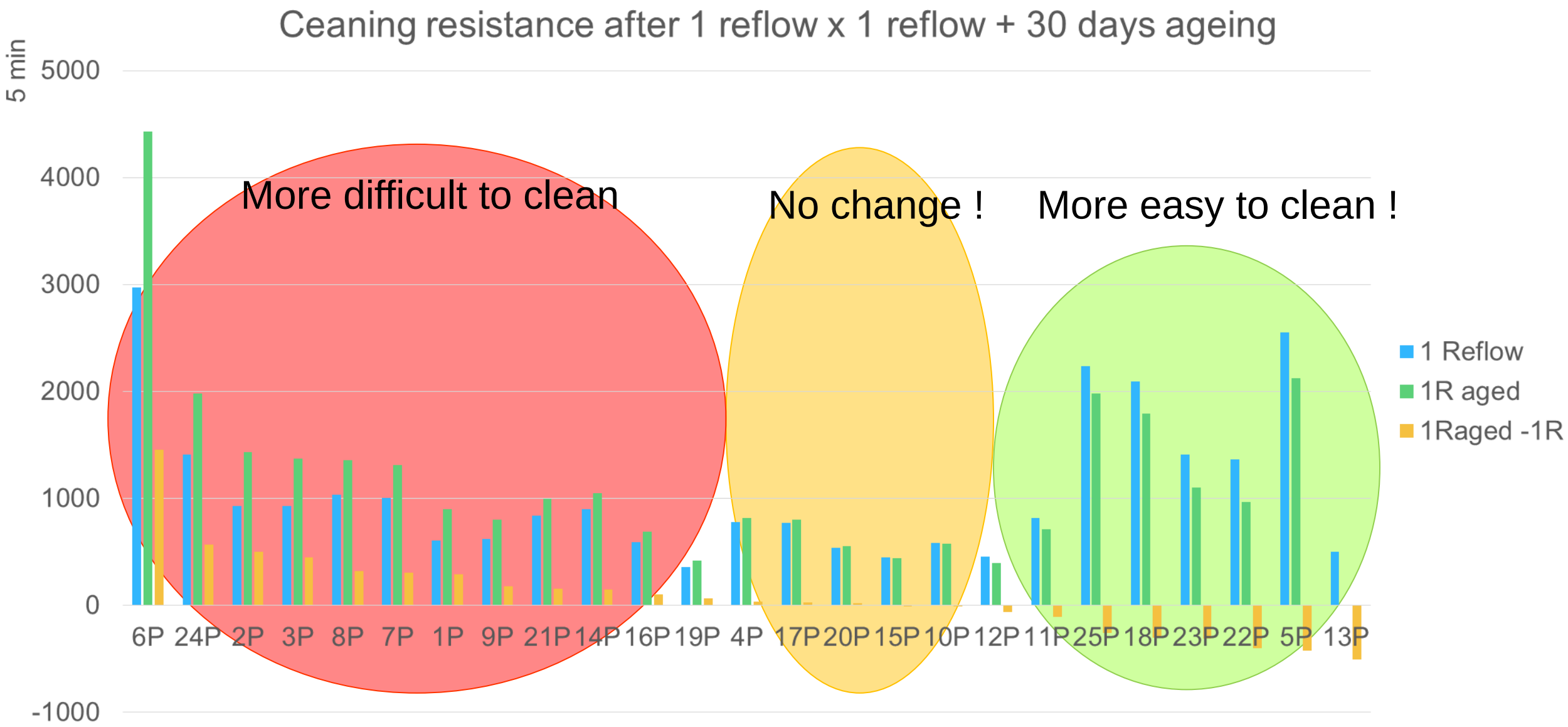
Difference between 1 and 2x reflow exposure



Freshly and aged cleaned flux residues

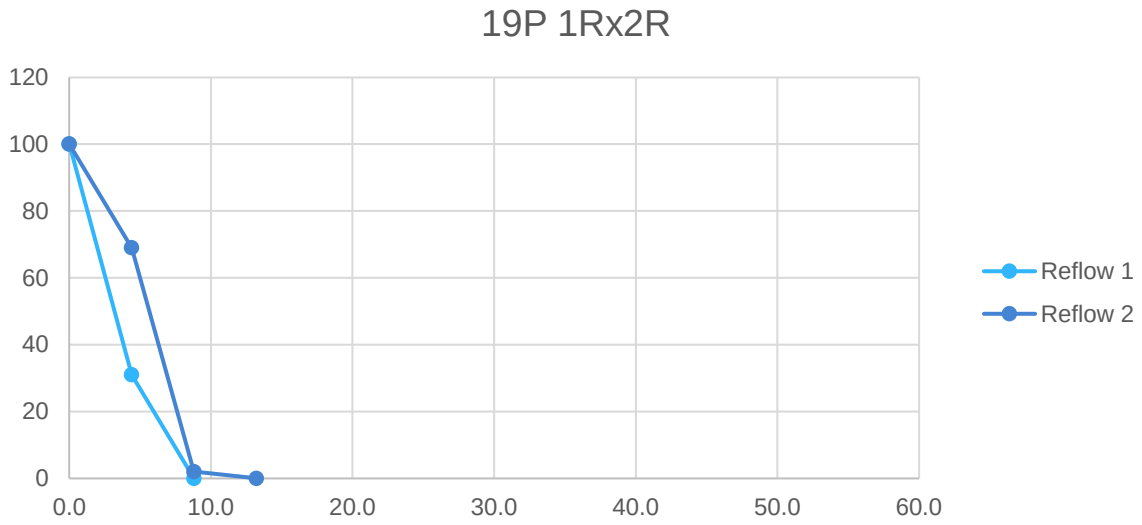


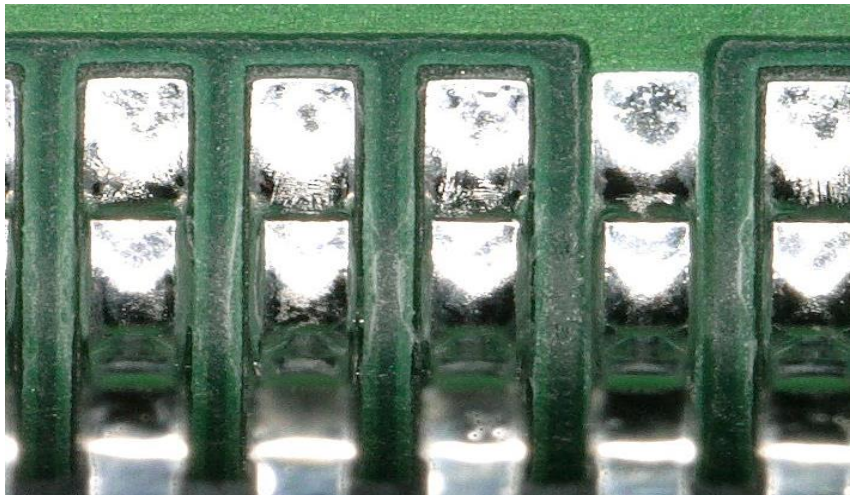
Freshly and aged cleaned flux residues

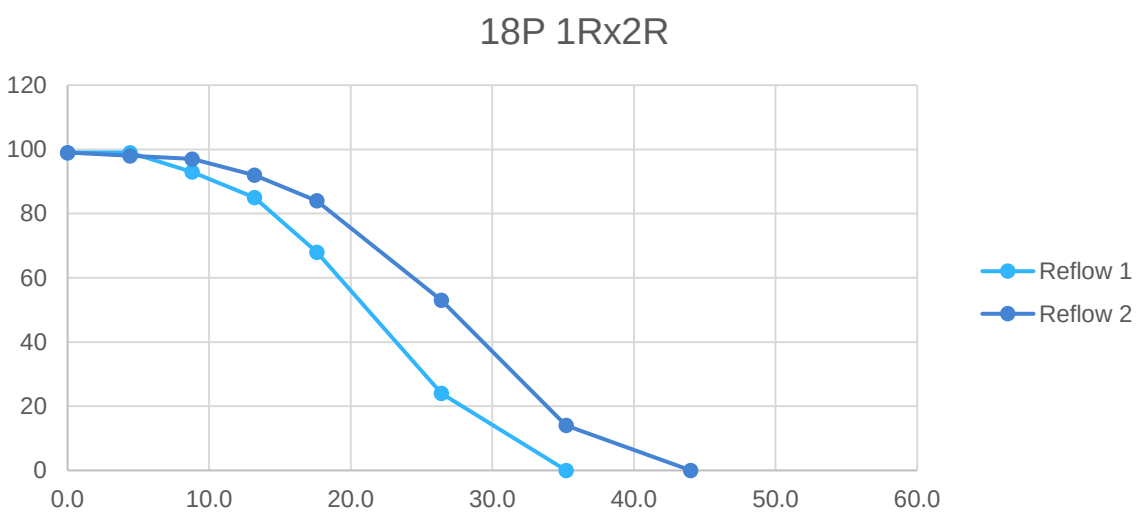


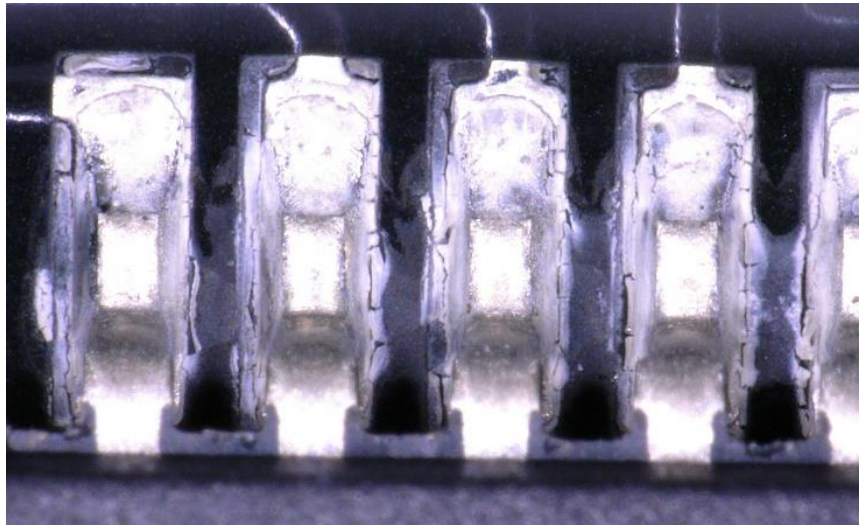
Interpretation of cleanability data

- On real boards (presency of metalo- carboxylic salts) white residues are generated









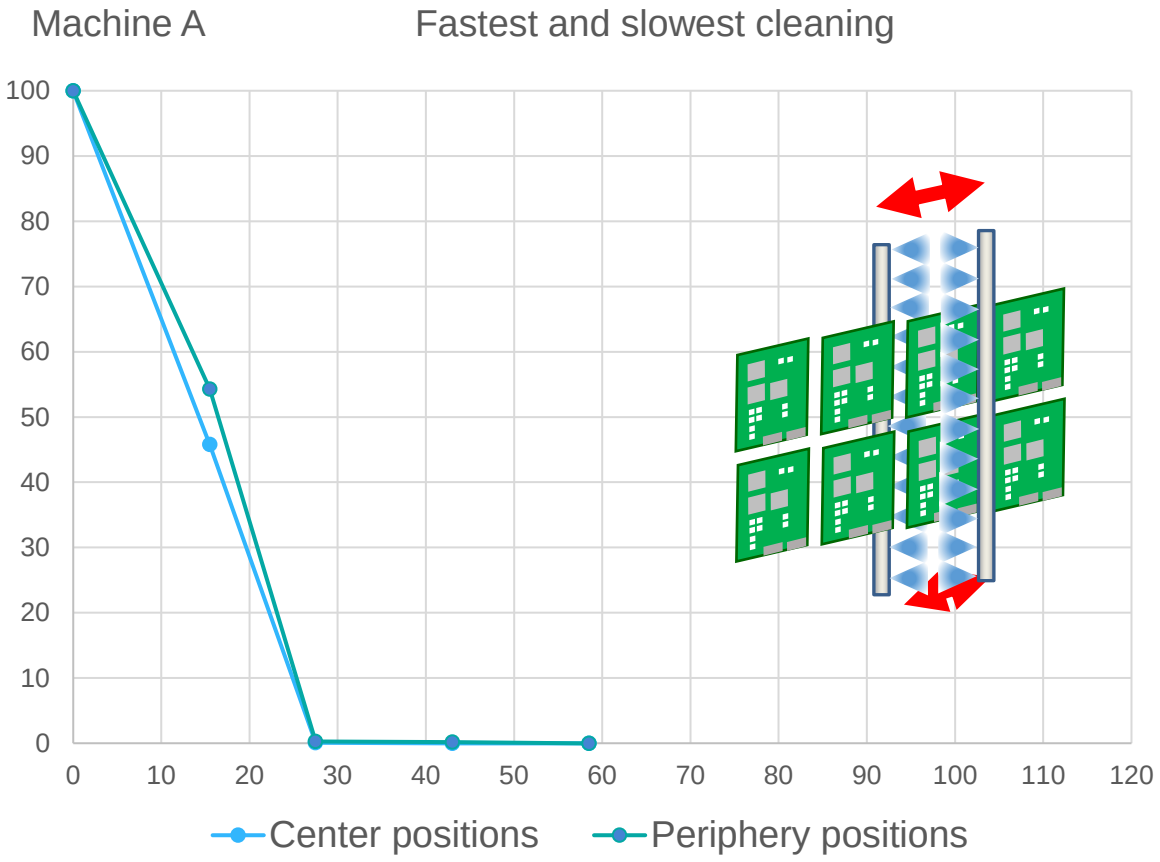
Conclusion for flux – cleaner cleanability studies

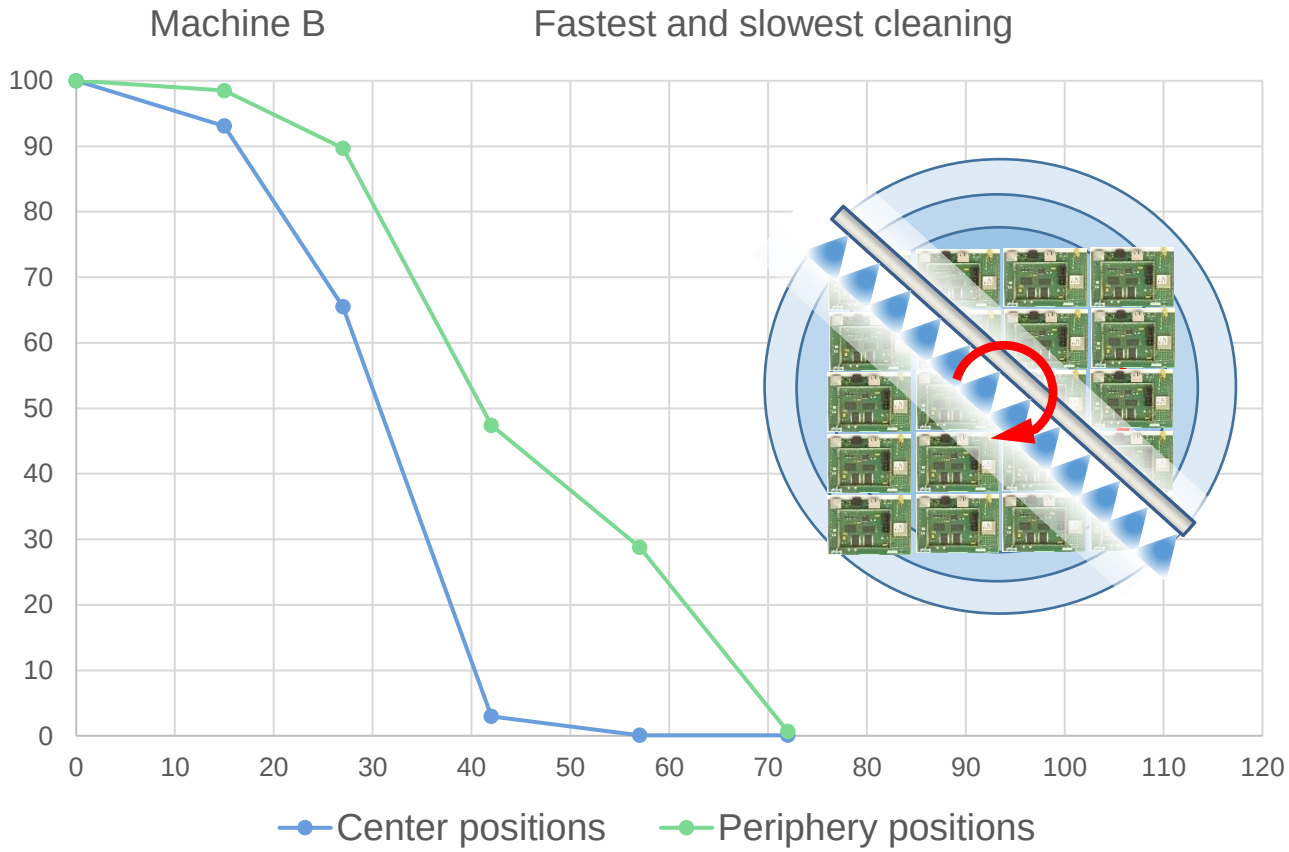
- Measuring cleanability (Washing resistence values) is an essential infor mation needed for every start of new project
- Proper flux / cleaner matching

  - Protects component from unnecessary chemical and moisture stress
  - Increases productivity of cleaning
  - Lowers chemistry and water consumption
  - Increases quality of cleanlinnes level
  - Saves costs

Machine capability studies

1. Measuring of cleaning field uniformity
   - Two different machines with the same flux residues and same cleaner.

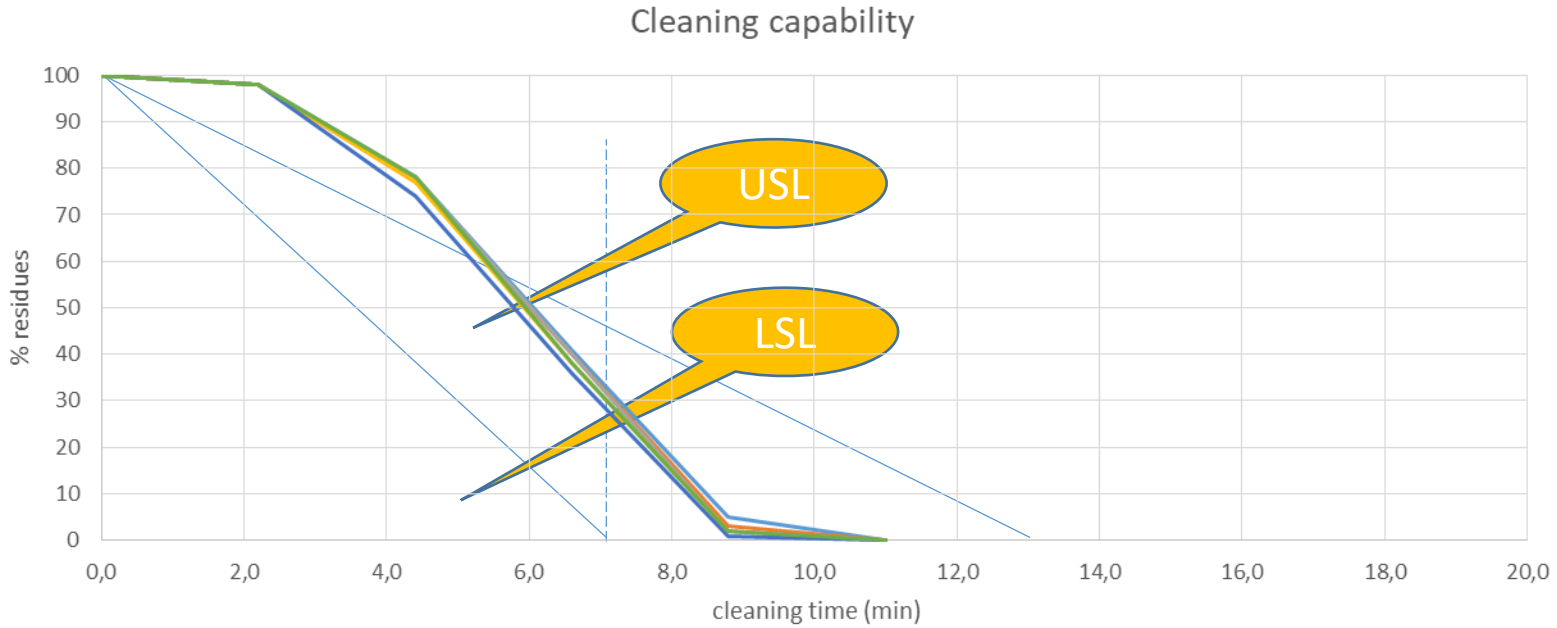




Machine capability studies

2. Measuring of Cpk

- Measuring of cleaning curve (10x)
  - Calculation of Cpk from cleanability resistence against customer expectation
- Measuring of repeated cleaning results
  - Proces with Glass Test Boards set for time, which gives about 50% of expected result (6,6 min)
  - Calculation of Cpk from results at nominal time (6,6 min)

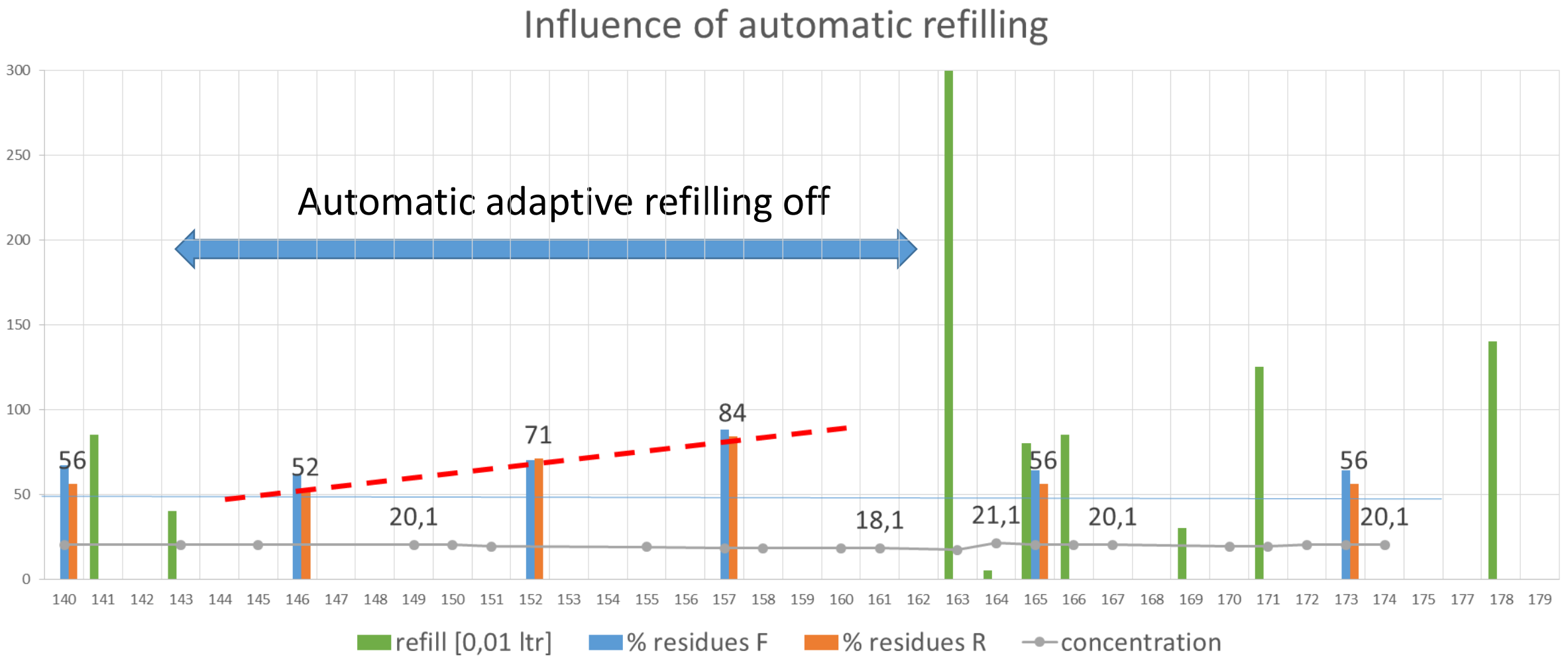


Expectations (cleanability):
USL = 650
LSL = 330
Mean = 585,93
δ = 9,5051
Cpu = USL-M/ 3* δ = 2.24
Cpl = M-LSL/3* δ = 8,97

Cpk= 2,24

Process monitoring (heavily loaded process)

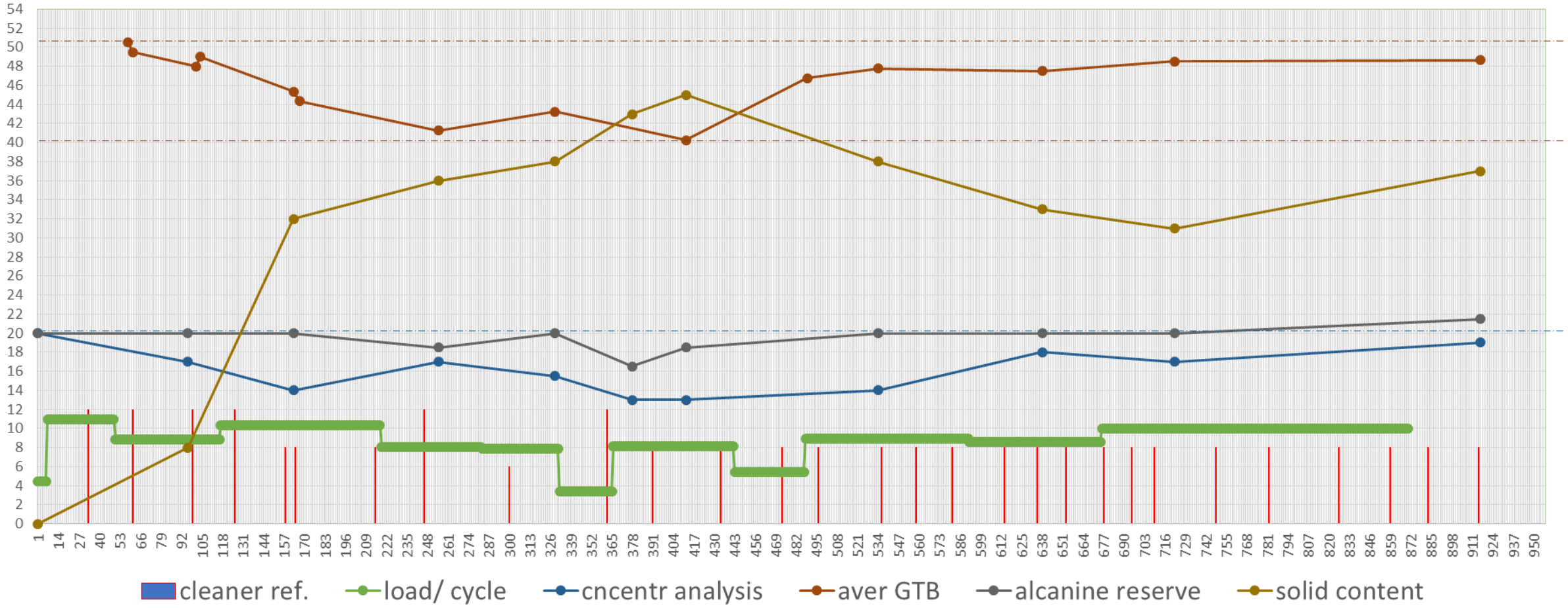
- **Comparison of cleaning proces with ADD / without ADD**



Essential for heavy- loaded processes, monitors dissoving speed , not only concentration !

Process monitoring (light loaded process)

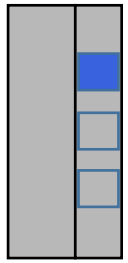
- **Process runs only on manual dosing of fixed concentration**

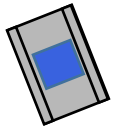


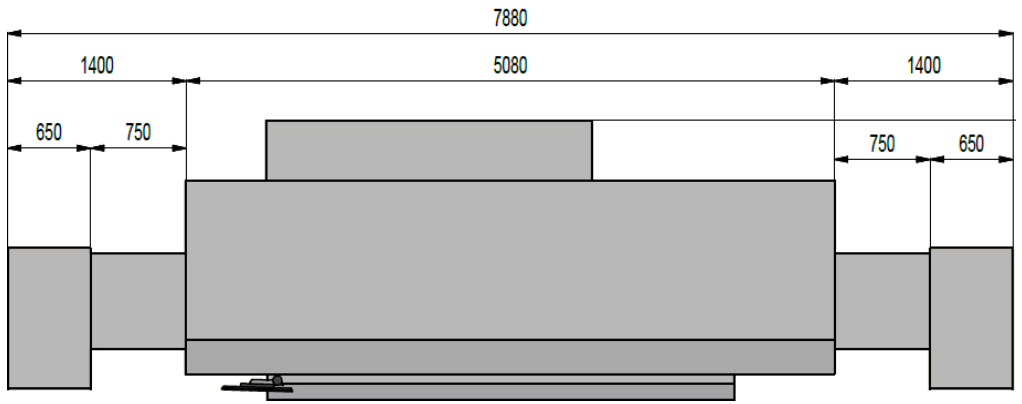
Complete bath Exchange
before analysis 300 cycles

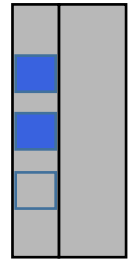
Complete bath Exchange after
analysis 1200 cycles

Cleaning in PCB magazines









Transport to assembly line

Cleaning line loading

Magazine in carrier

Line unloading

High performance cleaning process

HyperSWASH

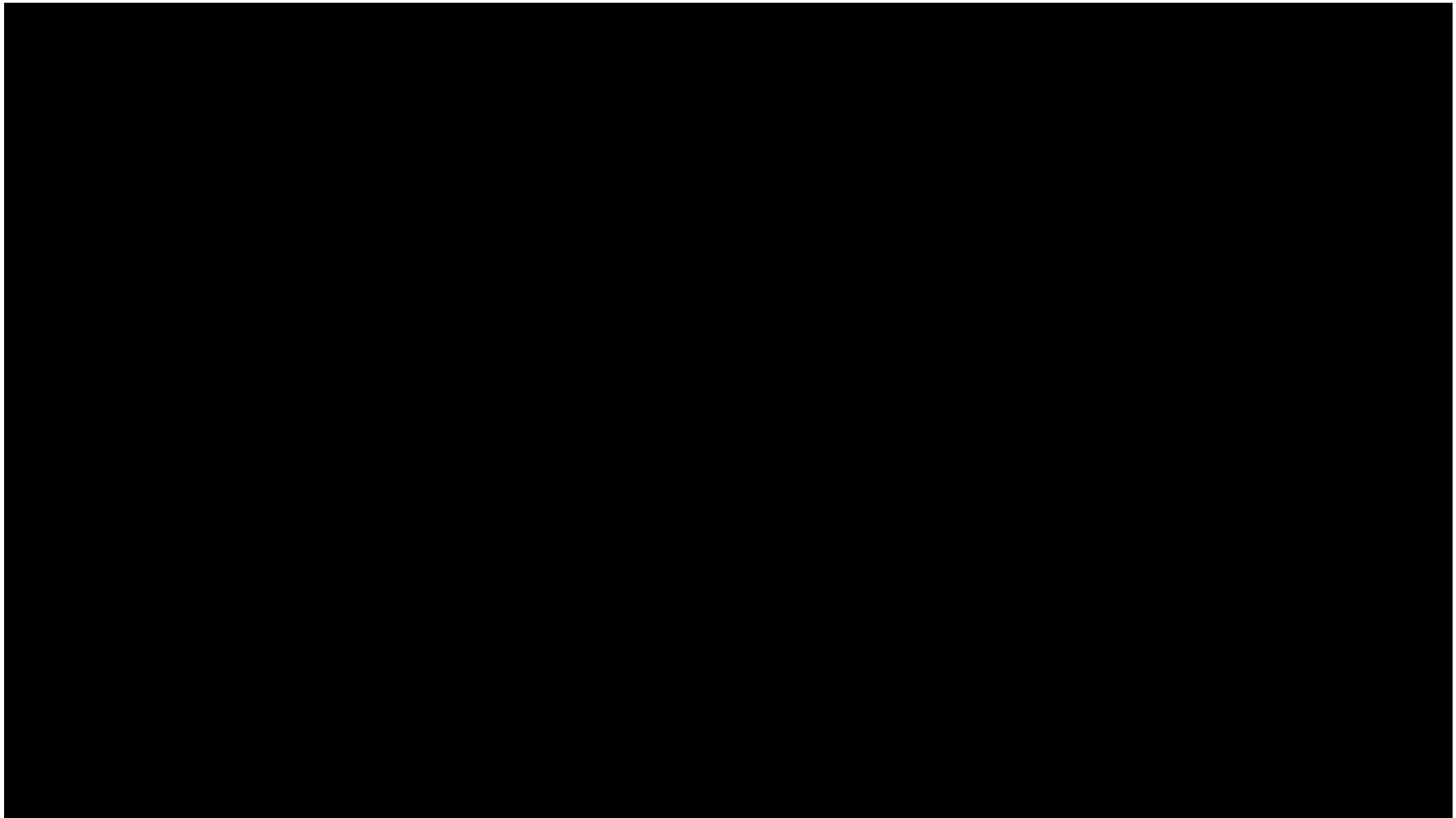
Automatic maintenance
Data communication to MES
Automatic loading/ unloading of material
Configuration change – water management – by software
- spray configuration by factory maintenance

168 Eurocards

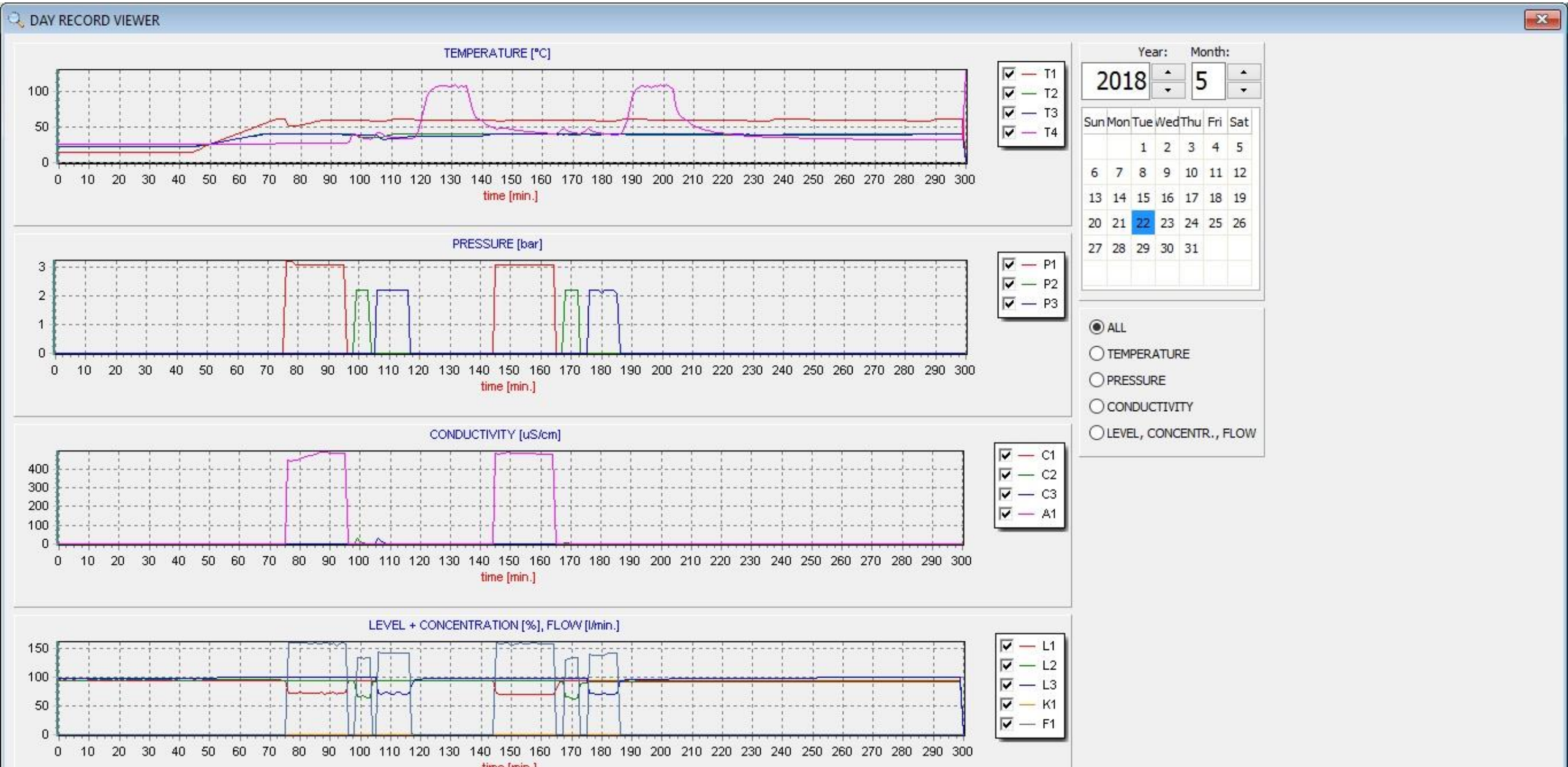
40 Eurocards

High performance cleaning process

Automatic loading/ unloading



Parameter tracking



Conclusion

- **Cleaning proces**
  - More important for future requirements
  - Clanlinnes testing moves to SIR and more sophisticated methods
  - Dedicated simulating with optical ionspection can speed- up cleaning project preparation
- **State – of the art cleaning**
  - New cleaning machines must be capable to clean gaps under 25um.
    - Design must be supported by many studies of proces
  - Cleaning is more a statistical control proces.
    - This requires more and new data from proces
  - Quality demands require full automation.
    - Maintenance
    - Loading / unloading to exclude operator influence
- **New and innovative test methods are applied for quality control**