XRF Measurement of Residual Materials in Electronics Studio

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JIP Partners

RoHS
RS Components
Tin Technology
Research in Motion

Tin Whisker Mitigation
Alcatel Alenia Space
EADS Astrium
MBDA
Rolls-Royce

Suppliers
Fischer Inst.
Niton
Oxford Inst.
RMD
Roentgenanalytik

Instrument Types

- Sources
  - Portable
    - Approx. 40kV, 10uA
    - Isotope
  - Benchtop
    - Approx. 50kV, 1000uA
- Detectors
  - Proportional (resolution ~1000eV)
  - Pin diode (resolution ~250eV)
  - Si(Li) diode (resolution ~140eV)

Instrument Types

BenchTop	X	X	X	X	X	X		X	X	X			X	X	
Portable							X				X	X			X
SiLi								X							
PIN	X	X	X	X	X	X	X				X	X	X		X
Prop. Count									X	X				X	
Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**G**	**H**	**J**	**J**	**L**	**M**	**N**
System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**T**	**U**	**V**	**W**	**X**	**Y**	**Z**

- Total of 15 XRF systems
  - 11 Bench-tops
    - 8xPIN
    - 1xSiLi
    - 3xProportional Counters)
  - 4 Portables (PIN) (1xCo57 source)
- 12 Partners, 11 different systems

Workplan

- Phase 1
  - Acquire samples
  - Undertake analysis of example of each sample
  - Designate master sample for round-robin analysis
- Phase 2
  - Round-robin to partner or partners designated test house for testing for RoHS compliance
- Phase 3
  - Chemical analysis of round-robin samples (LGC)
  - Correlation of results
  - Report

Main Chemical Analysis

- Cadmium, mercury, lead and chromium
  - Microwave acid digestion and Inductively Coupled Plasma with Mass Spectrometry (ICP-MS).
- Bromine
  - Extraction by combusting sample in oxygenated atmosphere (Schöniger flask method) and dissolving free bromine ions into solution to be determined by ion chromatography.
- Chromium VI
  - Reaction of chromium VI with hydrogen peroxide to form a blue colouration being one such test.

Supplementary Chemical Analysis

- Cadmium and lead
  - Acid digestion and Inductively-Coupled Plasma – Atomic Emission Spectrometry (ICP-AES)

NPL EDX Analysis

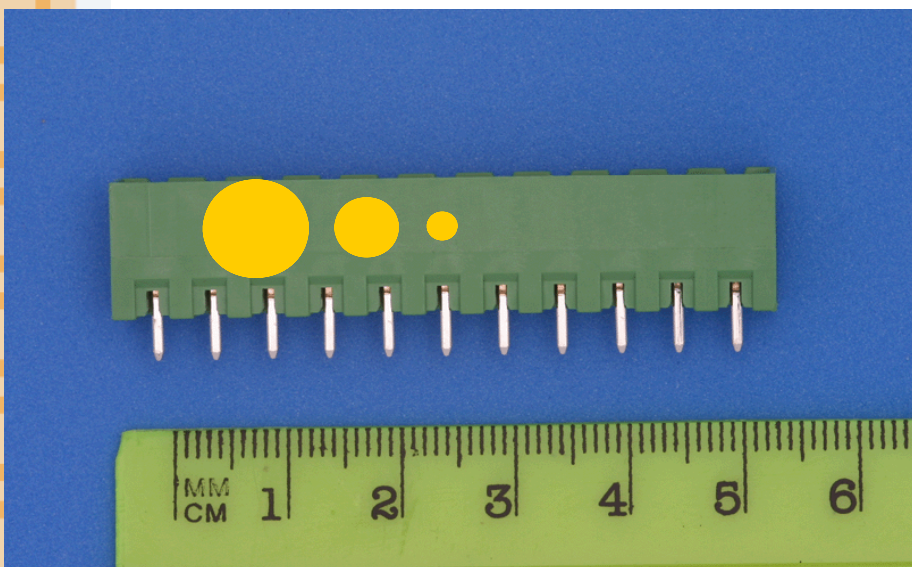
- Lead
  - Energy Dispersive X-ray Analysis attached to scanning electron microscope
  - Only analyses surface of sample (1 micron depth)

Typical Spot Sizes and Test Times

		Plastics		Metals		Bench				*Prop.*
Partner	**System**	**SpotSize**	**TestTime**	**SpotSize**	**TestTime**	Top	Portable	*SiLi*	*PIN*	*Count.*
A	**P**	0.2-2mmΦ	340s	0.2-2mmΦ	210s	X			X	
B	**P**	1-2mmΦ	340s	1-2mmΦ	205s	X			X	
A	**Q**	0.1-0.6mmΦ	340s	0.1-0.6mmΦ	210s	X			X	
C	**Q**	0.1-0.6mmΦ	350s	0.1-0.6mmΦ	95s	X			X	
D	**Q**	0.3-0.6mmΦ	360s	0.3-0.6mmΦ	210s	X			X	
E	**Q**	0.6mmΦ	200s	0.1-0.6mmΦ	100s	X			X	
F	**R**	3x3mm	180s	3x3mm	30s		X		X	
F	**S**	1.2mmΦ	120s	1.2mmΦ	280s	X		X		
G	**T**	0.5-2mmΦ	120s	0.4-0.5mmΦ	20-100s	X				X
H	**U**	[redacted]		0.3mmΦ	15s	X				X
J	**V**	3mmΦ	120s	3mmΦ	100-200s		X		X	
J	**W**	10x20mm	120s	10x20mm	200s		X		X	
L	**X**	1mmΦ	200s	0.3-1mmΦ	210s	X			X	
M	**Y**	0.4mmΦ	30s	0.08-0.4mmΦ	30s	X				X
N	**Z**	3mmΦ	120s	3mmΦ	60s		X		X	

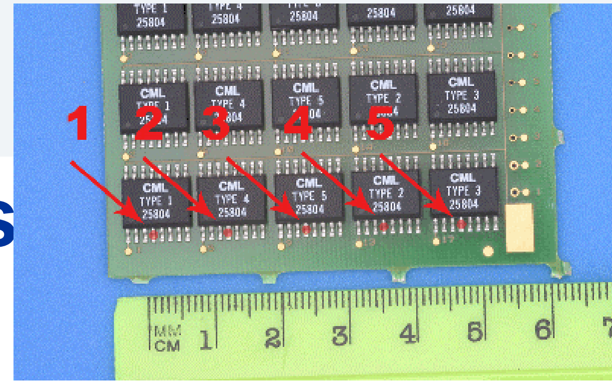
Spot Sizes

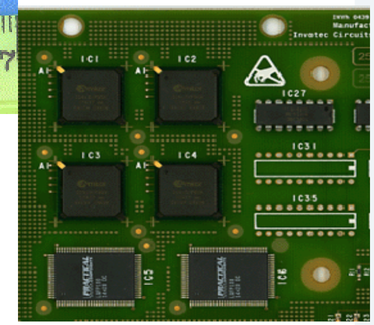
- Larger spot sizes
  - –Less segregation



- Smaller spot sizes
  - –Less background effects

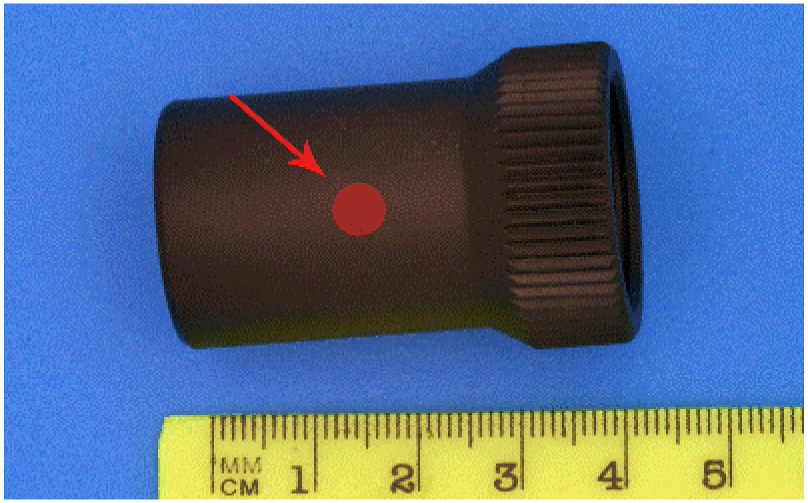
Round Robin Samples





- 9 Plastics samples with either Pb, Cd, Hg
- Cr passivated Zn plated screw, poss Cr^{6+}
- Sn contaminated with lead from 50 -> 20000ppm Pb
- SOIC solder joints from NPL test boards
  - 0,1,2,5,8% Pb in SAC joints from a manufactured PCB
- BGA, SnPb and LF, looking thru component and PCB
- Components in reels and sticks
- Solder paste

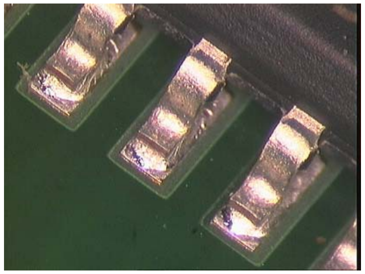
Test Procedure

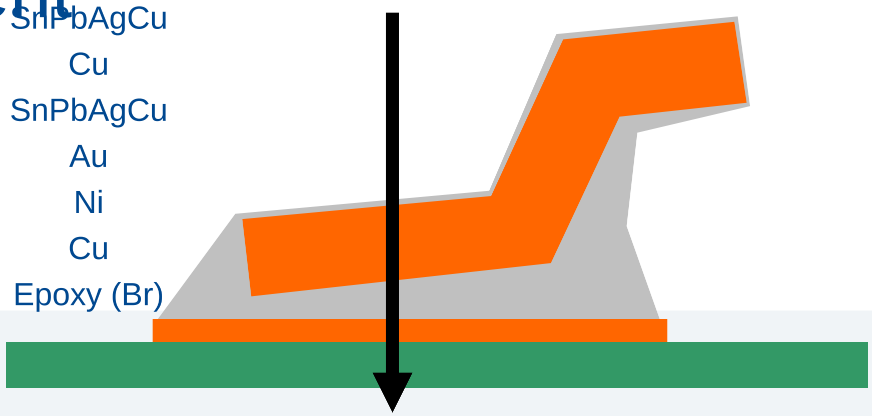


- Sample presented blind to equipment
- Equipment set-up/programming defined by end-user
- Each sample analysed 3 times with sample removed from equipment between each test
- Designated test area to ensure same test area for each test
  - Circular section samples cut in half to determine which side to be tested

Differences Between Chemical and XRF Results

- Homogeneity of sample
  - Chemical analysis averages larger sample
  - XRF “spot sizes” vary
- Penetration of X-rays
  - Materials “behind” sample dilute result
- Inaccurate measurement
  - Chemical analysis
  - XRF analysis





Presentation of Results

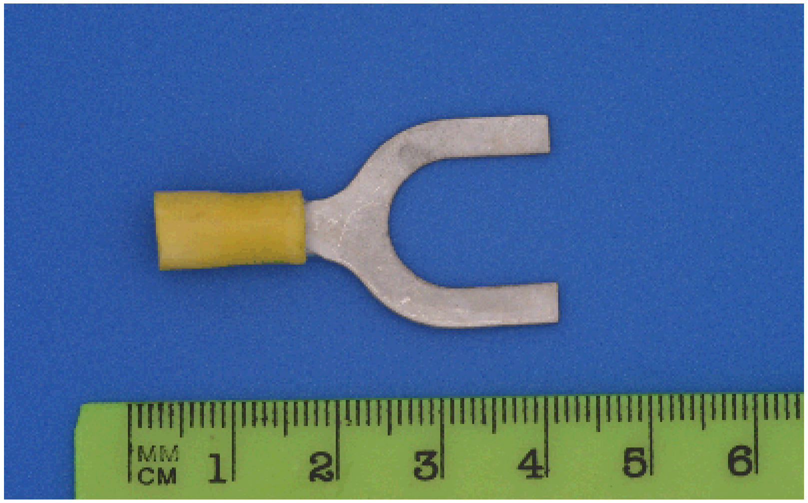
- Results for plastic components
  - ROHS compatibility
- Results for solders
  - ROHS compatibility
  - Tin whisker mitigation
- Results for other electronics components/joints
  - ROHS compatibility
  - Tin whisker mitigation

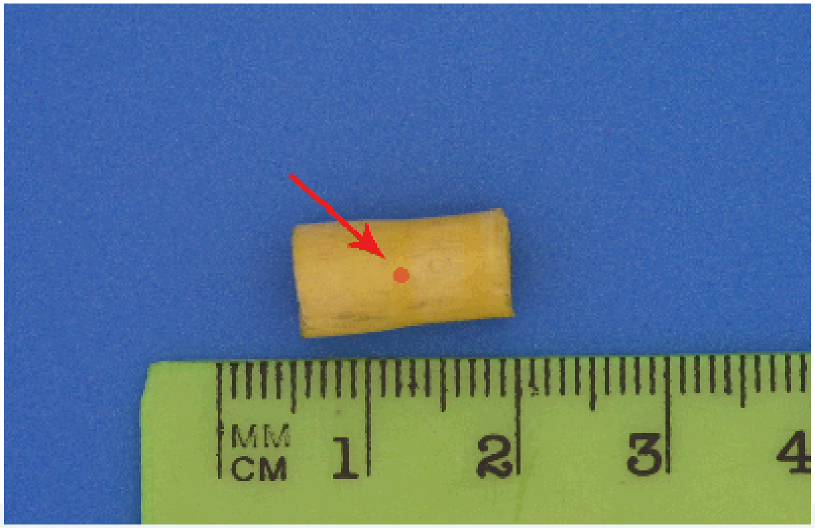
Plastics

1: SPDY

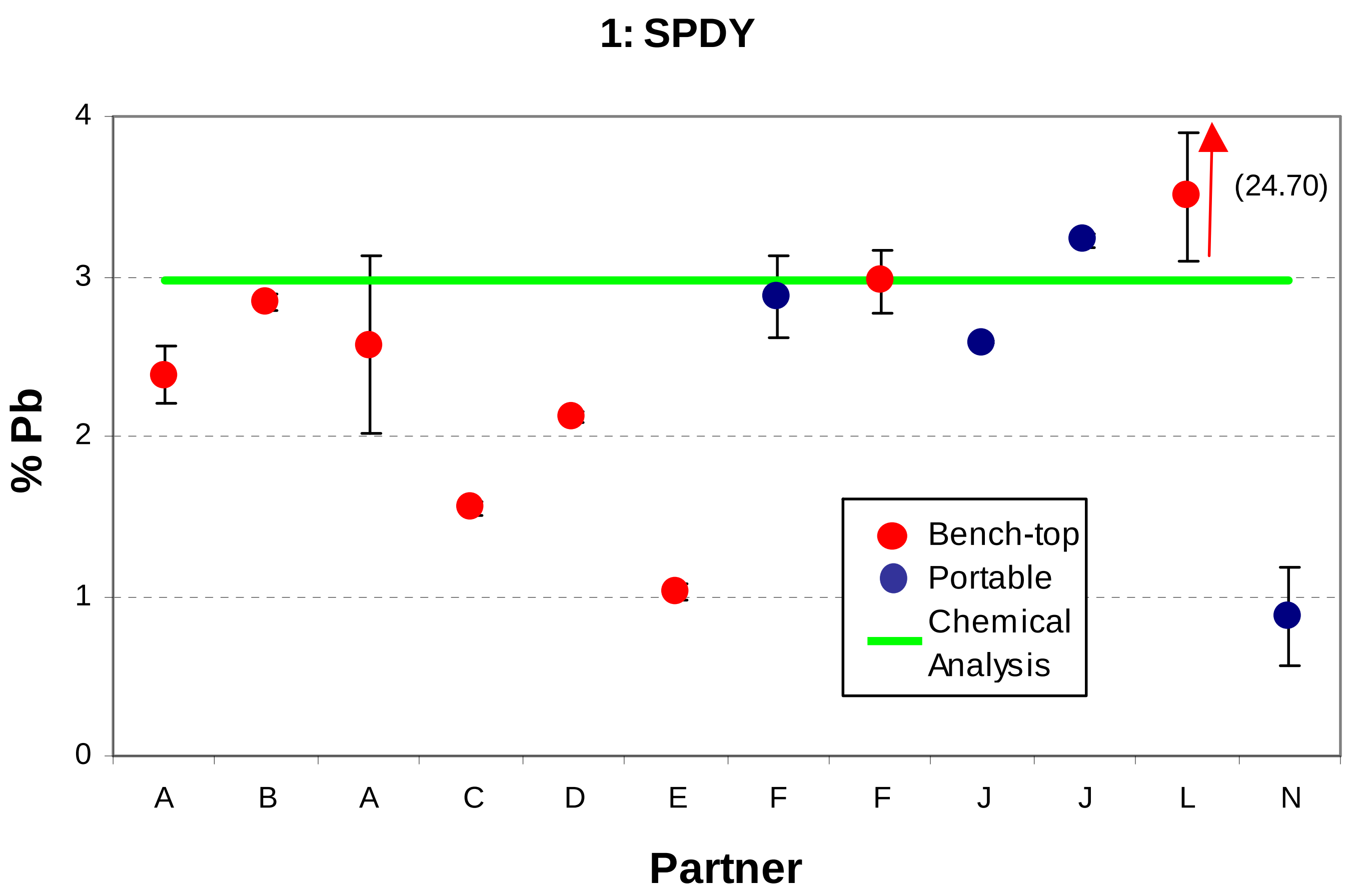
- Yellow PVC M4 spade terminal
- Tested sleeve only and as-received

	LGC Analysis
Pb	2.973
Cd	<0.001
Hg	<0.001
Br	N/A
Cr	0.046



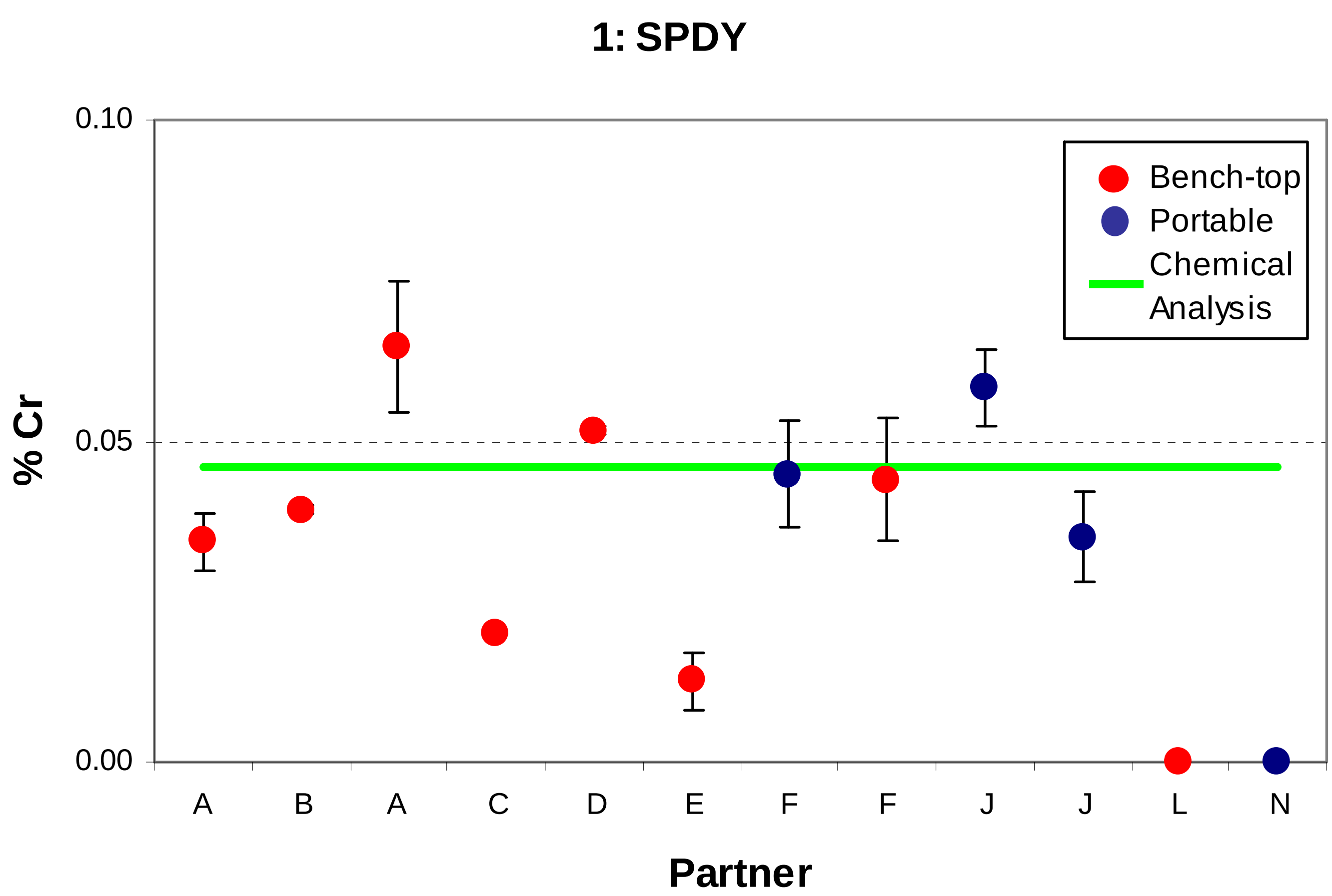


1: SPDY PIN/SiLi - Pb



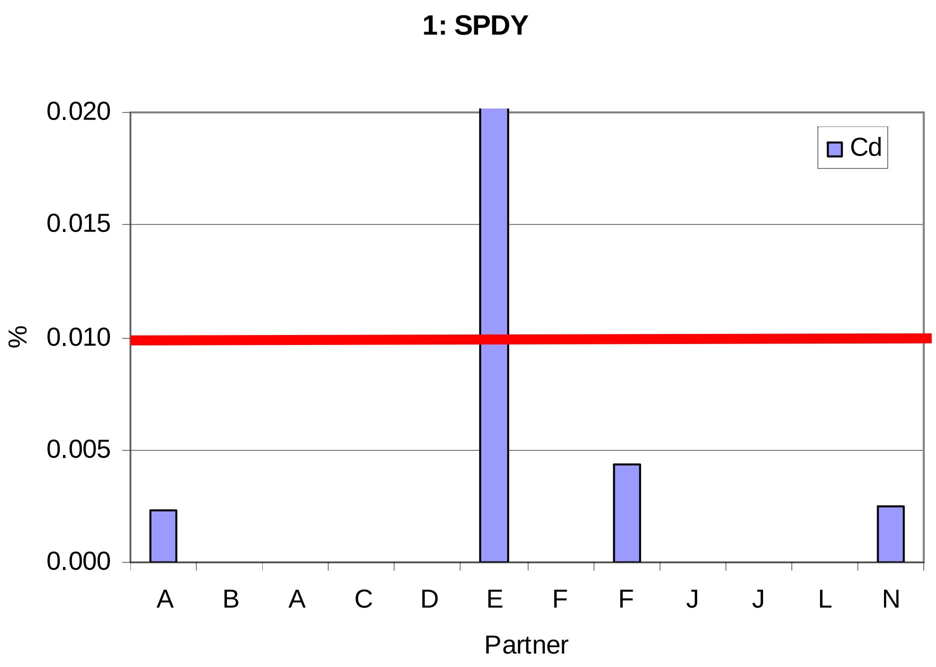
IPC MIDWEST Get Interconnected.™ CONFERENCE & EXHIBITION

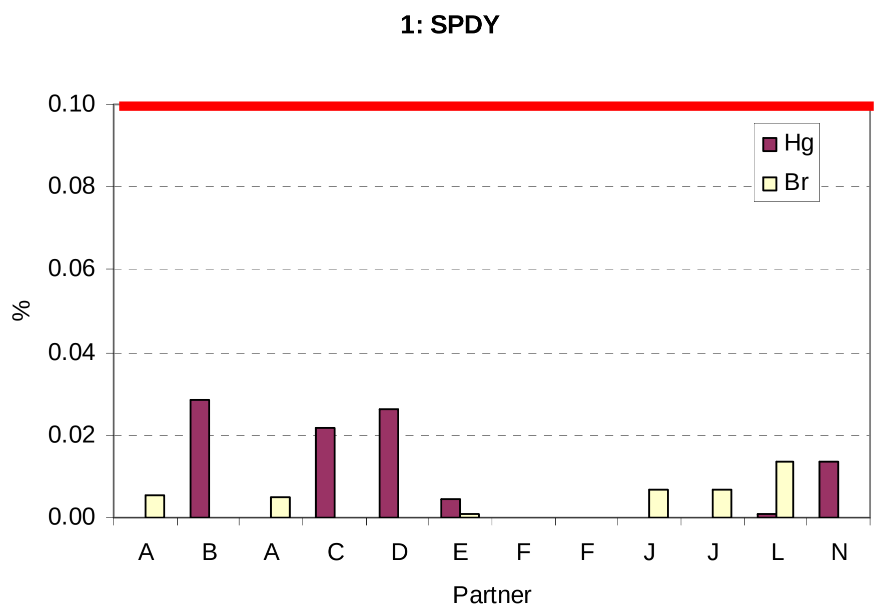
1: SPDY PIN/SiLi - Cr



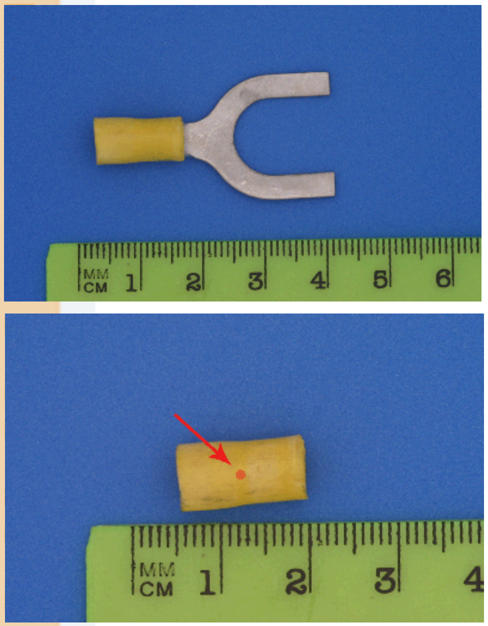
IPC ASSOCIATION CONNECTING ELECTRONICS INDUSTRIES®

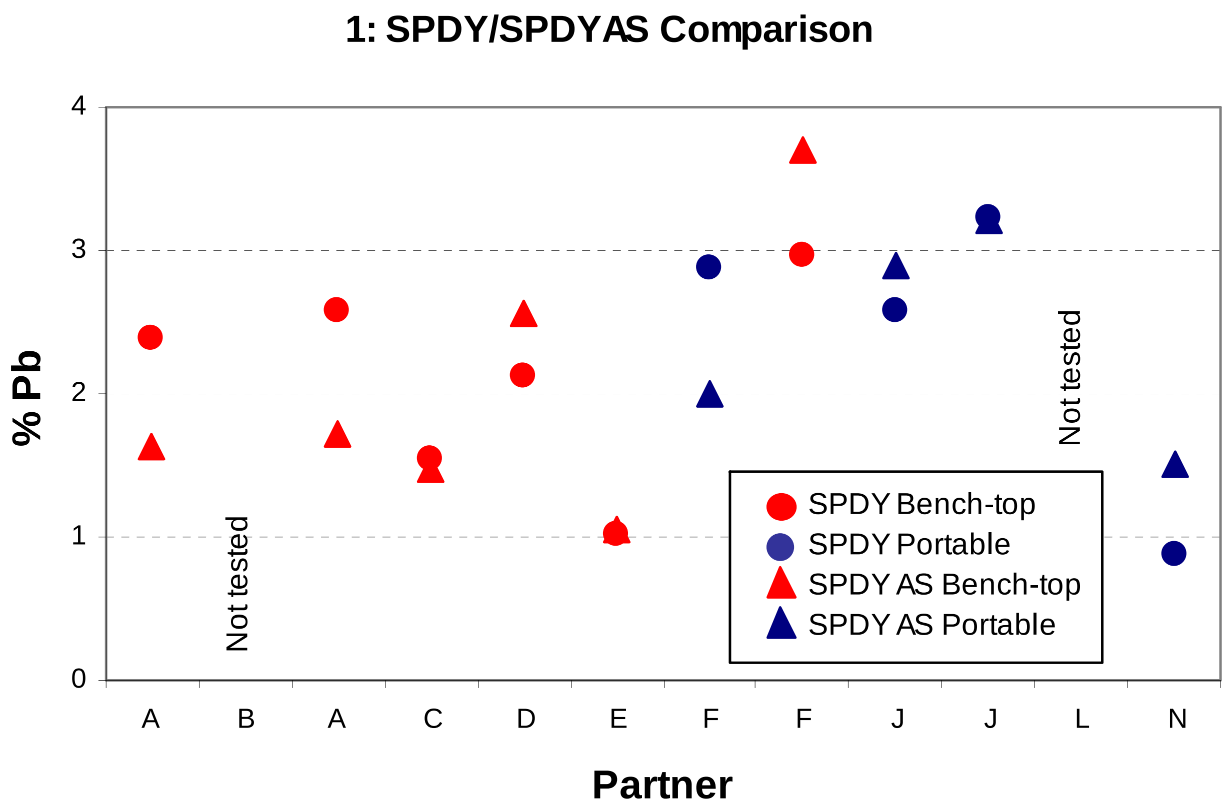
1: SPDY PIN/SiLi – Hg/Br/Cd





1:SPDY As Received

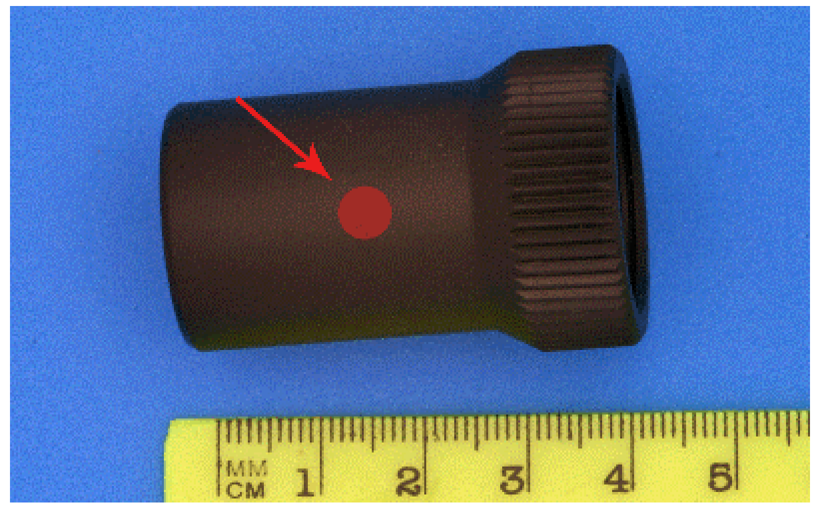




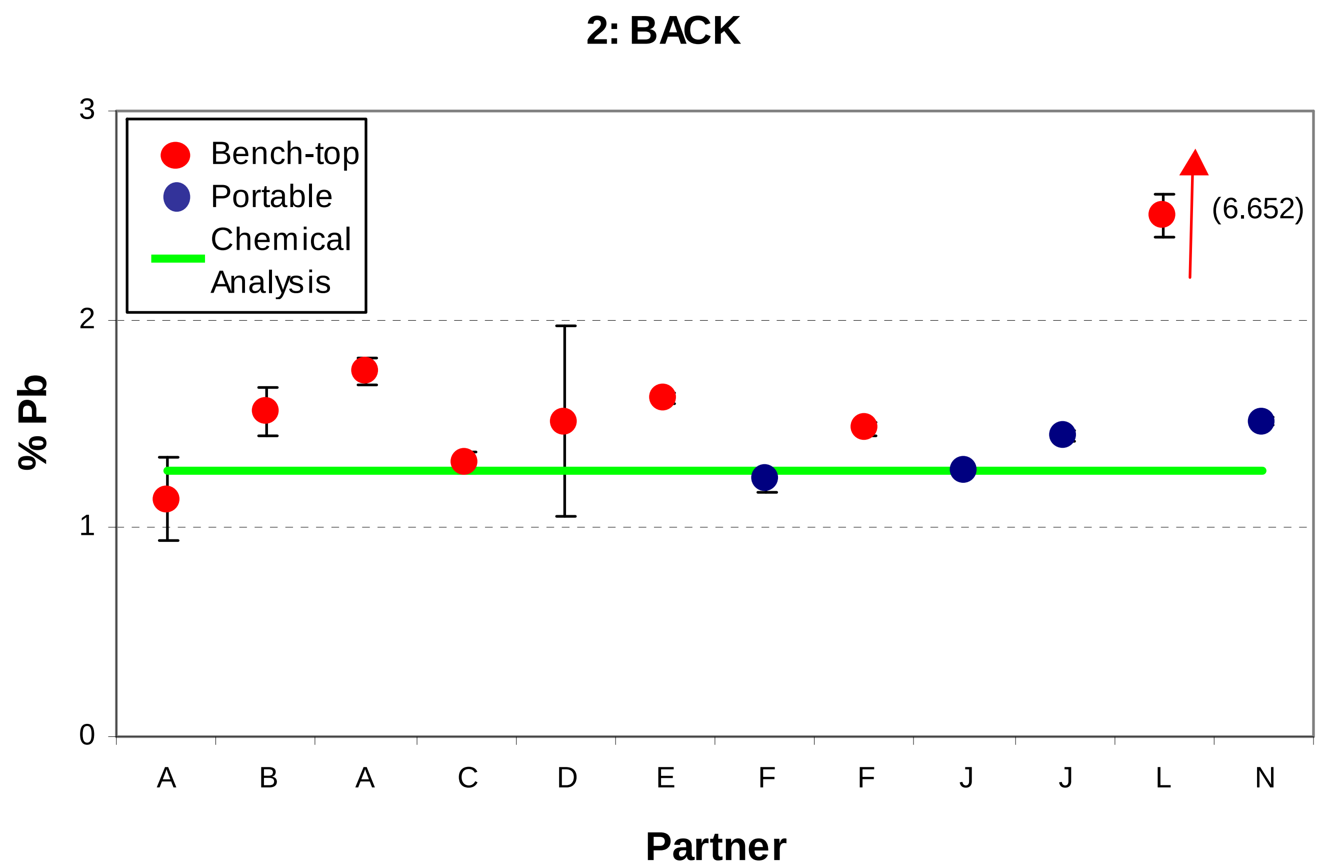
2: BACK

•Black PVC Gland adaptor backshell

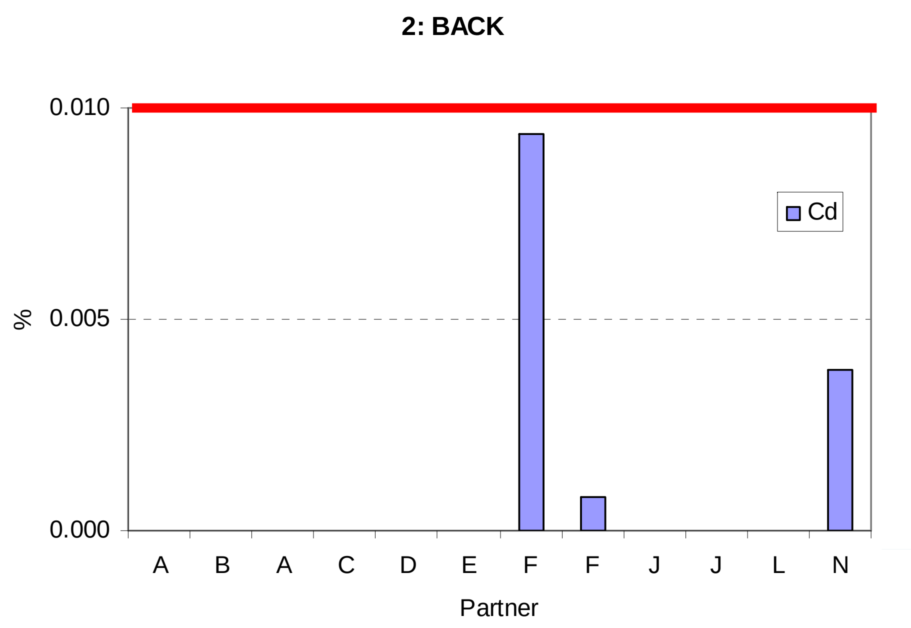
	LGC Analysis
Pb	1.271
Cd	<0.001
Hg	<0.001
Br	<0.07
Cr	<0.001

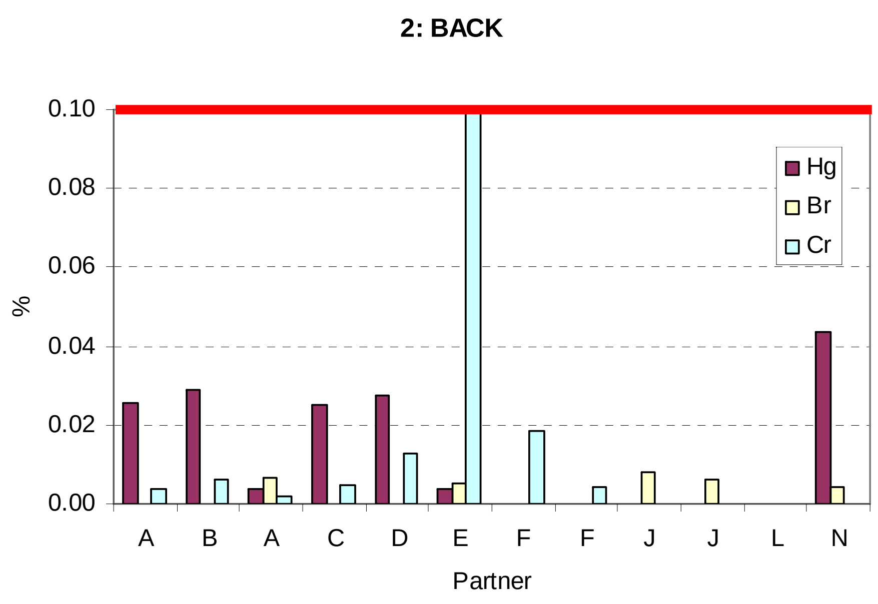


2: BACK PIN/SiLi - Pb



2: BACK PIN/SiLi – Hg/Br/Cr/Cd

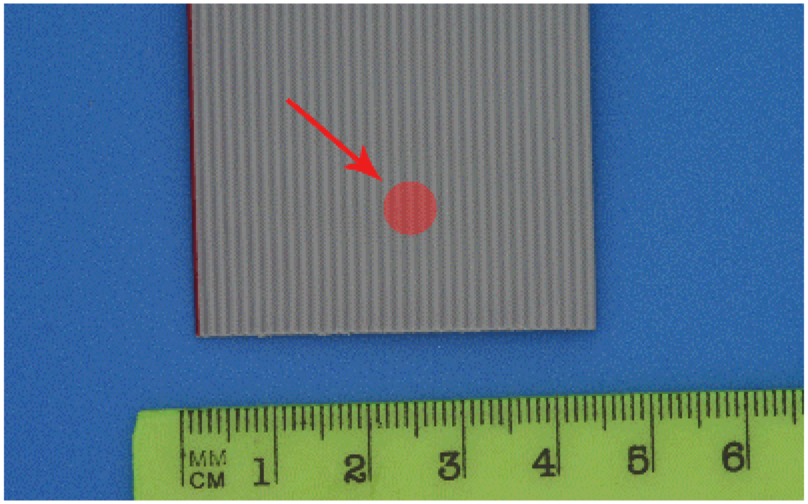




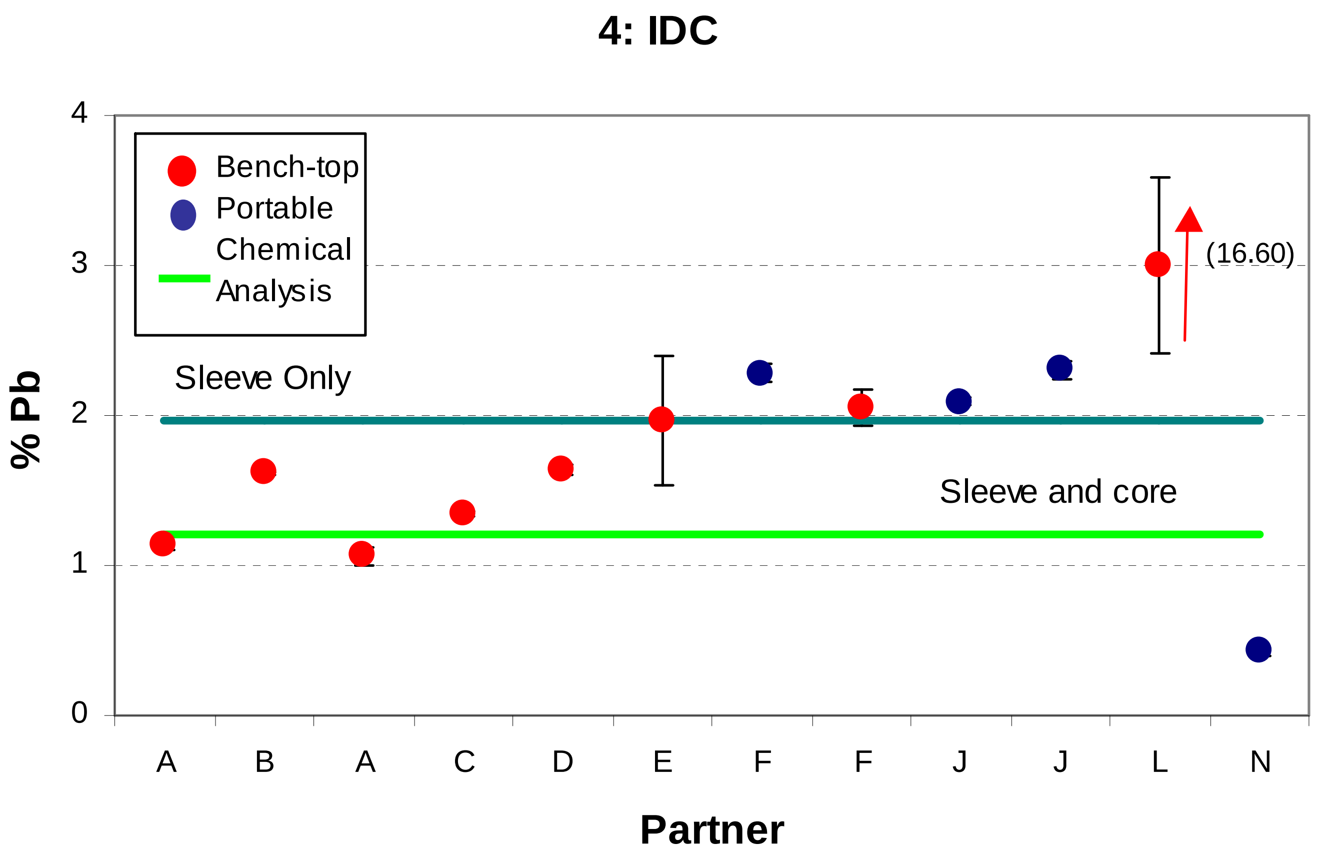
4: IDC

- Grey PVC Standard IDC cable (34 way)
- Chemical analysis for coating and wire

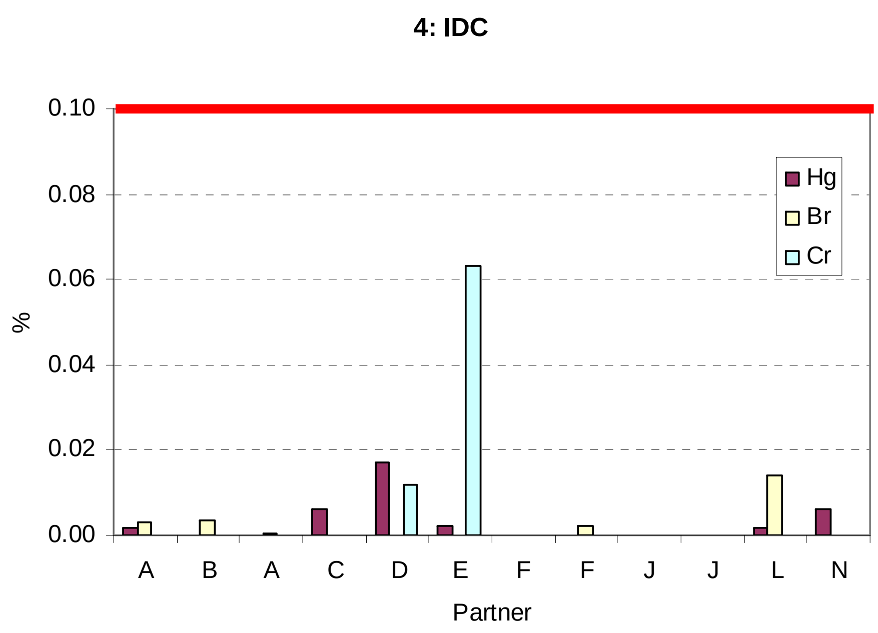
	LGC Analysis
Pb	1.206
Cd	<0.001
Hg	<0.001
Br	N/A
Cr	<0.001

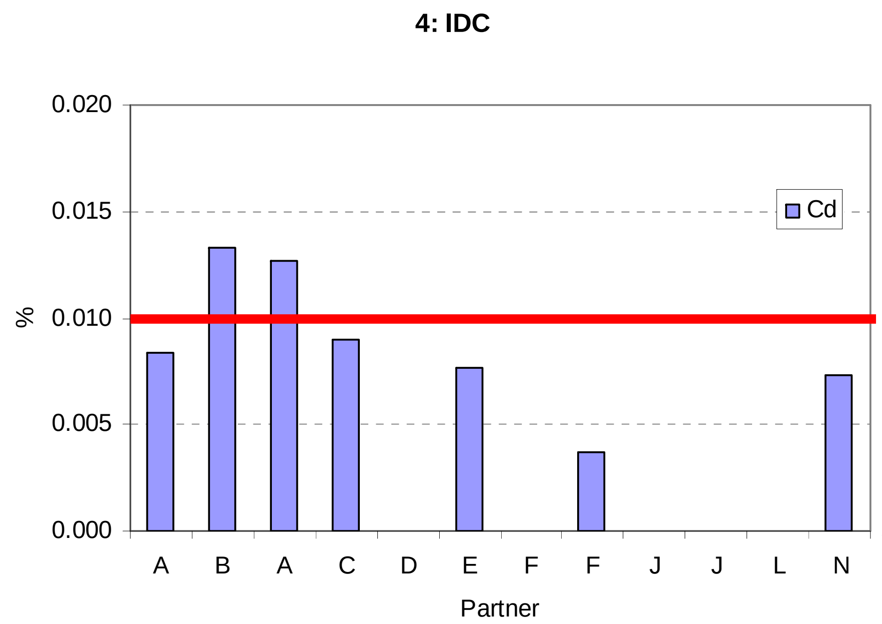


4: IDC PIN/SiLi - Pb



4: IDC PIN/SiLi – Hg/Br/Cr/Cd

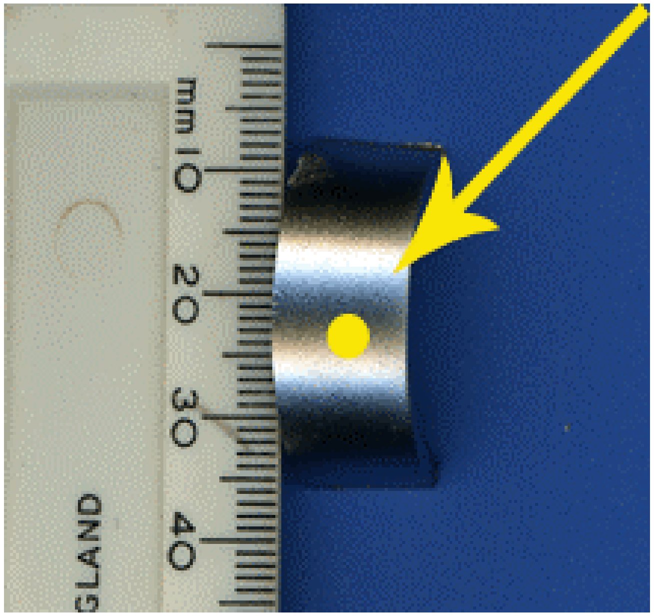




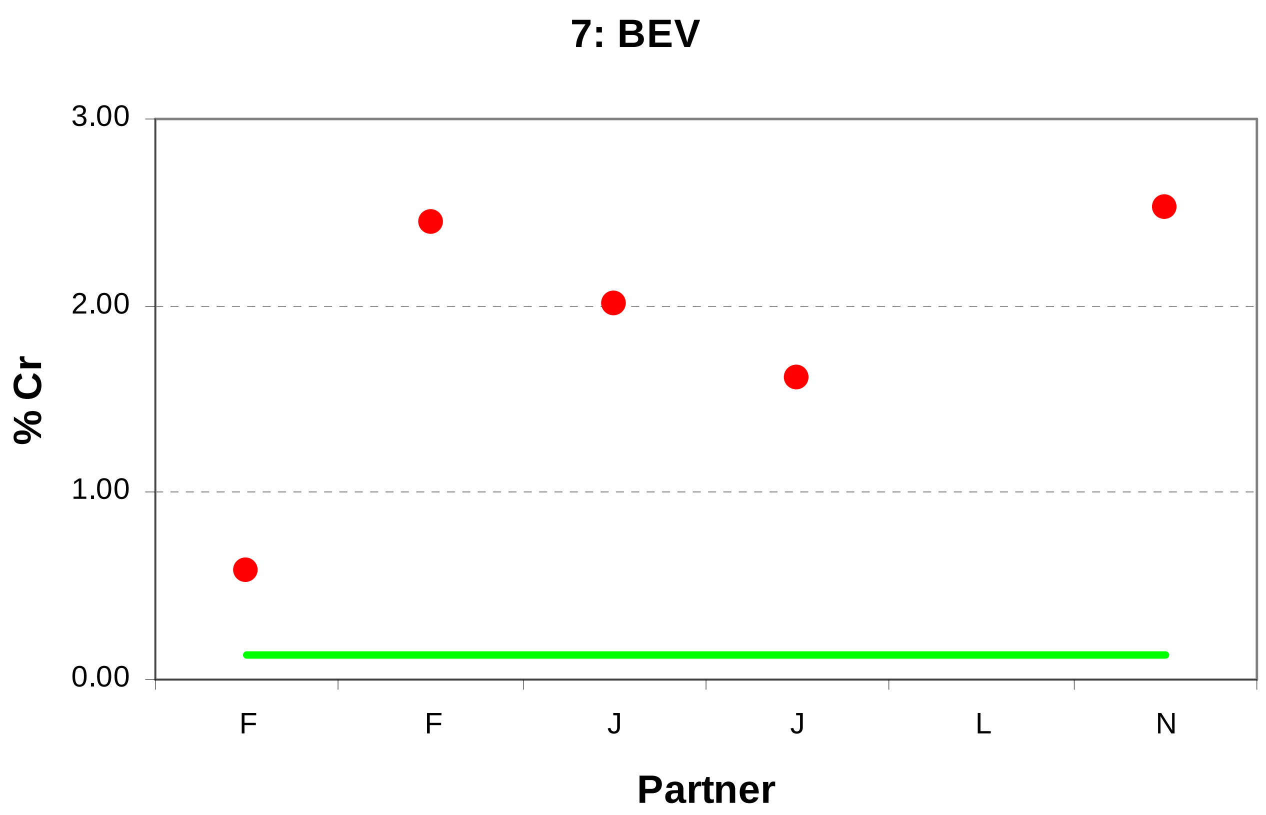
7: BEV

- Silvered push button bezel
- Chemical analysis is of whole sample not added coating

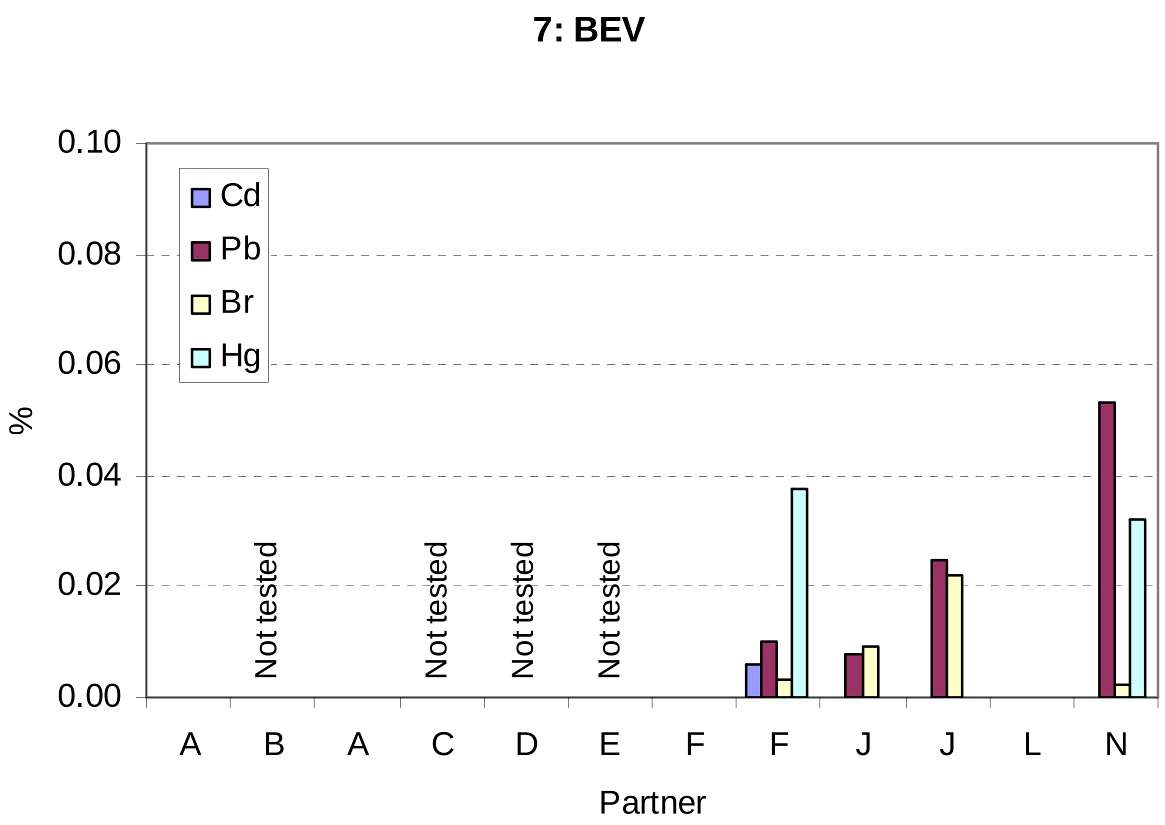
	LGC Analysis
Pb	<0.001
Cd	<0.001
Hg	<0.001
Br	N/A
Cr	0.139



7: BEV PIN/SiLi - Cr



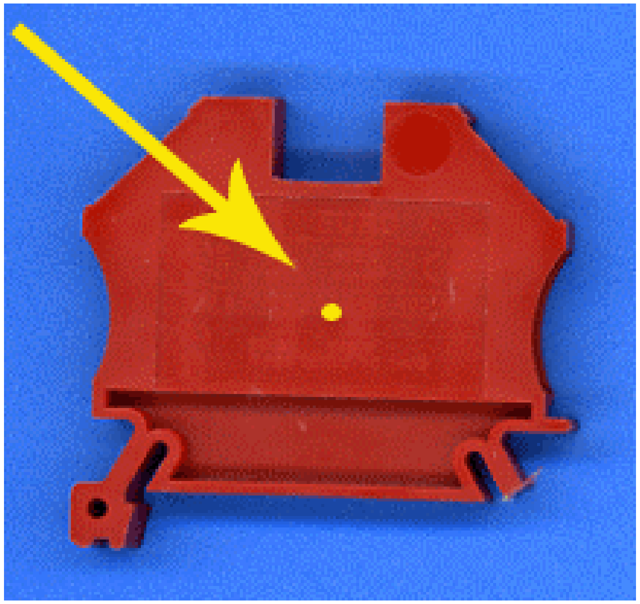
7: BEV PIN/SiLi – Pb/Hg/Br/Cd



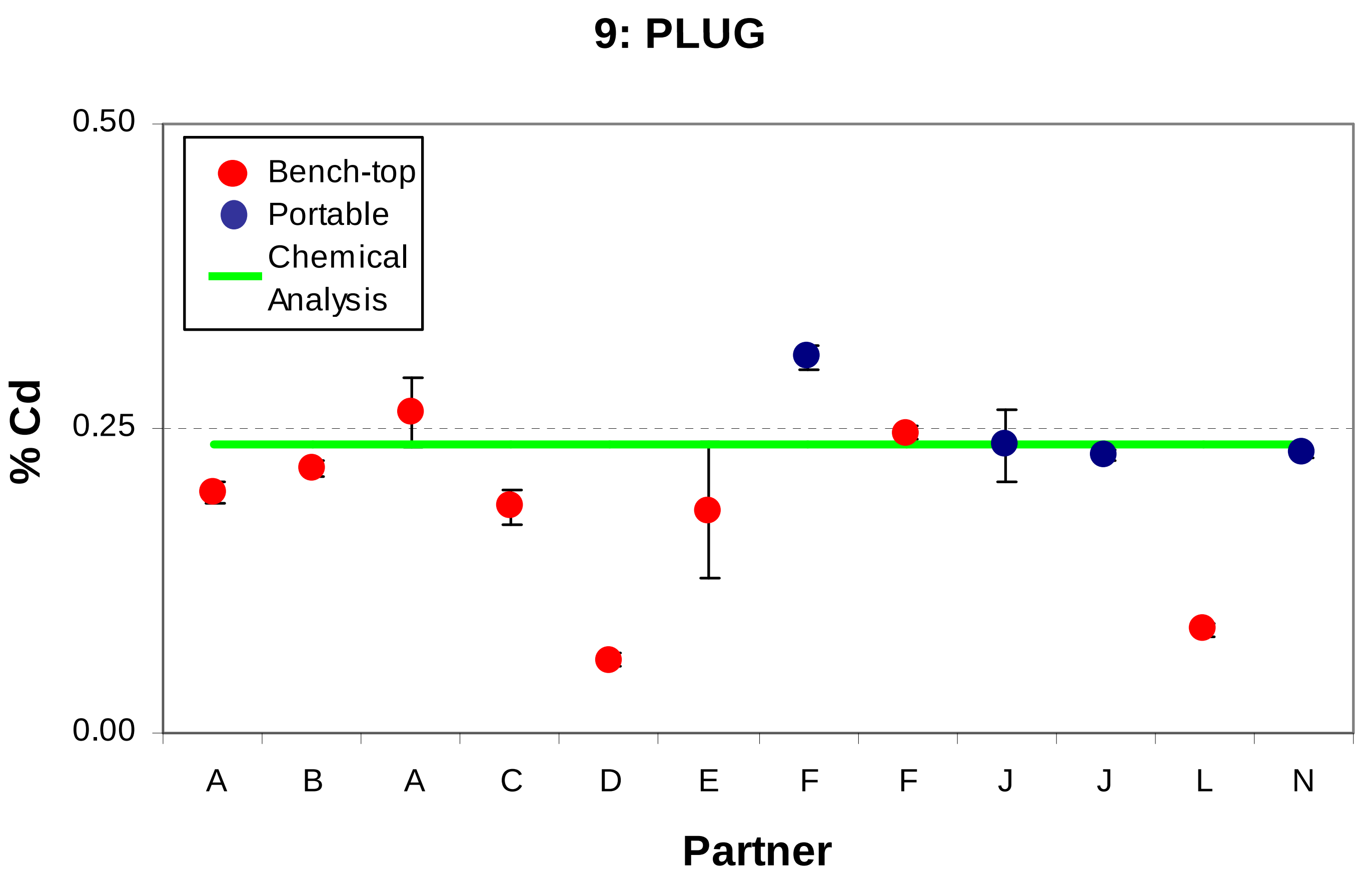
9: PLUG

- Non-PVC connector plug cover

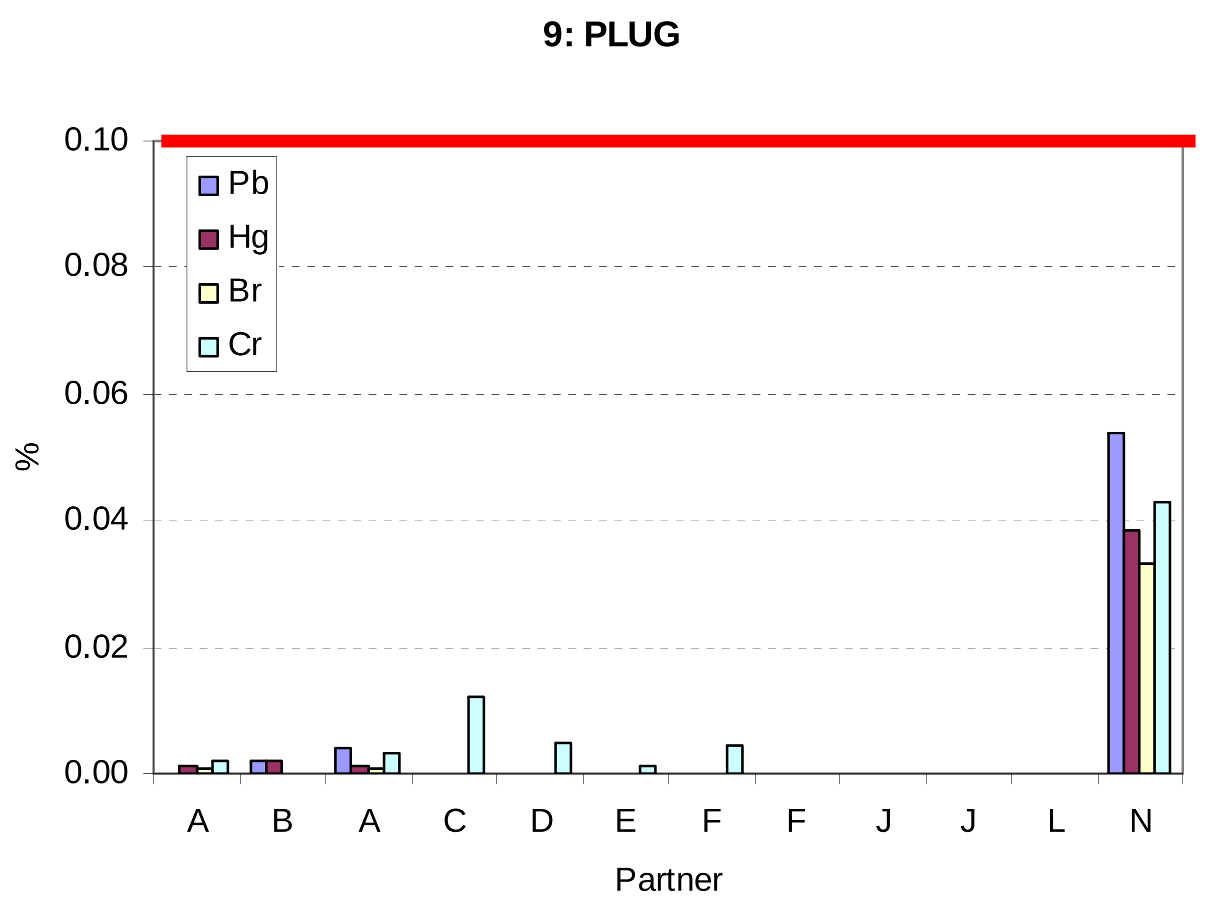
	LGC Analysis
Pb	<0.001
Cd	0.236
Hg	<0.001
Br	N/A
Cr	<0.001



9: PLUG PIN/SiLi - Cd



9: PLUG PIN/SiLi – Pb/Hg/Br/Cr



Plastics Conclusions – Pb, Hg, Br, Cr

- Typical electronics components do not contain 1000ppm Pb, Hg, Br or Cr
- PIN/SiLi based bench-top and portable XRF systems are excellent for distinguishing between non-compliant components (typically 5000+ppm) and compliant components (typically 500ppm)
- For levels between 500ppm and 2000ppm, additional techniques are recommended
- XRF systems have been shown to determine the presence of Br and Cr but not to speciate these elements.

Plastics Conclusions – Pb, Hg, Br, Cr, Cd

- Of the 8 typical electronics components tested containing Pb, Cd or Hg, the 12 PIN/SiLi systems achieved 100% identification of non-compliant components
- Of the 3 typical electronics RoHS compliant components tested, the 12 PIN/SiLi systems achieved 100% identification of compliant components for Pb and Hg. 4 Systems gave false detects for Cd (BP, AQ, DQ & NZ)
- 3 typical components containing Br or Cr were correctly identified as containing these elements and requiring alternative tests for speciation
- For tests of 12 components using 12 PIN/SiLi systems only 2 false detects for Cr at around 1000ppm were registered (EQ and NZ)

Plastics Conclusions - Cd

- For Cd, again bench-top and portable XRF systems excellent at distinguishing non-compliant systems above 1000ppm Cd
- Below this figure, additional techniques may be required
- For tests of 10 components (without Cd) using 12 PIN/SiLi systems, 7 false detects for Cd, all at 260ppm or below, were registered (BP(2), EQ(2), AQ, DQ & NZ)

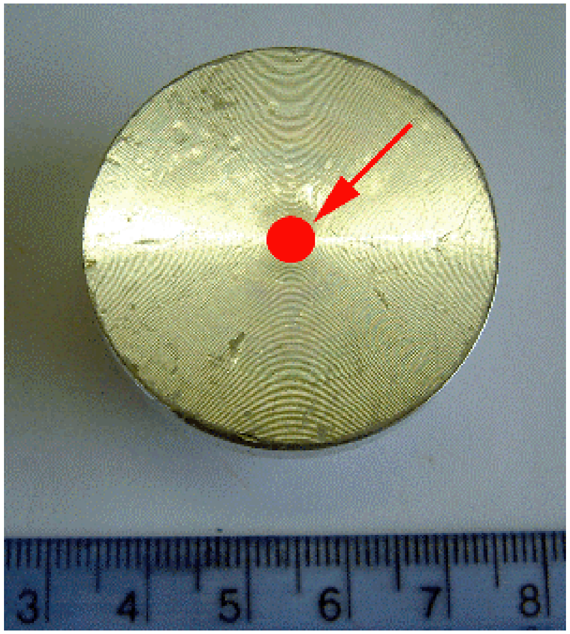
Plastics Conclusions – Proportional Counters

- Proportional counter based systems are capable of registering the presence of RoHS elements when they are at typical levels found in plastics (>3%) but below this level, their ability to find the elements is unproven
- Even at the higher levels, systems are not capable of given quantitative results

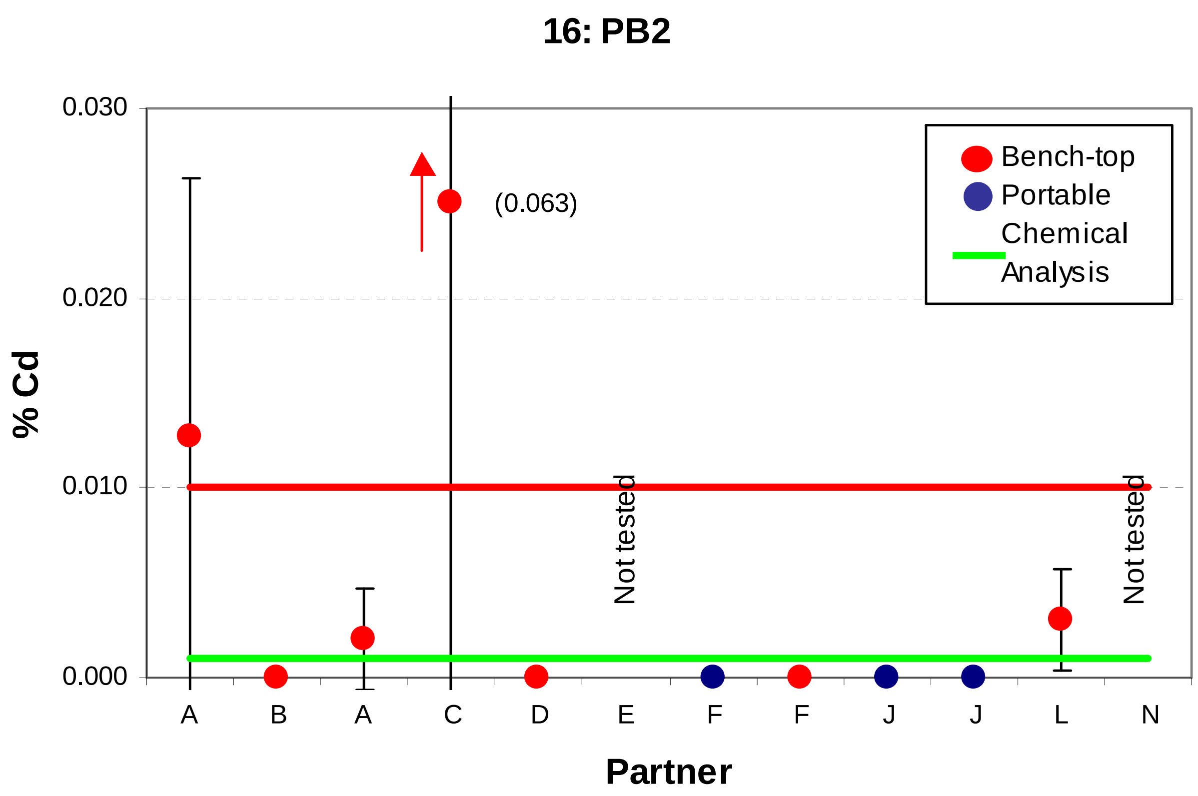
Solders

Pb Contaminated Sn Samples

- Pb1 to Pb8
- Nominal 0 to 20,000 ppm Pb in Sn
- Cd analysis for some samples

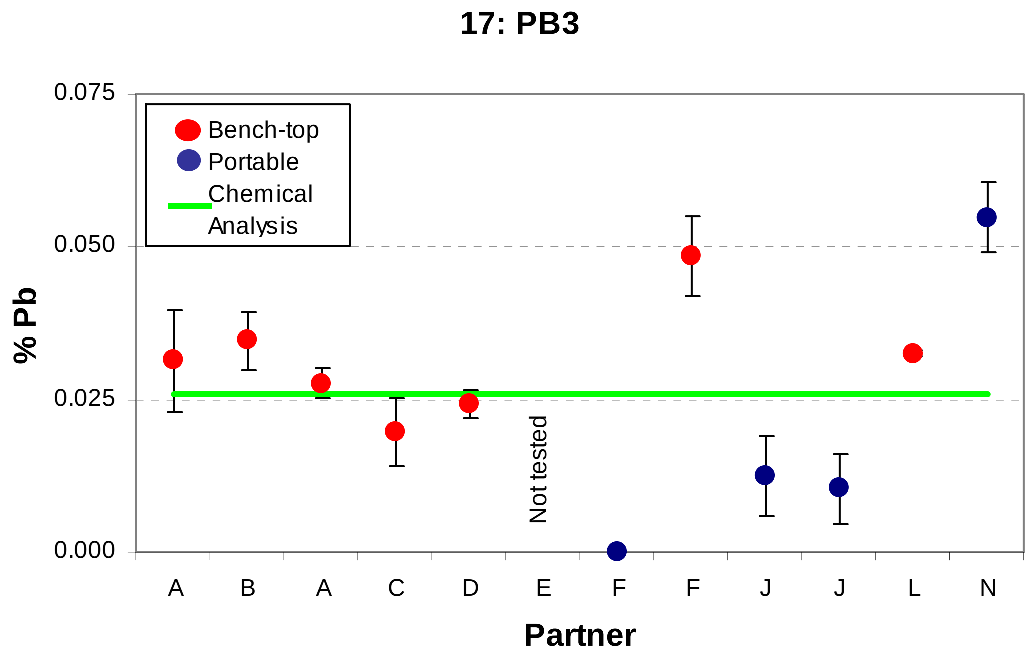


16: PB2 PIN/SiLi - Cd



17: PB3 PIN/SiLi

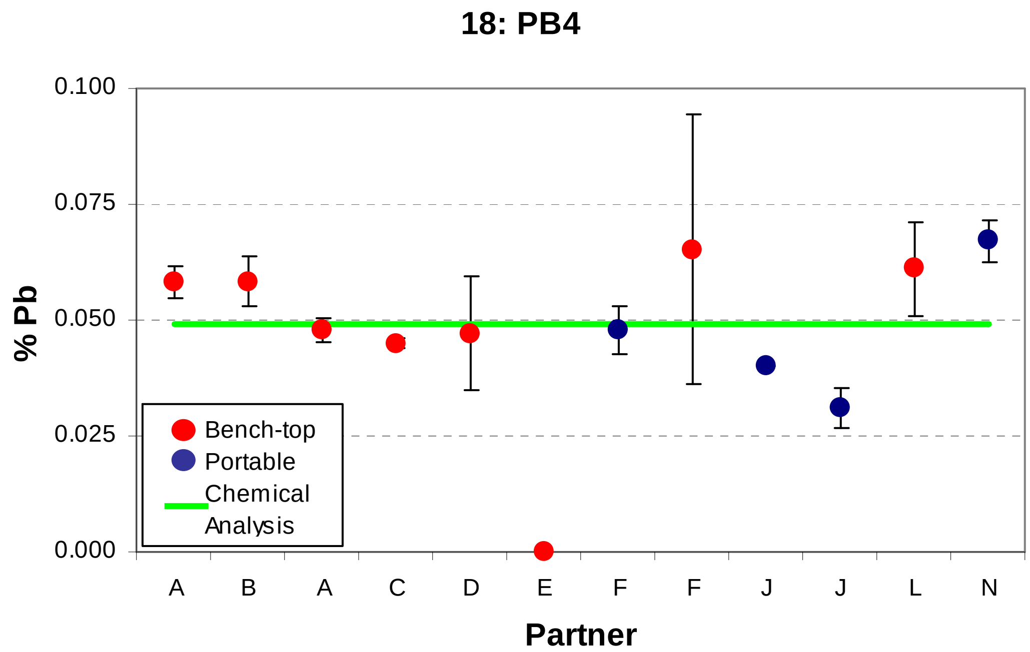
- 260ppm Pb
- One system with high Cd



		BenchTop	X	X	X	X	X	X		X			X	
	PB3	Portable							X		X	X		X
		SiLi								X				
		PIN	X	X	X	X	X	X	X		X	X	X	X
	ITRI Analysis	*Prop. Count*												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**0.026**	**Av.**	**0.031**	**0.035**	**0.028**	**0.020**	**0.024**	**NT**	**ND**	**0.048**	**0.012**	**0.010**	**0.033**	**0.055**
		STD.	*0.008*	*0.005*	*0.003*	*0.006*	*0.002*			*0.007*	*0.007*	*0.006*	*0.000*	*0.006*
Cd	**NT**	**Av.**	**0.009**	**ND**	**ND**	**0.058**	**ND**	**NT**	**ND**	**ND**	**ND**	**ND**	**ND**	**NT**
		STD.	**0.003**			*0.018*								

18: PB4 PIN/SiLi

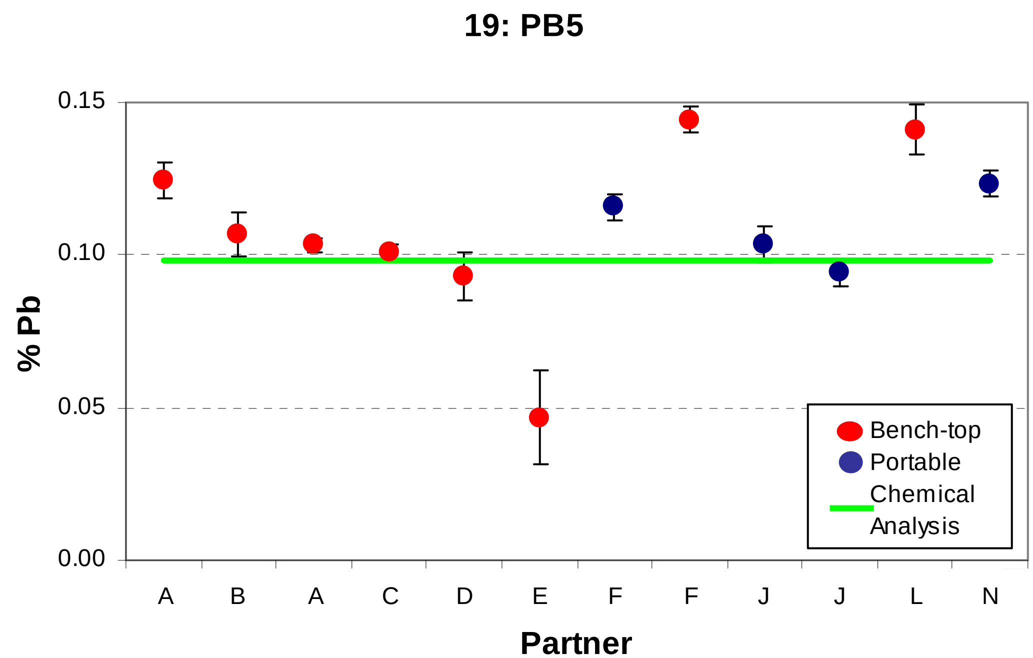
- 490ppm Pb
- One system with high Cd



PB4		BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	ITRI Analysis	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**0.049**	**Av.**	**0.058**	**0.058**	**0.048**	**0.045**	**0.047**	**ND**	**0.048**	**0.065**	**0.040**	**0.031**	**0.061**	**0.067**
		STD.	*0.004*	*0.006*	*0.003*	*0.001*	*0.012*		*0.005*	*0.029*	*0.000*	*0.004*	*0.010*	*0.004*
Cd	**NT**	**Av.**	**ND**	**0.004**	**ND**	**0.062**	**ND**	**NT**	**ND**	**ND**	**ND**	**ND**	**0.008**	**NT**
		STD.		*0.004*		*0.019*							*0.008*	

19: PB5 PIN/SiLi

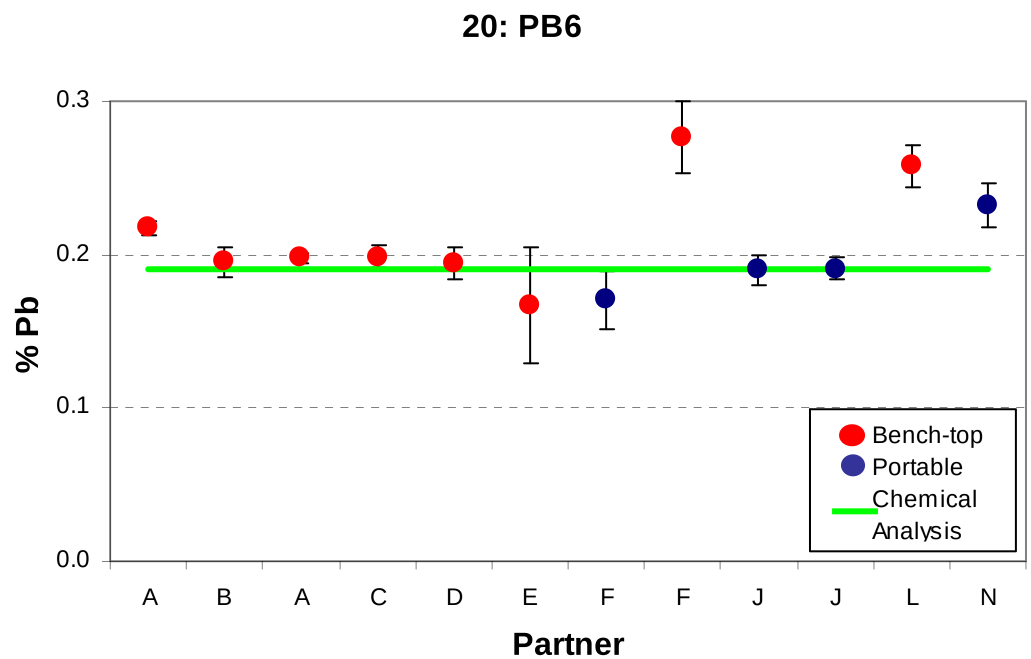
- 980ppm Pb
- Majority of systems failing for Pb
- One system with high Cd



PB5		BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	ITRI Analysis	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**0.098**	**Av.**	**0.124**	**0.107**	**0.103**	**0.101**	**0.093**	**0.047**	**0.116**	**0.144**	**0.103**	**0.094**	**0.141**	**0.123**
		STD.	*0.006*	*0.007*	*0.002*	*0.003*	*0.008*	*0.015*	*0.004*	*0.004*	*0.006*	*0.004*	*0.008*	*0.005*
Cd	**NT**	**Av.**	**ND**	**0.005**	**ND**	**0.067**	**ND**	**NT**	**ND**	**ND**	**ND**	**ND**	**0.001**	**NT**
		STD.		*0.004*		*0.018*							*0.002*	

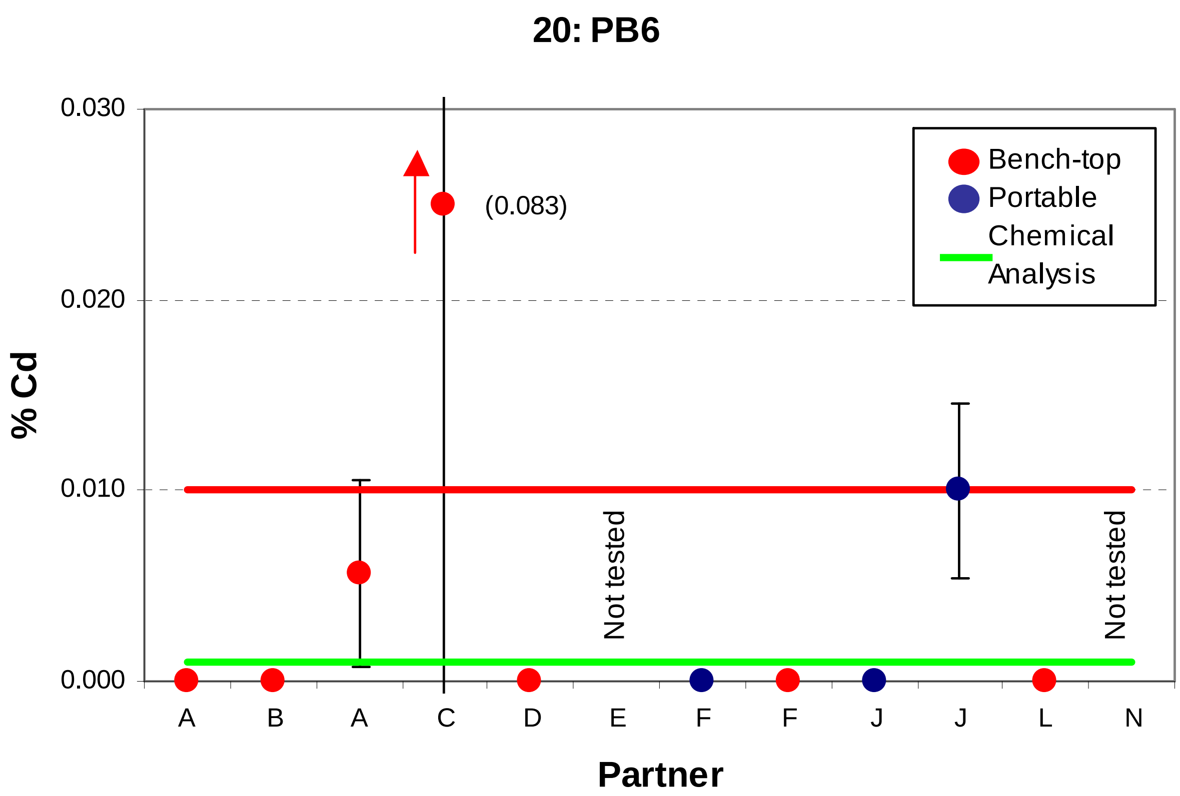
20: PB6 PIN/SiLi

- 1910ppm Pb
- All systems failing for Pb
- Two systems with high Cd



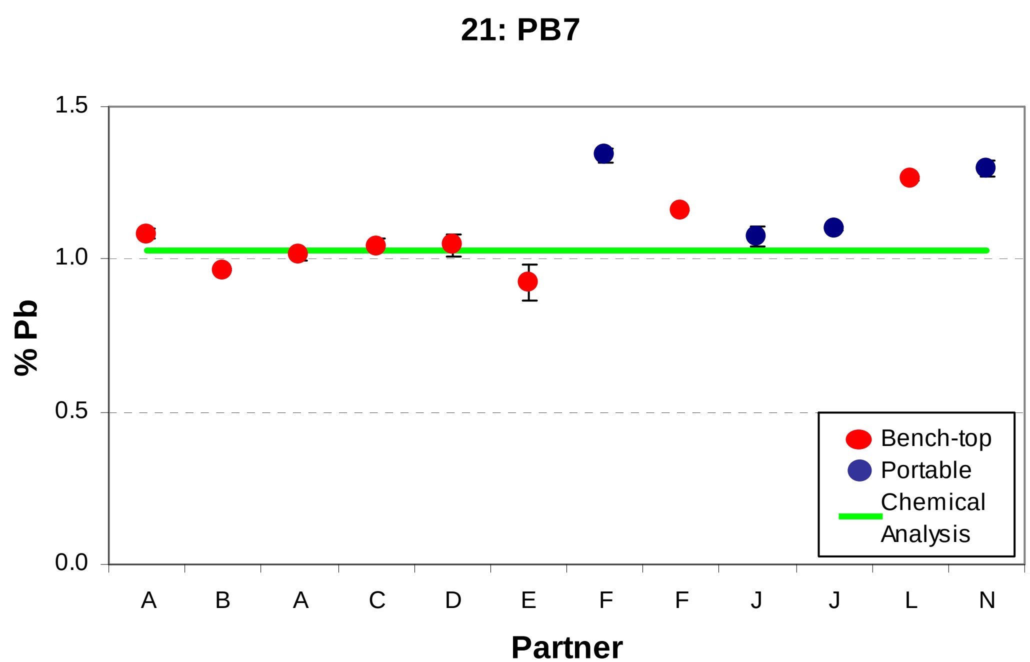
PB6		BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	ITRI Analysis	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**0.191**	**Av.**	**0.217**	**0.195**	**0.198**	**0.199**	**0.194**	**0.167**	**0.171**	**0.277**	**0.190**	**0.191**	**0.258**	**0.232**
		STD.	*0.005*	*0.010*	*0.003*	*0.007*	*0.010*	*0.038*	*0.019*	*0.023*	*0.010*	*0.007*	*0.014*	*0.015*
Cd	**<0.001**	**Av.**	**ND**	**ND**	**0.006**	**0.083**	**ND**	**NT**	**ND**	**ND**	**ND**	**0.010**	**ND**	**NT**
		STD.			*0.005*	*0.034*						*0.005*		

20: PB6 PIN/SiLi - Cd



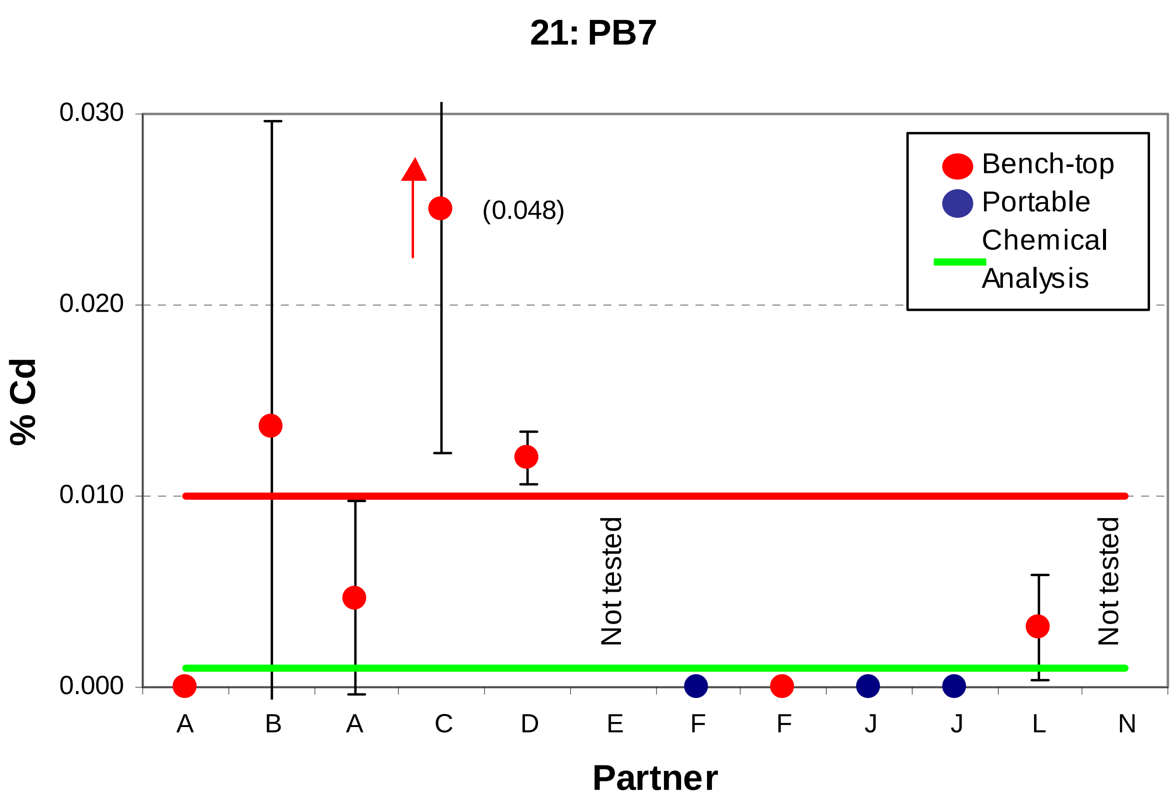
21: PB7 PIN/SiLi

- 10300ppm Pb
- All systems failing for Pb
- Three systems with high Cd



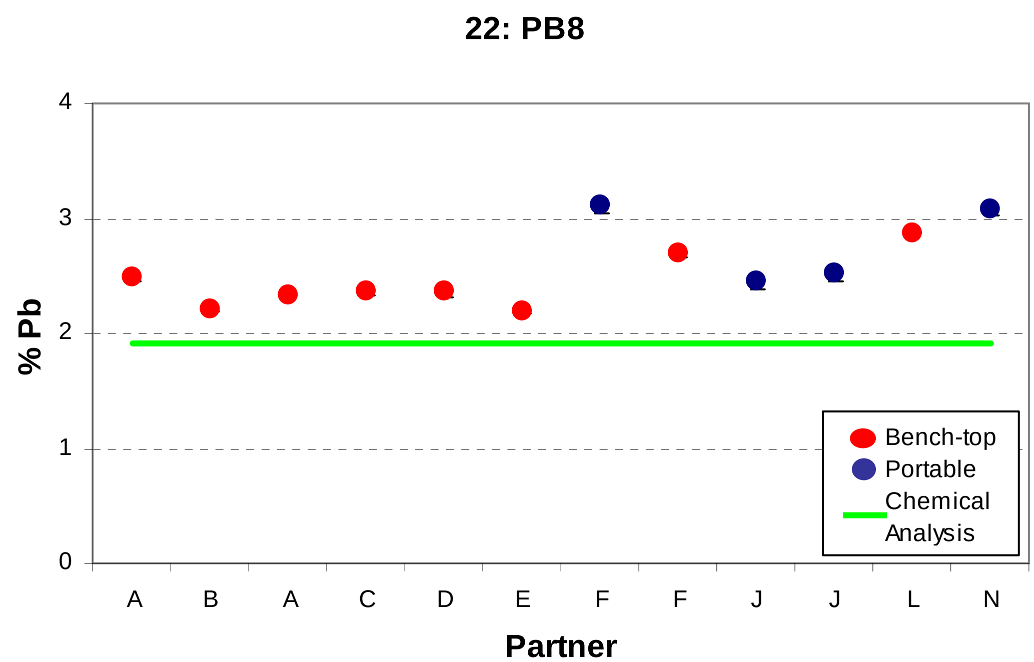
PB7		BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	ITRI Analysis	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**1.030**	**Av.**	**1.084**	**0.966**	**1.013**	**1.043**	**1.046**	**0.923**	**1.341**	**1.159**	**1.077**	**1.102**	**1.263**	**1.297**
		STD.	*0.019*	*0.003*	*0.014*	*0.023*	*0.035*	*0.059*	*0.025*	*0.002*	*0.032*	*0.008*	*0.007*	*0.028*
Cd	**<0.001**	**Av.**	**ND**	**0.014**	**0.005**	**0.048**	**0.012**	**NT**	**ND**	**ND**	**ND**	**ND**	**0.003**	**NT**
		STD.		*0.016*	*0.005*	*0.013*	*0.001*						*0.003*	

21: PB7 PIN/SiLi - Cd



22: PB8 PIN/SiLi

- 19210ppm Pb
- All systems failing for Pb
- One system with high Cd



PB8													
		BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	ITRI Analysis	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**1.921**	**Av.**	**2.483**	**2.209**	**2.334**	**2.360**	**2.364**	**2.200**	**3.119**	**2.690**	**2.450**	**2.514**	**2.878**	**3.081**
		STD.	*0.040*	*0.013*	*0.012*	*0.030*	*0.052*	*0.026*	*0.080*	*0.022*	*0.070*	*0.054*	*0.004*	*0.062*
Cd	**NT**	**Av.**	**ND**	**ND**	**ND**	**0.042**	**ND**	**NT**	**ND**	**ND**	**ND**	**ND**	**ND**	**NT**
		STD.				*0.029*								

Pb in Sn PIN/SiLi Conclusions

- PIN/SiLi based XRF systems are excellent for distinguishing Pb levels in bulk solder samples down to levels around 500ppm Pb
- Some systems can achieve good repeatability at 50ppm Pb
- All systems achieved 100% successful identification of 2000ppm Pb in Sn
- At 1000ppm lead, 11 out of 12 systems indicated failure for lead or within 10% of RoHS limit

Cd in Sn/Pb Conclusions

- 10 PIN/SiLi systems completed full matrix for Cd in SnPb
- 50% of systems gave at least 1 fall detect for Cd

Pb Contaminated Sn Samples – Proportional Counters

PB1

	ITRI Analysis				
		BenchTop	X	X	X
		Portable			
		SiLi			
		PIN			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**0.005**	**Av.**	**ND**	**NT**	**NT**
		STD.			
Cd	**NT**	**Av.**		**NT**	**NT**
		STD.			

PB3

	ITRI Analysis				
		BenchTop	X	X	X
		Portable			
		SiLi			
		PIN			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**0.026**	**Av.**	**ND**	**NT**	**NT**
		STD.			
Cd	**NT**	**Av.**		**NT**	**NT**
		STD.			

PB2

	ITRI Analysis				
		BenchTop	X	X	X
		Portable			
		SiLi			
		PIN			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**0.011**	**Av.**	**ND**	**NT**	**NT**
		STD.			
Cd	**<0.001**	**Av.**		**NT**	**NT**
		STD.			

PB4

	ITRI Analysis				
		BenchTop	X	X	X
		Portable			
		SiLi			
		PIN			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**0.049**	**Av.**	**ND**	**ND**	**ND**
		STD.			
Cd	**NT**	**Av.**	**NT**	**NT**	**NT**
		STD.			

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Pb Contaminated Sn Samples – Proportional Counters II

		BenchTop	X	X	X
PB5		Portable			
		SiLi			
	ITRI Analysis	*PIN*			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**0.098**	**Av.**	**0.05**	**ND**	**0.193**
		STD.	*0.006*		*0.225*
Cd	**NT**	**Av.**		**NT**	**NT**
		STD.			

		BenchTop	X	X	X
PB7		Portable			
		SiLi			
	ITRI Analysis	*PIN*			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**1.030**	**Av.**	**0.99**	**1.333**	**1.107**
		STD.	*0.010*	*0.070*	*0.021*
Cd	**<0.001**	**Av.**		**NT**	**NT**
		STD.			

		BenchTop	X	X	X
PB6		Portable			
		SiLi			
	ITRI Analysis	*PIN*			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**0.191**	**Av.**	**0.15**	**0.167**	**0.170**
		STD.	*0.021*	*0.030*	*0.035*
Cd	**<0.001**	**Av.**		**NT**	**NT**
		STD.			

		BenchTop	X	X	X
PB8		Portable			
		SiLi			
	ITRI Analysis	*PIN*			
		Prop. Count	X	X	X
		Partner	**G**	**H**	**M**
		System	**T**	**U**	**Y**
Pb	**1.921**	**Av.**	**2.46**	**3.100**	**2.607**
		STD.	*0.017*	*0.170*	*0.040*
Cd	**NT**	**Av.**		**NT**	**NT**
		STD.			

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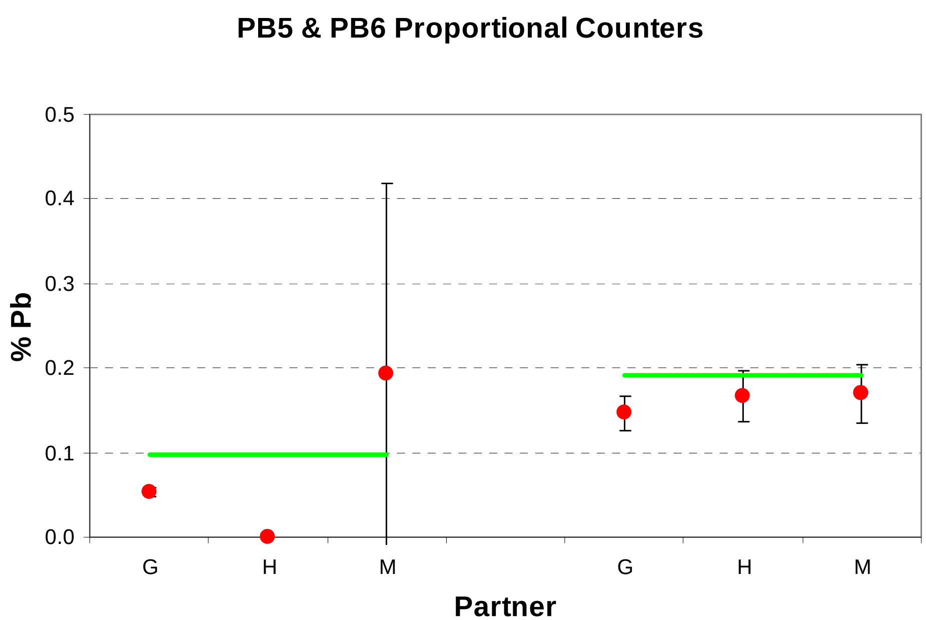
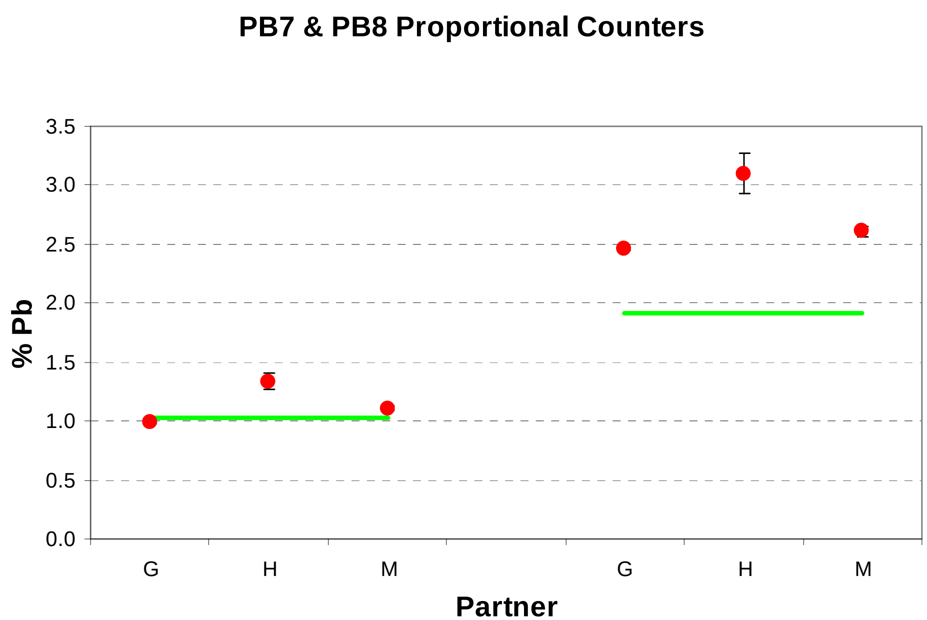
Pb Contaminated Sn Samples – Proportional Counters II



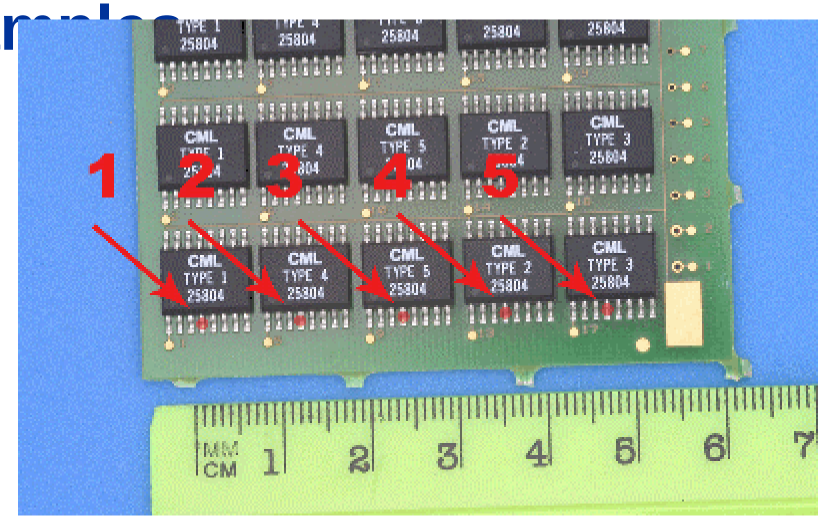


Pb Contaminated Sn Samples – Proportional Counters III

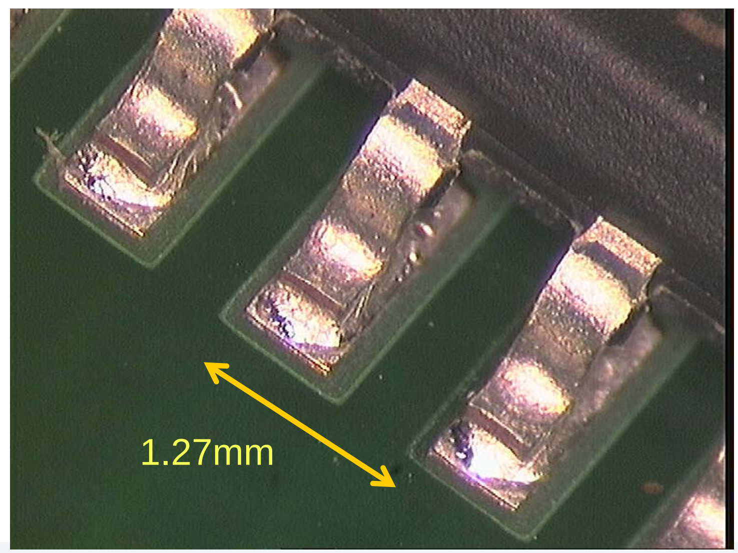
- All PC systems measuring Pb at 0.2%
- Only one system detecting at 0.1%
- No systems detecting below 0.1%
- Adequate for tin whisker mitigation where lead levels above 1% required
- Potential issue with smaller samples if minimum spot size too large
- For RoHS, problems for samples containing 0.1 to 0.2% lead, these will not be detected

Pb Contaminated SAC Sa

- NPL1 to NPL5
- Nominal 0 to 20% Pb in SnAgCu

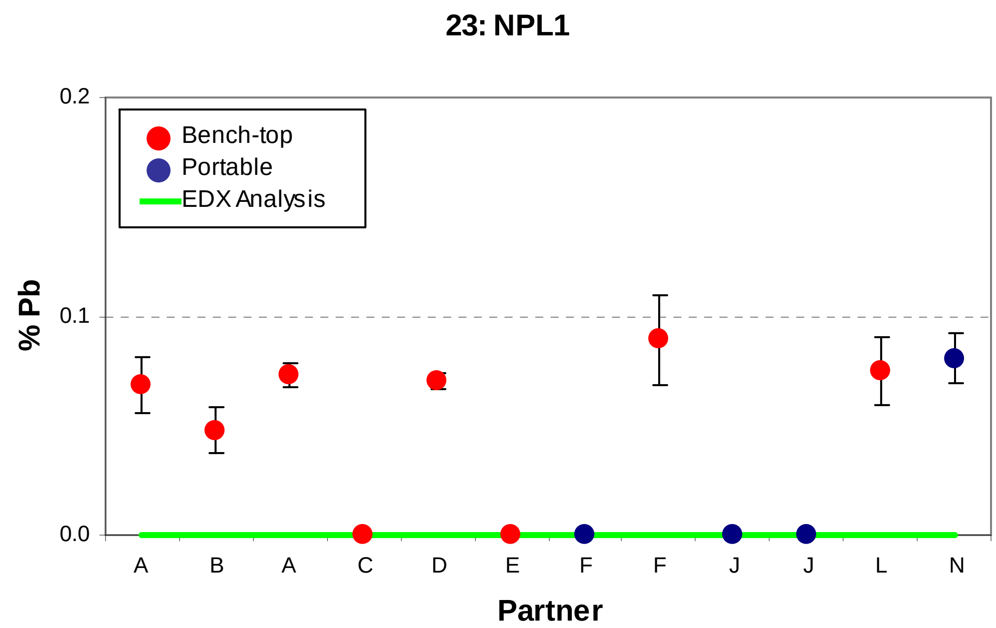


Pb in SnAgCu
solder with Au
Ni
Cu
Glass reinforced epoxy



23: NPL1 PIN/SiLi

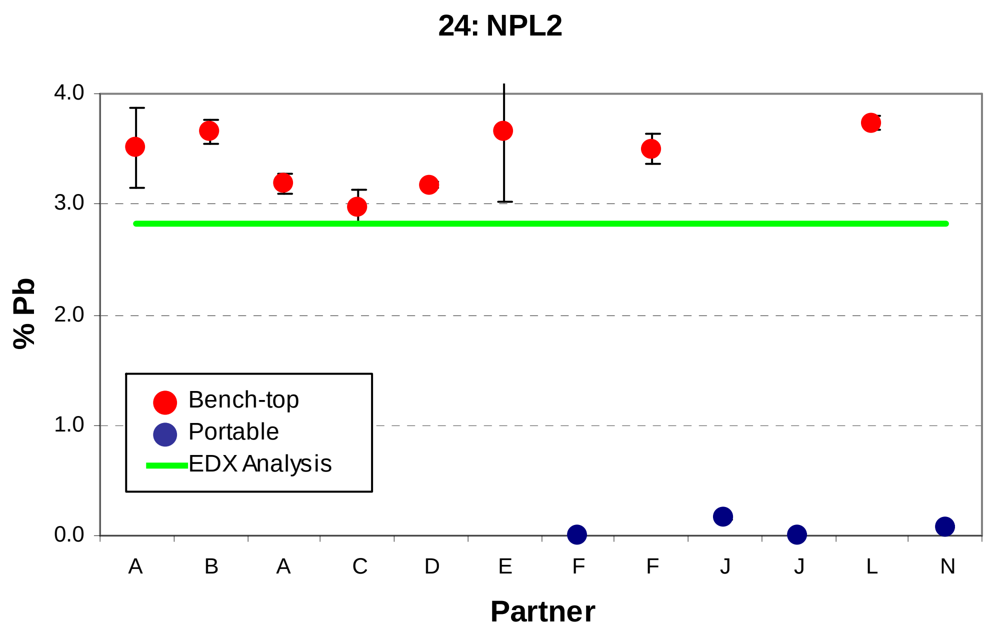
- Lead-free system
- Two systems with high Cd



	NPL1	BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	EDX Analysis Termination NPL	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	<0.1	**Av.**	**0.069**	**0.048**	**0.073**	**ND**	**0.070**	**ND**	**ND**	**0.089**	**ND**	**ND**	**0.075**	**0.081**
		STD.	*0.013*	*0.010*	*0.005*		*0.004*			*0.020*			*0.015*	*0.011*
Cd	<0.1	**Av.**	**ND**	**ND**	**0.022**		**ND**	**ND**	**ND**	**0.012**	**ND**	**ND**	**NT**	**NT**
		STD.			*0.032*					*0.004*				

24: NPL2 PIN/SiLi

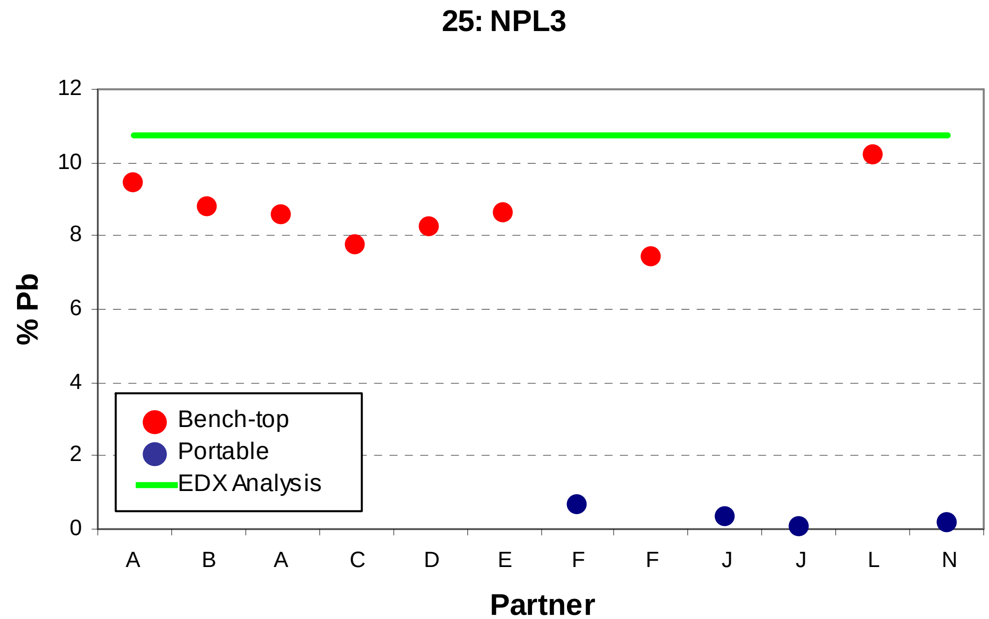
- ~3% Pb in joint
- 3 handheld systems did not fail for Pb
- One system with high Cd



	NPL2	BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	EDX Analysis Termination NPL	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	A	B	A	C	D	E	F	F	J	J	L	N
		System	P	P	Q	Q	Q	Q	R	S	V	W	X	Z
Pb	2.8	Av.	3.520	3.662	3.187	2.973	3.170	3.657	ND	3.499	0.156	0.008	3.730	0.077
		STD.	0.362	0.107	0.087	0.150	0.026	0.638		0.131	0.016	0.002	0.062	0.009
Cd	<0.1	Av.	ND	ND	0.056	NT	ND	NT	ND	0.003	ND	ND	NT	NT
		STD.			0.044					0.003				

25: NPL3 PIN/SiLi

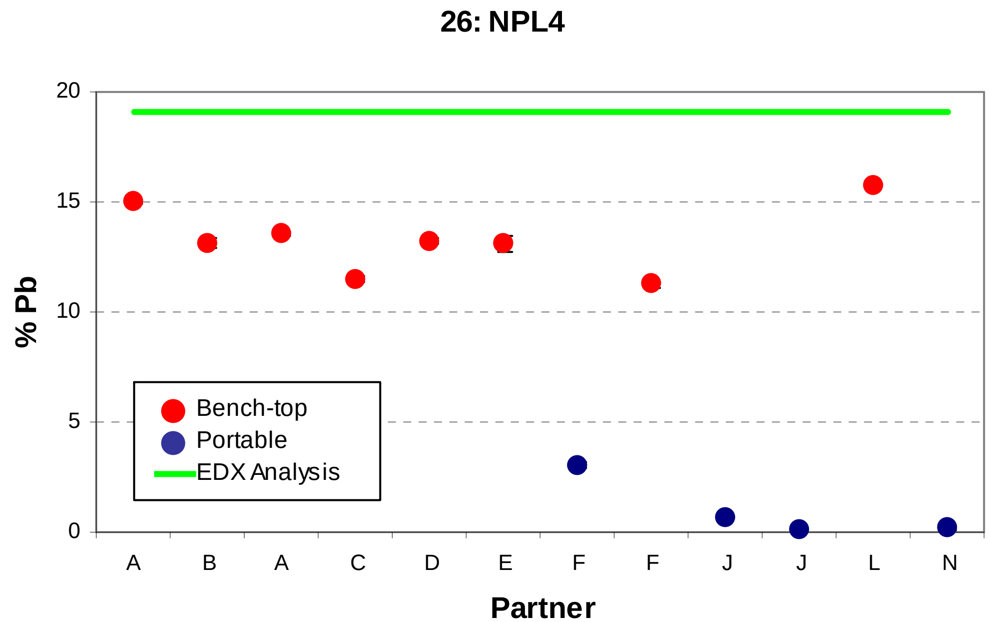
- ~11% Pb in joint
- 1 handheld system did not fail for Pb
- One system with high Cd



NPL3														
		BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	EDX Analysis	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
	Termination	**Partner**	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
	NPL	**System**	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**10.8**	**Av.**	**9.439**	**8.795**	**8.553**	**7.740**	**8.246**	**8.603**	**0.655**	**7.424**	**0.329**	**0.040**	**10.176**	**0.157**
		STD.	*0.218*	*0.188*	*0.121*	*0.142*	*0.119*	*0.184*	*0.064*	*0.029*	*0.049*	*0.011*	*0.094*	*0.011*
Cd	**<0.1**	**Av.**	**ND**	**ND**	**0.064**	**NT**	**ND**	**NT**	**ND**	**0.002**	**ND**	**ND**	**NT**	**NT**
		STD.			*0.033*					*0.003*				

26: NPL4 PIN/SiLi

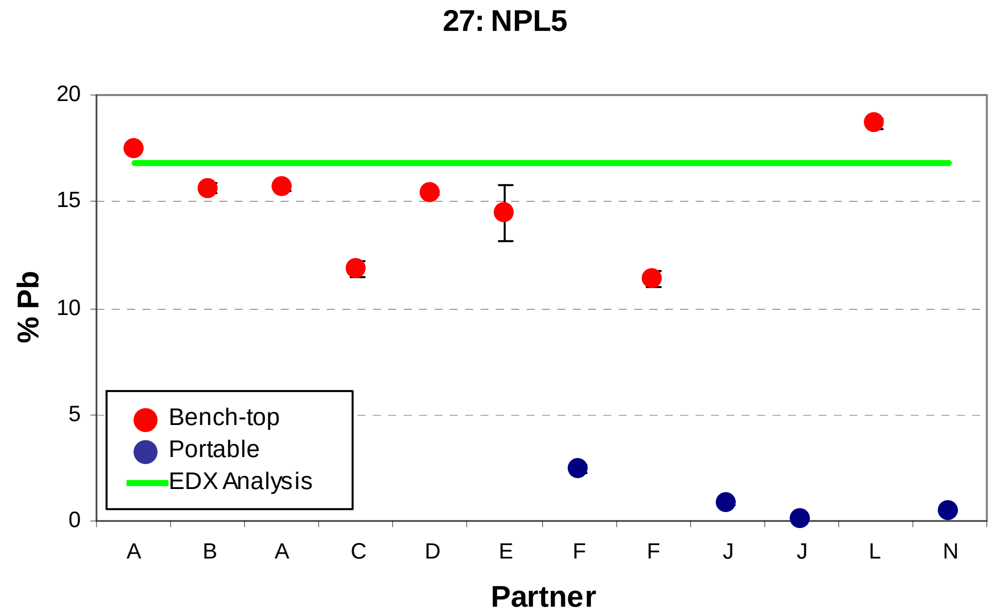
- ~19% Pb in joint
- 1 handheld system did not fail for Pb
- One system with high Cd



	NPL4	BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	EDX Analysis Termination NPL	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**19.1**	**Av.**	**15.030**	**13.133**	**13.533**	**11.500**	**13.193**	**13.100**	**3.038**	**11.229**	**0.661**	**0.068**	**15.750**	**0.166**
		STD.	*0.087*	*0.264*	*0.058*	*0.100*	*0.125*	*0.346*	*0.118*	*0.153*	*0.058*	*0.006*	*0.056*	*0.066*
Cd	**<0.1**	**Av.**	**ND**	**ND**	**0.037**	**NT**	**ND**	**NT**	**ND**	**0.002**	**ND**	**ND**	**NT**	**NT**
		STD.			*0.011*					*0.002*				

27: NPL5 PIN/SiLi

- ~17% Pb in joint
- 1 handheld system did not fail for Pb
- One system with high Cd

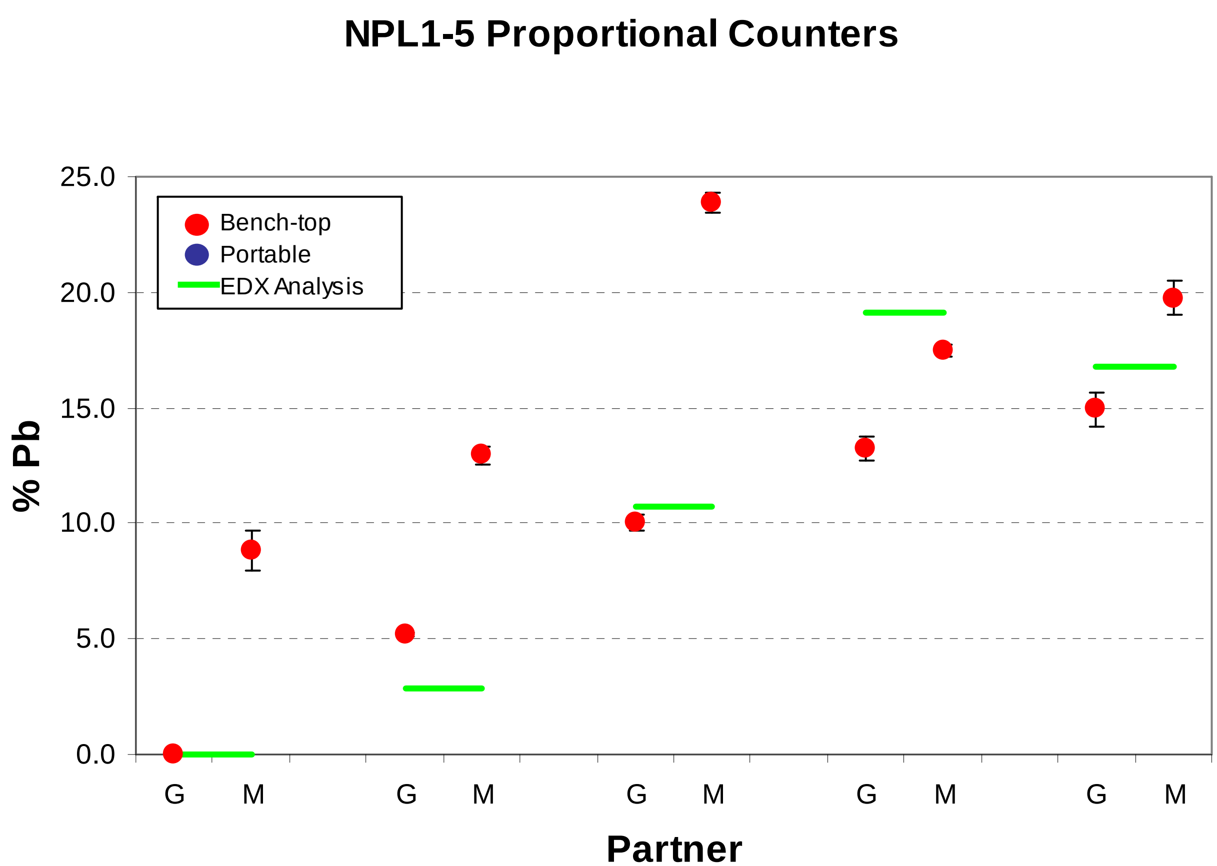


	NPL5	BenchTop	X	X	X	X	X	X		X			X	
		Portable							X		X	X		X
		SiLi								X				
	EDX Analysis Termination NPL	*PIN*	X	X	X	X	X	X	X		X	X	X	X
		Prop. Count												
		Partner	**A**	**B**	**A**	**C**	**D**	**E**	**F**	**F**	**J**	**J**	**L**	**N**
		System	**P**	**P**	**Q**	**Q**	**Q**	**Q**	**R**	**S**	**V**	**W**	**X**	**Z**
Pb	**16.8**	**Av.**	**17.510**	**15.633**	**15.667**	**11.800**	**15.397**	**14.433**	**2.454**	**11.338**	**0.820**	**0.087**	**18.673**	**0.498**
		STD.	*0.020*	*0.225*	*0.153*	*0.361*	*0.096*	*1.305*	*0.204*	*0.376*	*0.075*	*0.011*	*0.225*	*0.008*
Cd	**<0.1**	**Av.**	**ND**	**ND**	**0.059**	**NT**	**ND**	**NT**	**ND**	**ND**	**ND**	**ND**	**NT**	**NT**
		STD.			*0.057*									

NPL1-5 PIN/SiLi Conclusions

- Spot size is a issue for small samples
- For accurate Pb determination, sample should fill measuring window
- 8 systems completed the full matrix for Cd measurements, giving 6 false detects (40 measurements) on 2 systems

NPL1-5 Proportional Counters



NPL1–5 Proportional counters

- Proportional counter performance was variable
- Only two systems completed measurements
- One system performed well giving acceptable levels for Pb in joints
- Other system gave high lead (8%) for lead free

Summary of Conclusions

Lead, Mercury, Bromine, Chromium

- Typical electronics components do not contain 1000ppm Pb, Hg, Br or Cr
- XRF systems generally excellent for distinguishing between non-compliant components (typically 5000+ppm) and compliant components (typically 500ppm)
- For levels between 500ppm and 2000ppm, additional techniques are recommended if accurate elemental analysis is required
- XRF systems have been shown to determine the presence of Br and Cr but to speciate these elements.

Cadnium

- For Cd, again XRF systems excellent at distinguishing non-compliant systems above 1000ppm Cd
- Below this figure, additional techniques may be required
- The lower RoHS limit for Cd did generate a level of false detects for this element

Proportional Counter Conclusions

- Primarily used for ensuring Pb levels in solder are above 1% for Sn whisker mitigation
- Acceptable for use for this purpose provided the sample is large enough to fill measurement window particularly where Pb levels are closer to 1%

Tin Whisker Mitigation Conclusions

- All systems proved capable of ensuring Pb levels above 1% in solder providing smaple size is large enough
- False positives can be given for samples which have Pb in base material beneath metallisation.