Optimizing Reel-to-Reel Hard Gold Plating

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Over recent years advances have been made with hard acid gold solution formulations as well as reel to reel plant design. This paper will discuss the optimization of high speed gold performance by choosing the right gold process for the right application. Results in terms of efficiency, speed, distribution and deposit characteristics will be discussed as well as the parameters of the processes needed to give these optimized results in various plant designs (dip selective, spot selective, brush selective etc).

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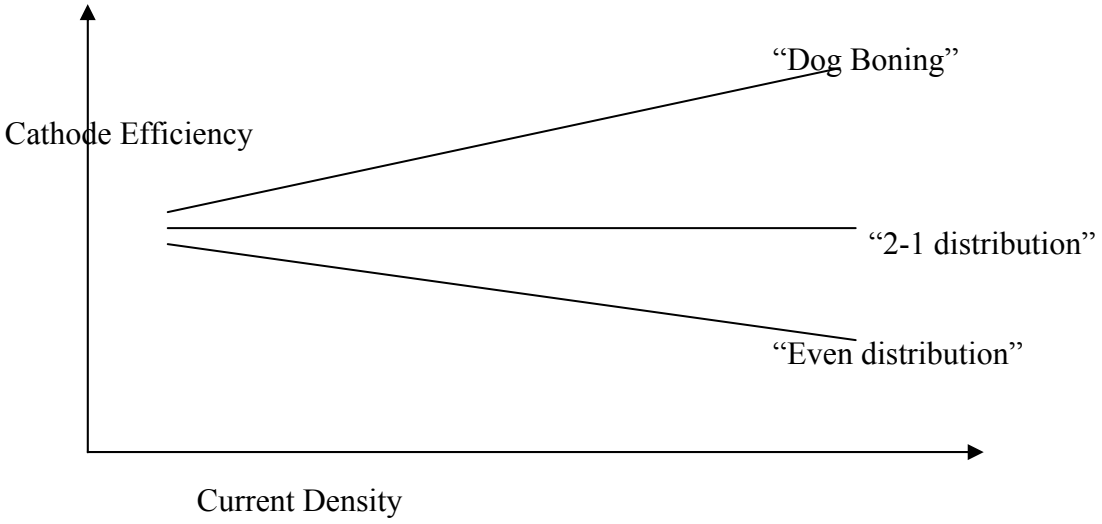
Introduction

Gold has been used on components in the electronics industry for many years and in more recent years (the past three - four decades) the use of hard acid gold has become widespread. It has excellent corrosion resistance and low contact resistance which makes it very suitable as a wearing connector. However it is still an expensive commodity and contributes quite significantly to the cost of components. Early gold plating processes tended to have poor deposit distribution, therefore to reach a minimum thickness at a given point often the part would have to have a much greater average thickness. This was particularly true for deposits from barrel gold processes but also true for high speed acid gold processes.

The theory behind traditional distribution profiles can be shown below. Increase current = increase in efficiency = increased usage of gold at the higher current density spots.

Theory



As a result of the increasing cost of depositing gold pressure was applied to gold process suppliers to improve the technology regarding the distribution of gold on the component both in barrel, rack and high speed applications. Thus, the current range of organically brightened hard acid golds giving excellent deposit distribution were developed.

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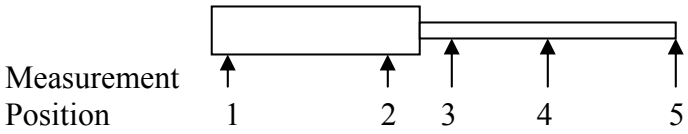
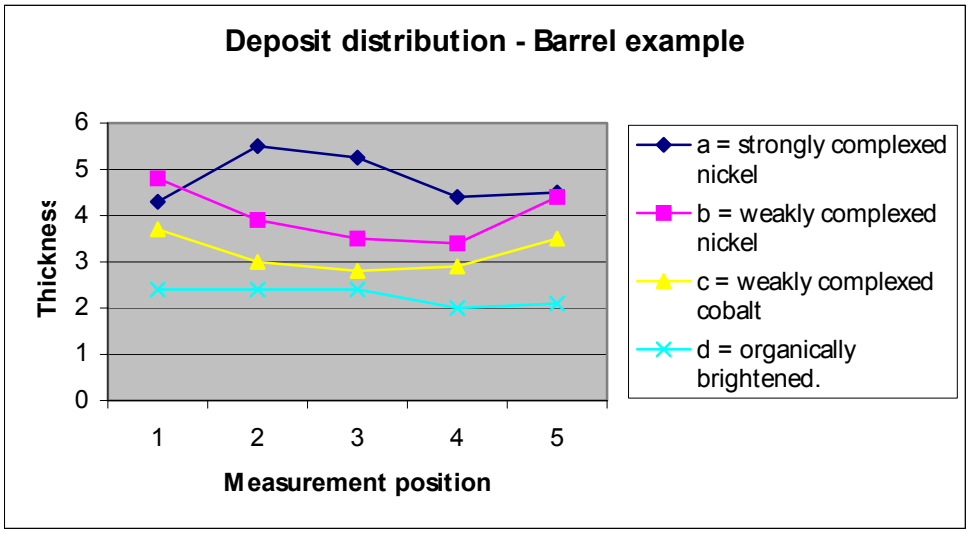
An example of how the distribution profiles of gold plated pin connectors can be changed by the bath chemistry is shown below.





With the increase in "Reel to Reel" plating came specifications calling for a given thickness at one specific point. Process solutions were evaluated regarding their distribution and chemical parameters were found to affect the distribution. Information was taken initially from the work with barrel solutions. From this information factors known to affect the distribution were investigated and the most significant revealed (1). It was found therefore that the distribution from an acid hard gold electrolyte could be manipulated and solutions could be formulated to optimise the parameters needed.

With this increase in High Speed connector plating also came differing types of plant capable of selectively plating Hard Gold on a "Reel to Reel" basis. It was seen that with differing types of plating heads (see appendix 1) that variations in distribution and plating speeds could be found.

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Further advancements have also been made in the field of measurement over the last two decades. With the ability to plate smaller and smaller areas came the necessity to make precise measurements (2). For this reason XRF measurements can now be made in exacting areas leading to the requirement to plate more accurately defined areas. This requirement to plate more precise areas along with production speed requirements has lead to the desire to achieve different profiles, different speeds on differing types of "Reel to Reel" plating plant.

This paper will present the attempts to clarify the potentials available regarding differing chemical formulations of Acid Hard Golds (all cobalt brightened) and their characteristics on differing types of plant.

Gold Processes.

The chemical basis for the gold processes were all of a typical type and were as follows.

Component	Unit	Range
Au as PGC	g/l	2-20g/l
Citrate/Phosphate	g/l	100-150g/l
Cobalt/Nickel	g/l	0.25 – 2.0g/l
Additive	g/l	0.25 – 2.0g/l
Surfactant	ml/l	0.1 – 5.0ml/l
pH		4.0 – 5.0
Temperature	ºC	30 – 60

In order to reduce the amount of processes to evaluate three types were chosen from the various formulations available from above as the main types currently in use today.

	Type 1	Type 2	Type 3
Au as GPC	6-12g/litre	6-20g/litre	6-20g/litre
Citrate/Oxlate (Total)	100-150g/litre	100-150g/litre	100-150g/litre
Brightener Cobalt	0.7-1.1g/litre	0.8-1.2g/litre	0.5-1.6g/litre
Additive Single Type	0.4-0.6g/litre	----------	0.5-1.6g/litre
Additive as a Mixture	----------	2-4g/litre	----------
Additional Additive	----------	----------	6-12ml/litre
pH	4.2 - 4.9	4.3-4.7	4.3 - 4.7
Temperature	30 - 60ºC	35 -50ºC	50 - 60ºC

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Laboratory Experimental Data

Each of the three processes were evaluated in a laboratory Hull cell experimentation and the results compared with the actuality seen in differing reel to reel plant designs

The three solutions chosen can be seen to be similar in many respects in their basis formulation. It has been reported previously how significant the additive system is and recently reports using new additional additives have been made (3 & 4).

It can be seen that two of the processes showed similar results in the laboratory hull cell tests (at pH 4.0) regarding plating rates throughout. At the lower temperatures and lower current densities all were similar in terms of their plating rates but differing in their appearance. (see appendix 2, 3 & 4).

When we look at the actual data from field experience we see that the appearance criteria as expected also has a significant impact and can be directly related to the hull cell experience.

When evaluating the actual results from lines running in production we see that the general trends hold true. As mentioned above, pictorial representation of the various reel to reel lines can be seen in appendix 1

The general comments regarding the effect of changing parameters also holds true for all these solutions.

1) Raising the pH.	Increases efficiency. Increases purity. Decreases hardness.
2) Raising the Temperature.	Increases efficiency. Increases purity. Decreases hardness.
3) Raising the Current Density.	Decreases efficiency. Decreases purity. Increases hardness.
4) Raising the Gold Concentration.	Increases efficiency. Increases purity. Decreases hardness.
5) Raising the Cobalt Concentration.	Decreases efficiency. Decreases purity. Increases hardness.

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It should be remembered that as well as the above affecting the deposit the plant can also have a part to play regarding the deposit speed and appearance etc. The most obvious being the amount of agitation that can be provided to each cell. Generally the greater the agitation the greater the line speed due to increased current densities available due to the transportation of ions more quickly to the area of deposition.

With Brush plating heads increasing agitation (pumping the solution with a greater force) can lead to solution spread and a following larger area of deposition. This inevitably means higher gold consumptions therefore any increase in flow needs to be controlled carefully.

Examples of Field Results.

Type One.

10 – 15g/l Gold
0.9g/l Cobalt
Additive 0.5g/l
pH 4.5
Temperature 55ºC

1) Belt Cell. Wheel (10-15g/l).

2.4 microns minute with 10A/dm^2 at 4 metres minute through a 36in cell length.
4.8 microns minute with 30A/dm^2 at 6 metres minute through a 36in cell length.

2) Controlled Depth Immersion Cell (12-15g/l).

6 microns minute with 20A/dm^2 at 7 metres minute through a 24in cell length.

3) High Speed Impingement Cell.

10 microns minute with 28A/dm^2 at 10 metres minute through a 24in cell length.

4) Rotary Brush Cell. (12-15g/l)

5 microns minute with 12A/dm^2 at 6 metres minute through a 24in cell length.

12g/l Gold
0.9g/l Cobalt
Additive 0.5g/l
pH 4.5
Temperature 55ºC
Reduced salt balance ratio between citrate and oxalate

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5) Belt Cell. Wheel (12g/l) with very high agitation.

10 microns minute with 40A/dm^2 at 15 metres minute through a 39in cell length.

Type Two

12g/l Gold
1.25g/l Cobalt
Additive 2.6g/l
pH 4.6
Temperature 55ºC

1) Belt Cell. Robins & Craig.

10.2 microns minute with 29A/dm^2 at 7.62 metres minute through a 24in cell length.

2) Controlled Depth Immersion Cell.

6.75 microns minute with 19A/dm^2 at 5.02 metres minute through a 24in cell length.

3) High Speed Impingement Cell.

11.3 microns minute with 32A/dm^2 at 12.1 metres minute through a 30in cell length.

4) Rotary Brush Cell.

4.8 microns minute with 13A/dm^2 at 4.0 metres minute through a 26in cell length.

Type Three

12-15 g/l Gold
1.0 g/l Cobalt
Additive 1.0 g/l
Additive II 10ml/l
pH 4.4
Temperature 60ºC

1) Belt Cell. Wheel (12g/l).

15 microns minute with 50ASD at 4 metres minute through a 36in cell length.

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Effect of the nickel cell.

It can be seen also that the overall speed of the line can also be affected greatly by the nickel cell. Field experience has shown that the line speed and choice of gold can often be determined by the nickel cells (number and length) and the nickel process (Current Density).

As an example 8 x 750mm (6 metres total) cells are required to produce 1.5micron nickel at 15 metres minute and a current density of 15A/dm^2 (150A/ft^2). If we look to increase the line speed by using the highest plating rate solution available the plating rate for the gold will be such that 1) the current density will have to be increased in the nickel to a point where potential of burning could occur on fine point pin type connectors or 2) the CD in the gold may have to be reduced to an area where the appearance is not so aesthetic. It can be seen therefore that running a "less fast" process is actually of benefit.

Conclusions.

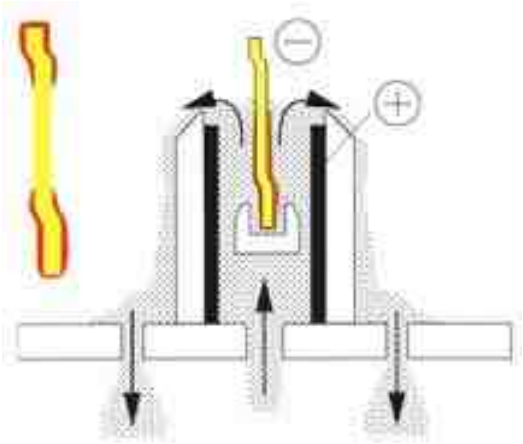
With the above gold processes currently available deposits can be directed to specific cathode areas in High Speed applications as well as in Rack and Barrel applications. These processes are well proven in field applications worldwide with varying plant designs, gold concentrations and various line speeds.

It can be seen that the length and plating conditions of the nickel cell can also have a limiting effect on line speeds and current densities.

APPENDIX 1

Selective Methods

Dip Selective Method



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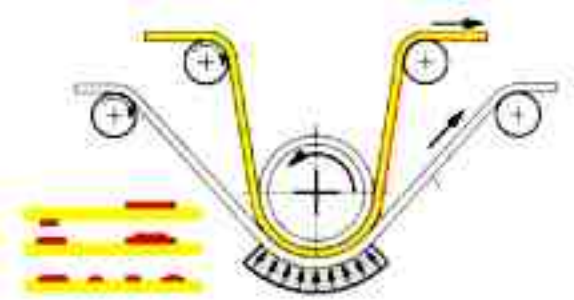
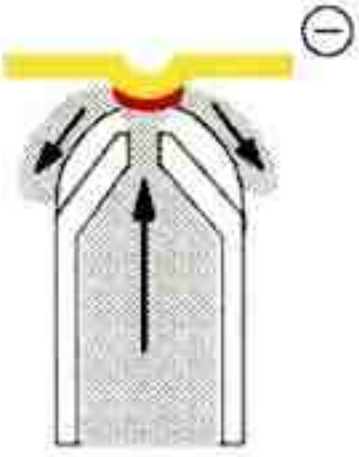
Mask Moving Belt



Impengment Method 1)

Brush Method 2)



The author wishes to thank Schempp & Decker GmbH for their kind permission in the use of the above drawings.

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APPENDIX 2

(1) Au thickness across the Hull Cell.

9 Measurements were taken across the hull cell - results as follows:

3A for 1minute at pH 4	**Temp. (ºC)**	1 (µ)	2 (µ)	3 (µ)	4 (µ)	5 (µ)	6 (µ)	7 (µ)	8 (µ)	9 (µ)
Hard Acid Gold Type 1	**60ºC**	0.71	0.65	0.67	0.66	0.64	0.60	0.56	0.48	0.40
Hard Acid Gold Type 2	**60ºC**	0.83	0.75	0.71	0.65	0.58	0.59	0.53	0.49	0.40
Hard Acid Gold Type 3	**60ºC**	1.31	1.08	0.89	0.78	0.72	0.61	0.56	0.49	0.42
Hard Acid Gold Type 1	**55ºC**	0.88	0.70	0.65	0.63	0.63	0.56	0.51	0.41	0.48
Hard Acid Gold Type 2	**55ºC**	0.74	0.58	0.65	0.61	0.59	0.56	0.49	0.43	0.44
Hard Acid Gold Type 3	**55ºC**	1.36	1.05	0.86	0.79	0.65	0.61	0.56	0.45	0.40
Hard Acid Gold Type 1	**50ºC**	0.66	0.69	0.63	0.53	0.52	0.51	0.47	0.41	0.38
Hard Acid Gold Type 2	**50ºC**	0.66	0.70	0.59	0.62	0.52	0.47	0.47	0.40	0.37
Hard Acid Gold Type 3	**50ºC**	1.43	1.16	0.94	0.81	0.68	0.61	0.50	0.45	0.42
Hard Acid Gold Type 1	**45ºC**	0.70	0.67	0.62	0.54	0.48	0.45	0.43	0.38	0.35
Hard Acid Gold Type 2	**45ºC**	0.66	0.70	0.59	0.62	0.52	0.47	0.47	0.40	0.37
Hard Acid Gold Type 3	**45ºC**	1.28	1.01	0.87	0.81	0.68	0.65	0.49	0.49	0.42
Hard Acid Gold Type 1	**40ºC**	0.65	0.63	0.56	0.53	0.48	0.45	0.43	0.38	0.34
Hard Acid Gold Type 2	**40ºC**	0.59	0.56	0.54	0.51	0.49	0.45	0.46	0.39	0.36
Hard Acid Gold Type 3	**40ºC**	1.17	0.93	0.77	0.71	0.65	0.57	0.45	0.42	0.36

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APPENDIX 3

(2) Appearance of Hull Cell - 3A for 1 minute pH 4

Gold Solution	Temperature (ºC)	Appearance of Hull Cell
Hard Gold Type 1	60	Bright to 3.0A/dm^2, dull to 7A/dm^2 and burnt above.
Hard Gold Type 2	60	Bright to 3.0A/dm^2, dull to 7.5A/dm^2 and burnt above.
Hard Gold Type 3	60	Bright to 3.0A/dm^2, cloudy above
Hard Gold Type 1	55	Bright to 1.8A/dm^2, dull to 9.0A/dm^2 and burnt above.
Hard Gold Type 2	55	Bright to 3.0A/dm^2, dull to 7.5A/dm^2 and burnt above.
Hard Gold Type 3	55	Bright to 9.0A/dm^2, cloudy above
Hard Gold Type 1	50	Bright to 3.6A/dm^2, dull to 9.0A/dm^2 and burnt above.
Hard Gold Type 2	50	Bright to 2.4A/dm^2, dull to 7.5A/dm^2 and burnt above.
Hard Gold Type 3	50	Bright to 12.0A/dm^2, dull above
Hard Gold Type 1	45	Bright to 7.5A/dm^2, dull to 12.0A/dm^2 and burnt above.
Hard Gold Type 2	45	Bright to 3.0A/dm^2, dull to 9.0A/dm^2 and burnt above.
Hard Gold Type 3	45	Bright to 12.0A/dm^2, dull above
Hard Gold Type 1	40	Bright to 7.5A/dm^2, dull to 12.0A/dm^2 and burnt above.
Hard Gold Type 2	40	Bright to 4.5A/dm^2, dull to 12.0A/dm^2 and burnt above.
Hard Gold Type 3	40	Bright to 12.0A/dm^2, dull above

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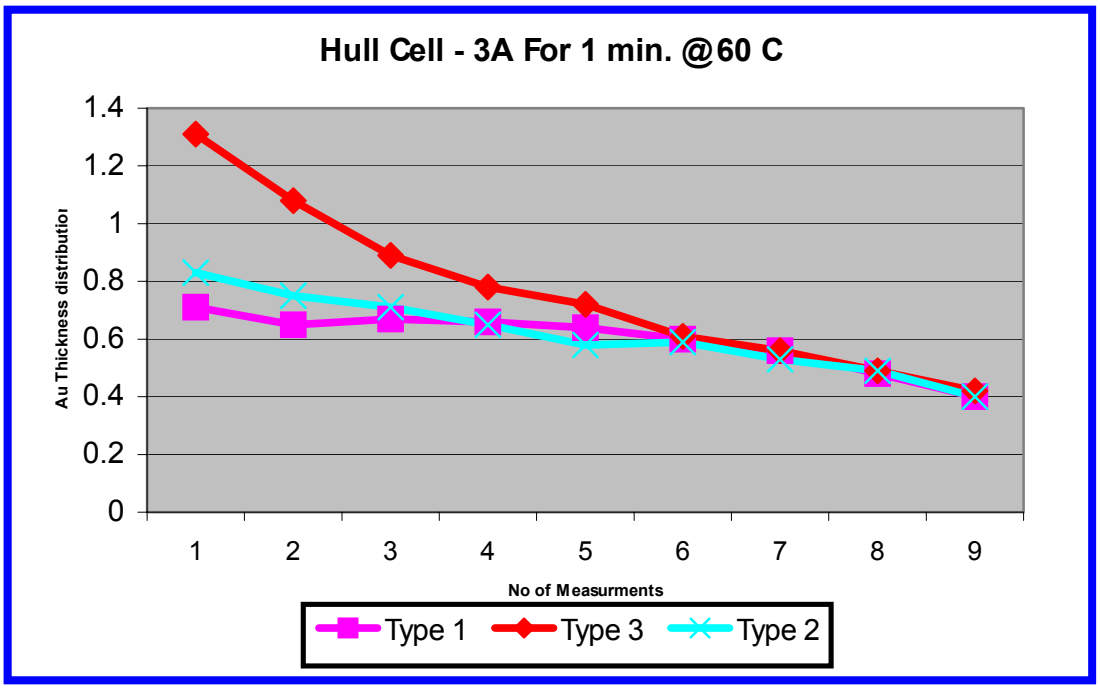
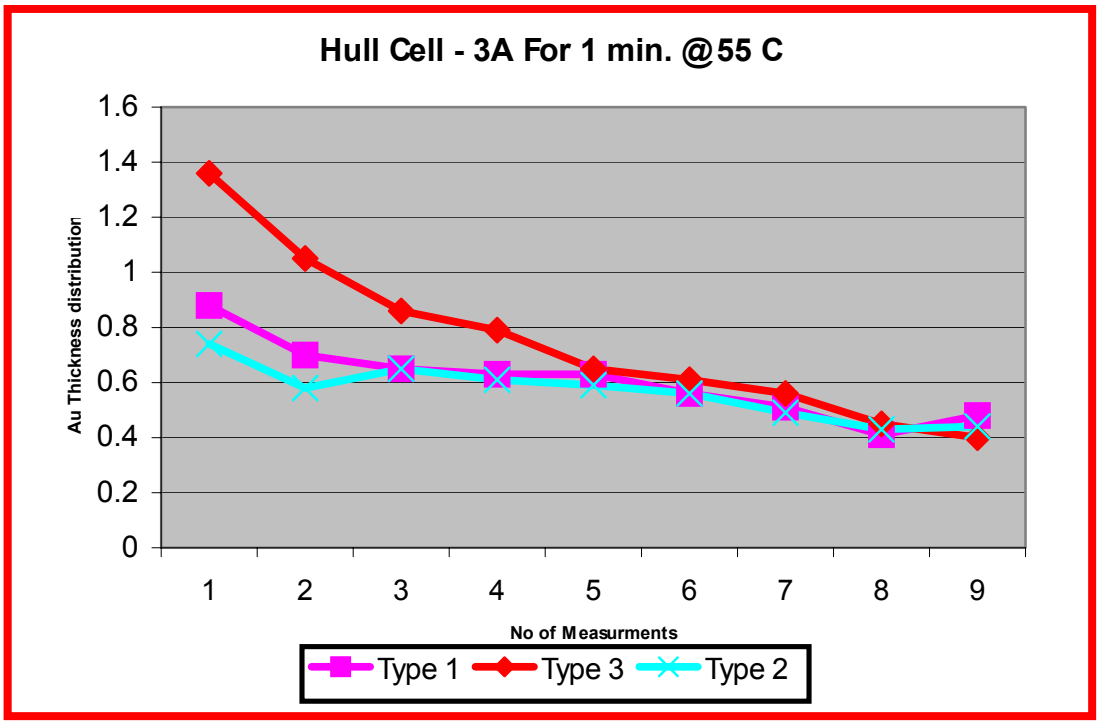
APPENDIX 4





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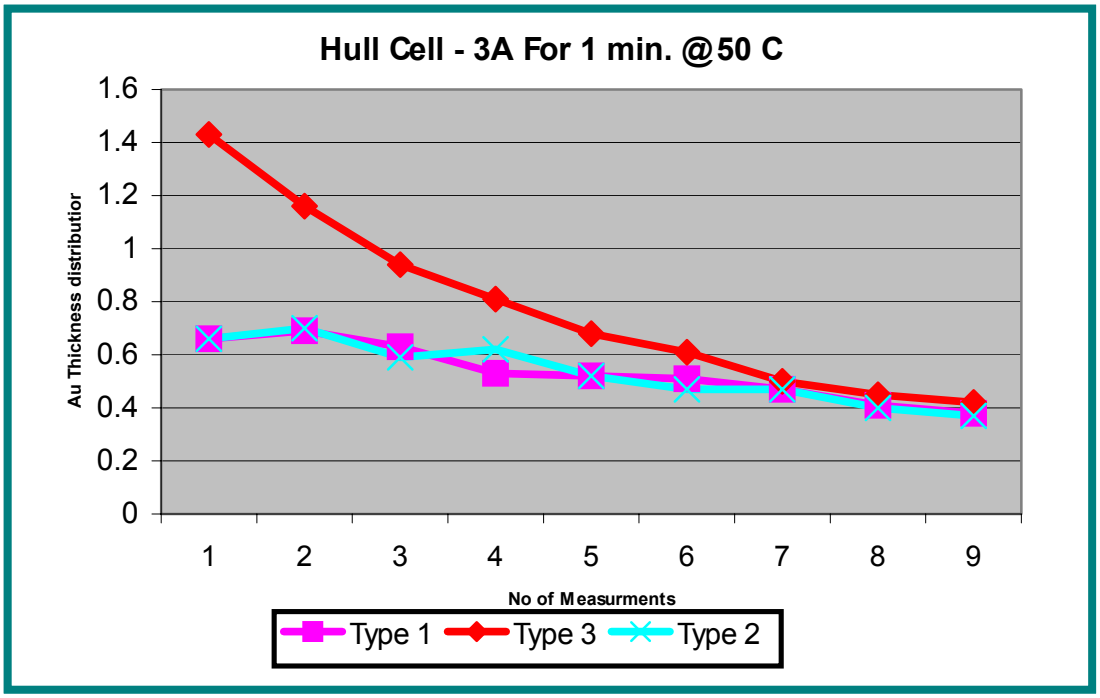
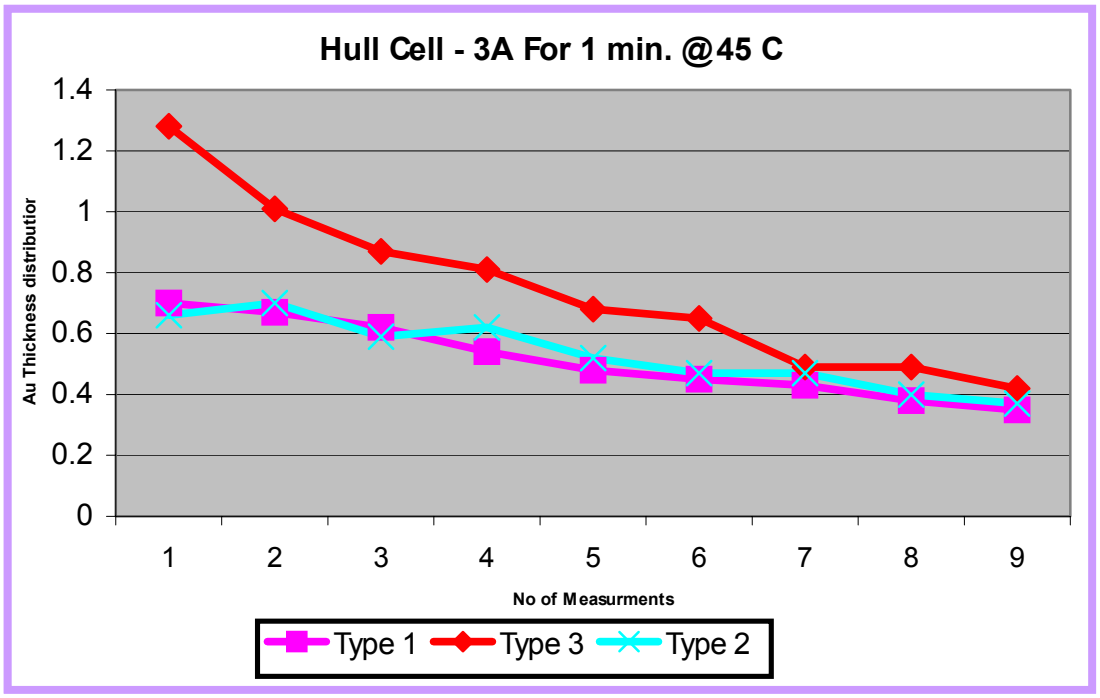

Hull Cell - 3A For 1 min. @50 C
Au Thickness distributior
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
No of Measurments
Type 1
Type 3
Type 2


Hull Cell - 3A For 1 min. @45 C
Au Thickness distributior
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
No of Measurments
Type 1
Type 3
Type 2

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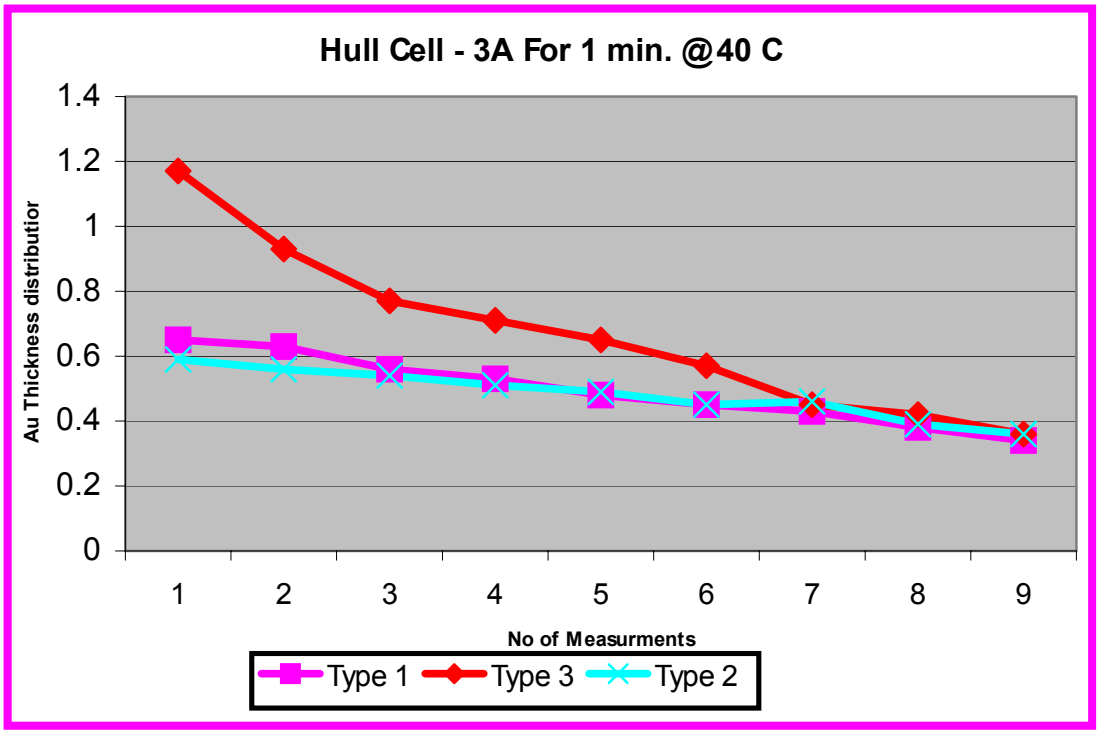
Hull Cell - 3A For 1 min. @40 C
Au Thickness distribution
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
No of Measurments
Type 1
Type 3
Type 2

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