CUPELLATION LOSS FOR GOLD AND SILVER MILLIGRAM BEADS FROM LOW GRADE MATERIAL

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RAND REFINERY

SMELTER PROCESS

PROCESS	Single site Refinery and Smelter process
	>100 different type of material throughput
	Gold range 1 to >15 000 g/t
	Silver range 1 to >27 000 g/t
	Physical Sample throughput >10 000 due to dual stream analysis

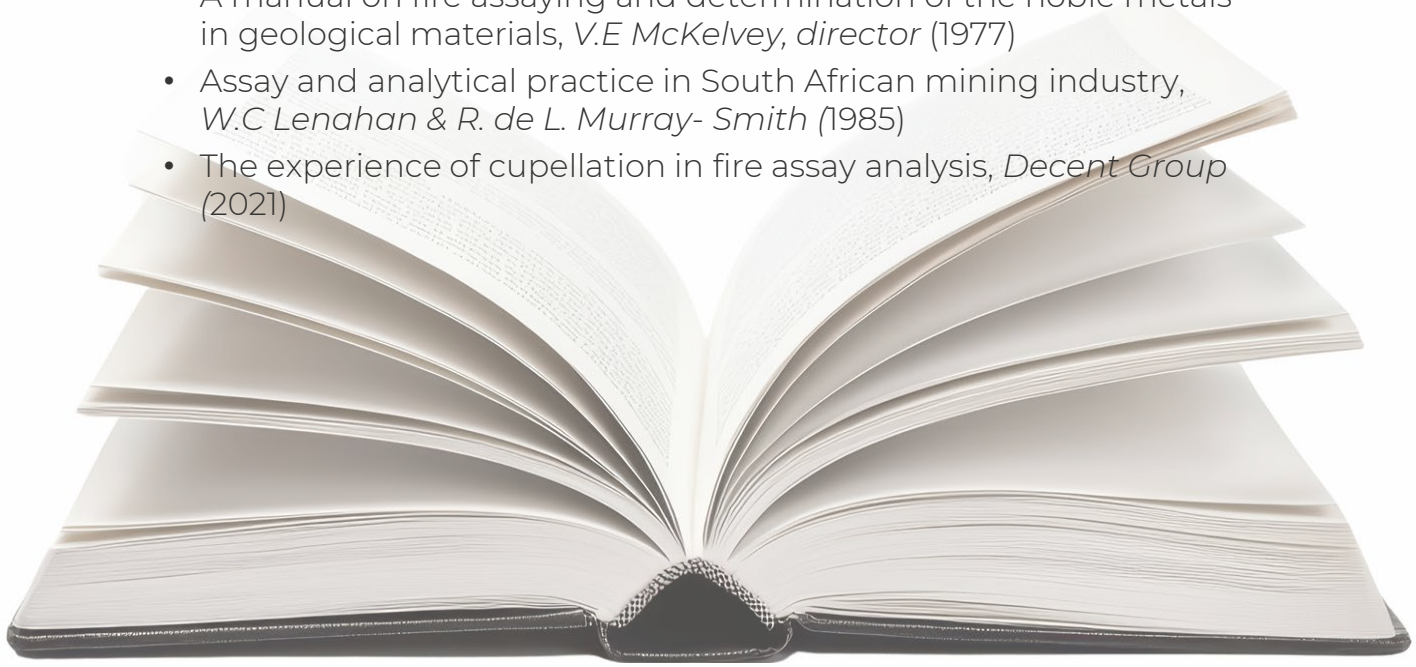
OVERVIEW

Publications since 1940

Used synthetic gold and silver alloys

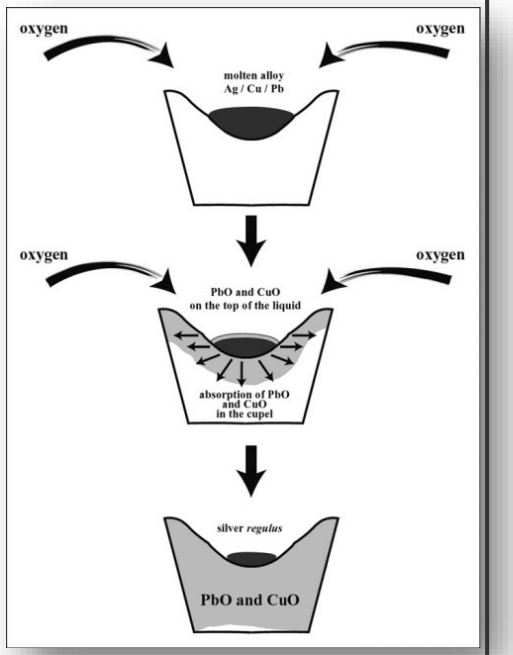
Synthetic alloy use not always feasible due to costs and time

- Controlling factors in the assay of silver by cupellation, *C.W Relly* (1940)
- An evaluation of the accuracy of the fire assay process when applied to the assay of low value residue samples, *W. A Sinclair* (1964)
- The determination of gold losses in the fire assay method, *Siegfried Gerhard Wall (*1972)
- The determination of losses in the fire assay of gold cupellation and parting losses (1973)
- A manual on fire assaying and determination of the noble metals in geological materials, *V.E McKelvey, director* (1977)
- Assay and analytical practice in South African mining industry, *W.C Lenahan & R. de L. Murray- Smith (*1985)
- The experience of cupellation in fire assay analysis, *Decent Group (*2021)



CUPELLATION PROCESS

- Heating the sample – inside preheated cupels
- Main goal - separate precious metals from lead
- Lead oxidized to molten litharge
- Molten precious metals not absorbed
- Base metals absorbed by the cupel
- Gold and other noble metals-bead



WHY LOSSES OF NOBLE METALS

- Silver is more rapidly oxidized than gold, therefore cupellation losses affects silver more than gold due to **absorption and volatilization**

- Loss of gold is less of a problem because it is **oxidised far less** rapidly than silver in normal process

"Where did my silver go?"

FACTOR AFFECTING LOSSES

- Extraction airflow
- Types of alloys
- Cupel selection
- Temperature and time control
- Analyst

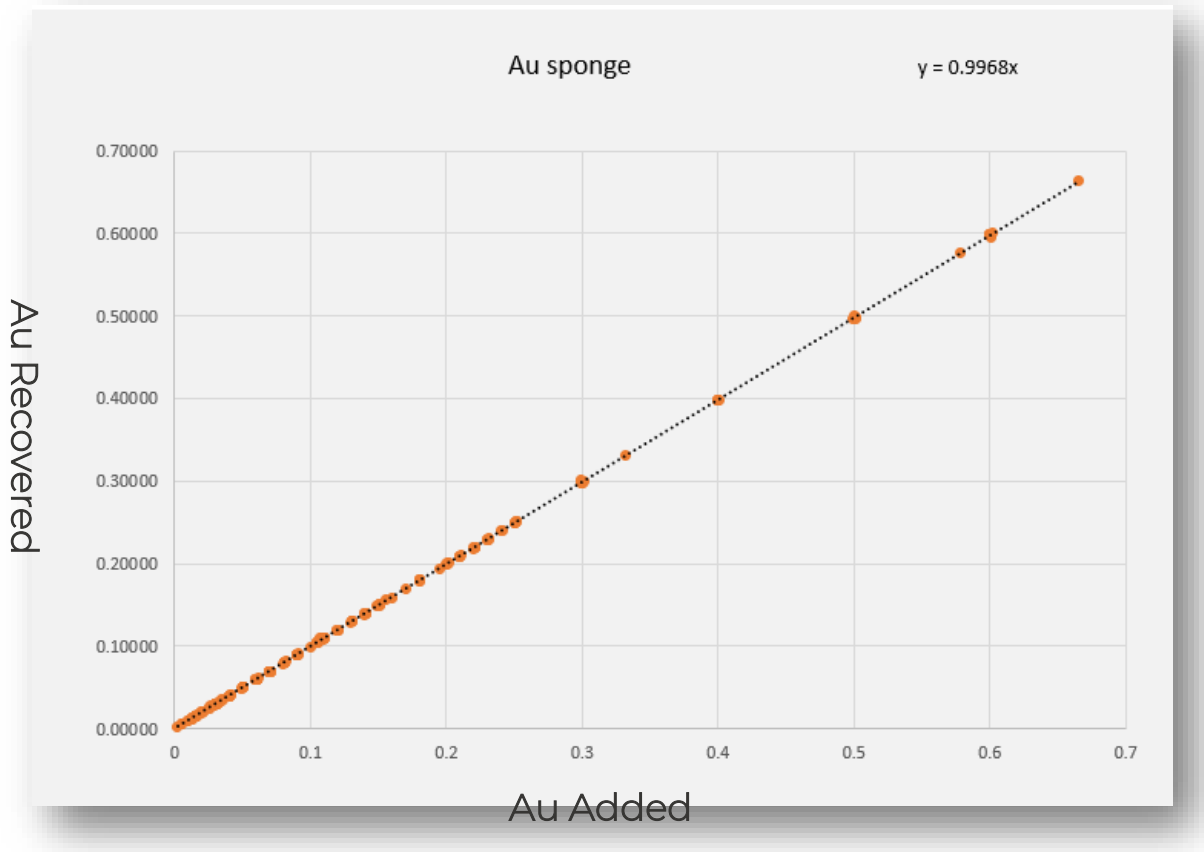
TEST PROTOCOL

The validation criteria included:

- Temperature variation (± 10°C)
- Cupel size variation (Size 9 & 10)
- Lead button mass variation (40-70g)
- Gold alloy variation (0-670mg)
- Silver alloy variation (0-2000mg)
- Addition of copper as an impurity (0-40mg)
- Different analysts and different cupellation furnace

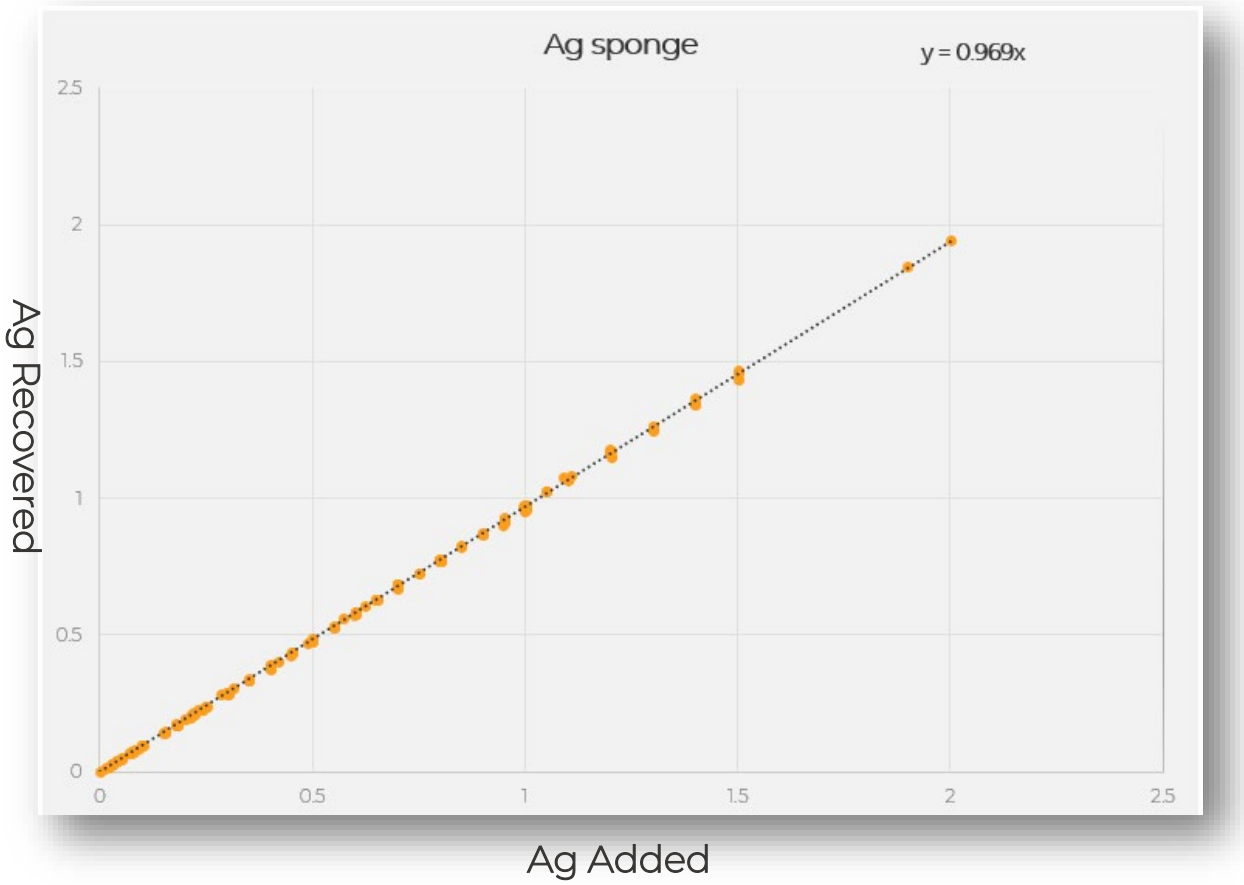
GOLD LOSSES

- Factor established within linearity of 0.9968
- Gold recovery >99.6%
- Gold recovery *did not* change significantly by adjusting the validation criteria in a controlled manner

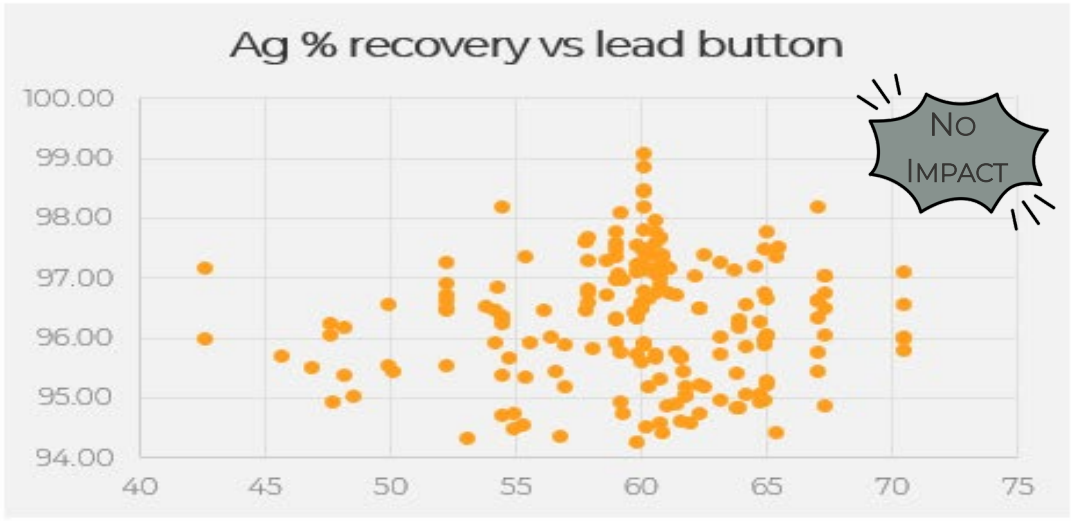


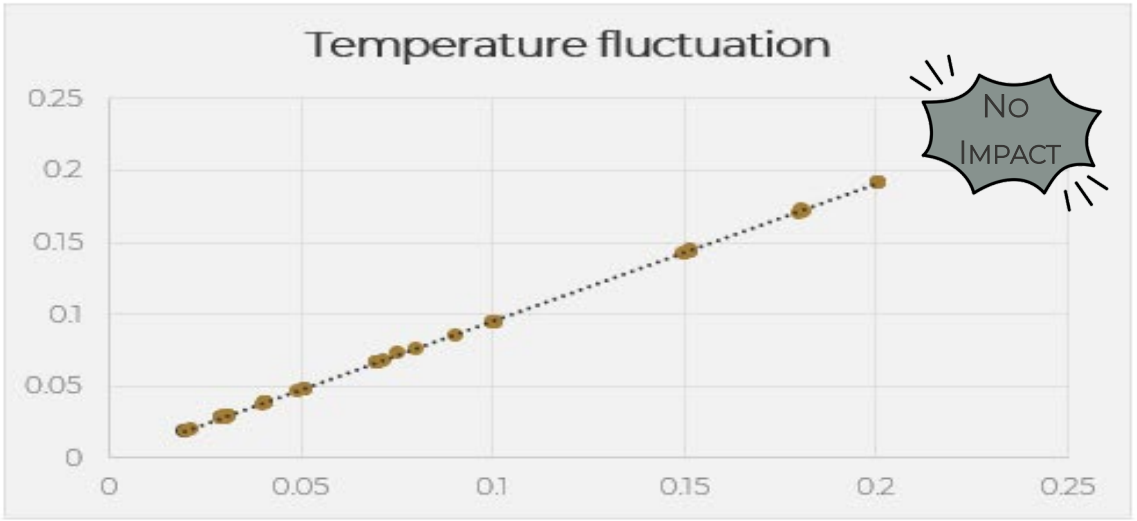
GOLD LOSSES

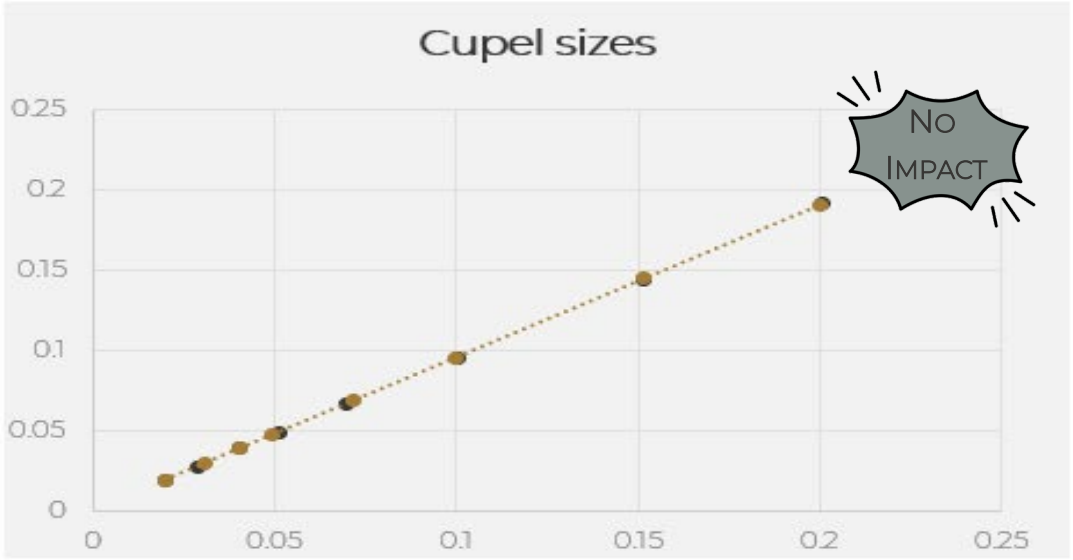
- Factor established within linearity of 0.969
- Silver recovery >96.3%
- Silver recovery *did not* change significantly by adjusting the validation criteria in a controlled manner, however the losses is more erratic and not as linear as with the gold losses

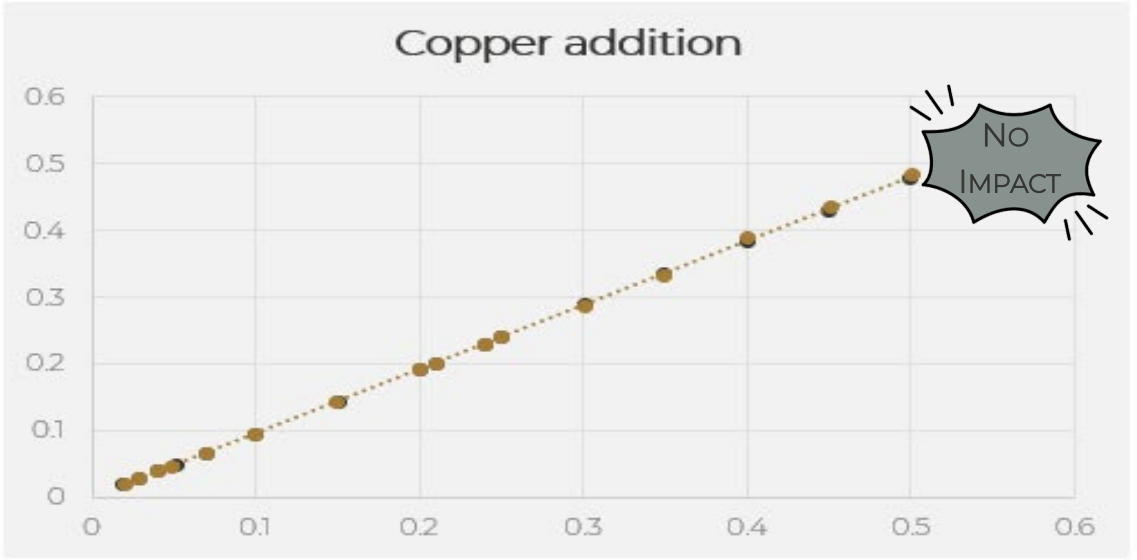


AG LOSSES DETAIL



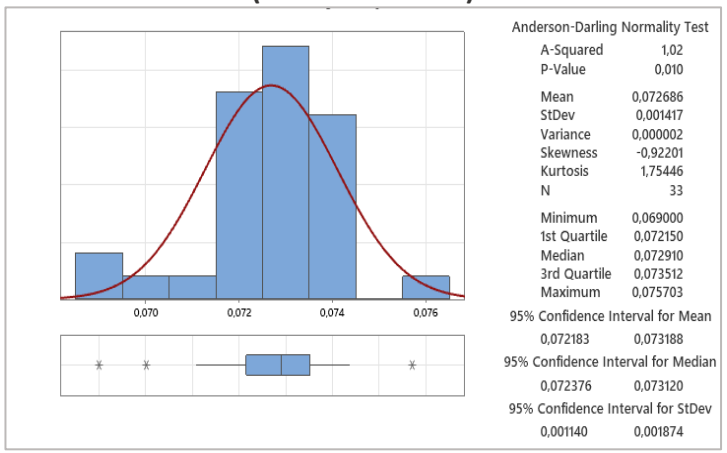






COMPARISON OF RESULTS (AU)

SUMMARY REPORT
(MULTIPLE LABS)



Anderson-Darling Normality Test

A-Squared	1,02
P-Value	0,010
Mean	0,072686
StDev	0,001417
Variance	0,000002
Skewness	-0,92201
Kurtosis	1,75446
N	33
Minimum	0,069000
1st Quartile	0,072150
Median	0,072910
3rd Quartile	0,073512
Maximum	0,075703

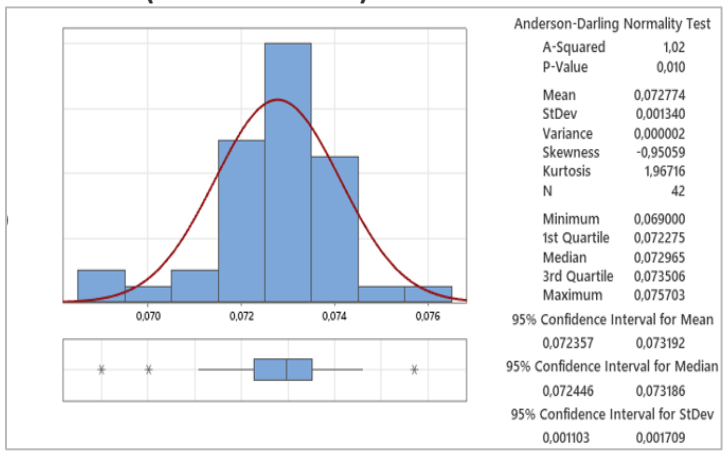
95% Confidence Interval for Mean: 0,072183 – 0,073188

95% Confidence Interval for Median: 0,072376 – 0,073120

95% Confidence Interval for StDev: 0,001140 – 0,001874

Average = 727 g/t
Z score < 1.0

SUMMARY REPORT
(MULTIPLE LABS) & NEW FACTOR



Anderson-Darling Normality Test

A-Squared	1,02
P-Value	0,010
Mean	0,072774
StDev	0,001340
Variance	0,000002
Skewness	-0,95059
Kurtosis	1,96716
N	42
Minimum	0,069000
1st Quartile	0,072275
Median	0,072965
3rd Quartile	0,073506
Maximum	0,075703

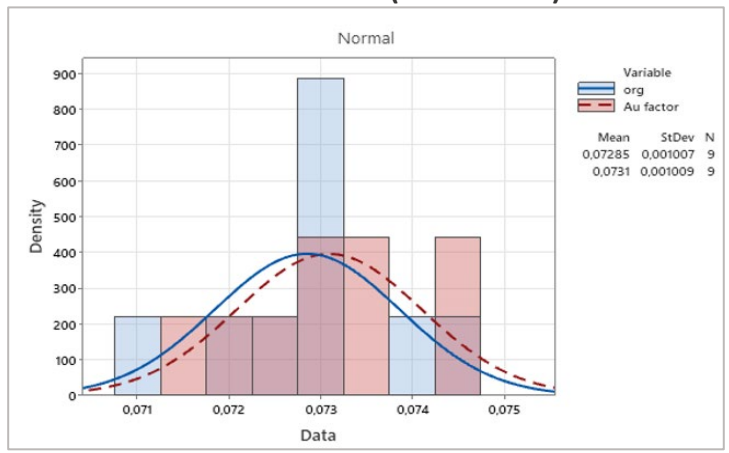
95% Confidence Interval for Mean: 0,072357 – 0,073192

95% Confidence Interval for Median: 0,072446 – 0,073186

95% Confidence Interval for StDev: 0,001103 – 0,001709

Average = 728 g/t
Z score < 1.0

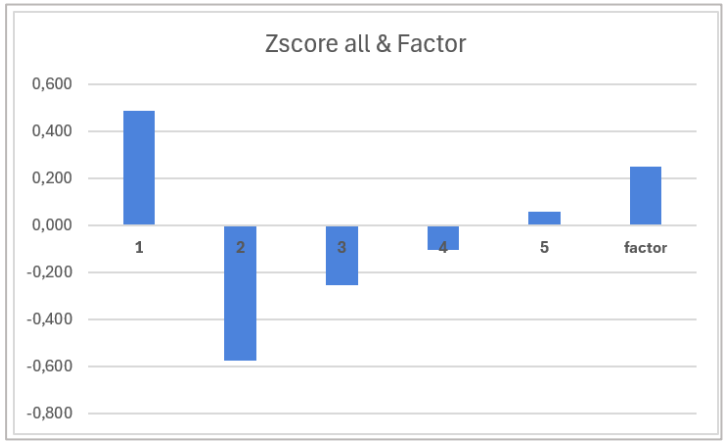
SUMMARY REPORT
ORG VS FACTOR (SINGLE LAB)



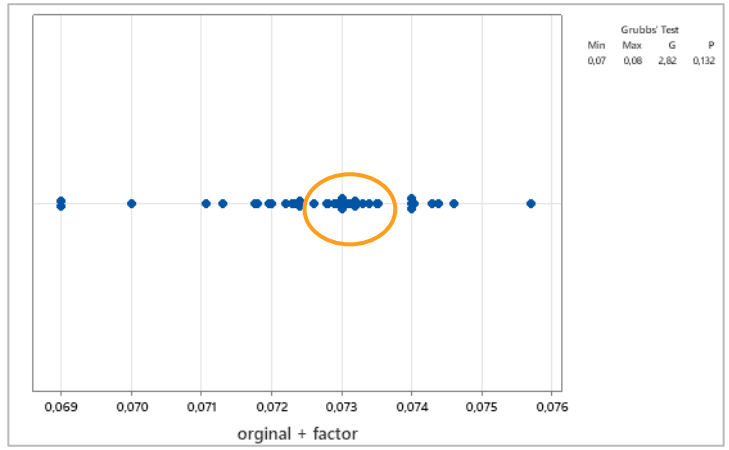
Abs diff = 2 g/t
Results = middle quadrant

Z SCORE (MULTIPLE LABS)

Z SCORE (ALL)

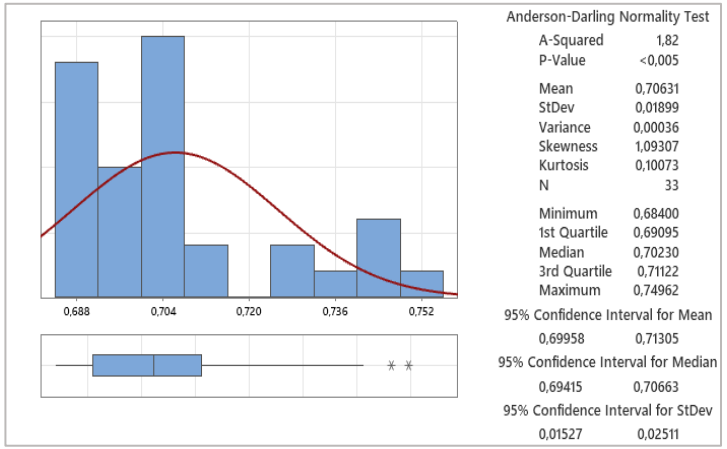


OUTLIER PLOT (ALL)



COMPARISON OF RESULTS (AG)

SUMMARY REPORT
(MULTIPLE LABS)



Anderson-Darling Normality Test

A-Squared	1,82
P-Value	<0,005
Mean	0,70631
StDev	0,01899
Variance	0,00036
Skewness	1,09307
Kurtosis	0,10073
N	33
Minimum	0,68400
1st Quartile	0,69095
Median	0,70230
3rd Quartile	0,71122
Maximum	0,74962

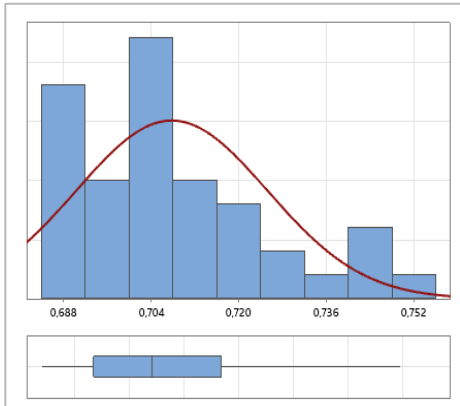
95% Confidence Interval for Mean: 0,69958 – 0,71305

95% Confidence Interval for Median: 0,69415 – 0,70663

95% Confidence Interval for StDev: 0,01527 – 0,02511

Average = 7063 g/t
Most Z score < 1.0

SUMMARY REPORT
(MULTIPLE LABS) & NEW FACTOR



Anderson-Darling Normality Test

A-Squared	1,02
P-Value	0,010
Mean	0,70781
StDev	0,01745
Variance	0,00030
Skewness	0,878739
Kurtosis	0,082542
N	41
Minimum	0,68400
1st Quartile	0,69355
Median	0,70420
3rd Quartile	0,71685
Maximum	0,74962

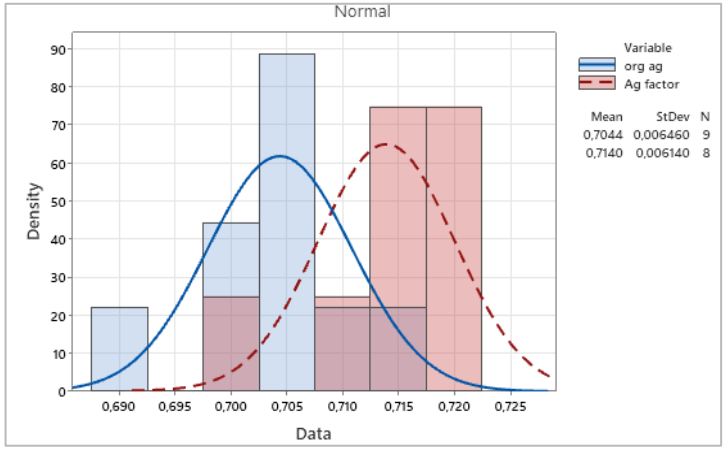
95% Confidence Interval for Mean: 0,70230 – 0,71332

95% Confidence Interval for Median: 0,69981 – 0,71218

95% Confidence Interval for StDev: 0,01433 – 0,02233

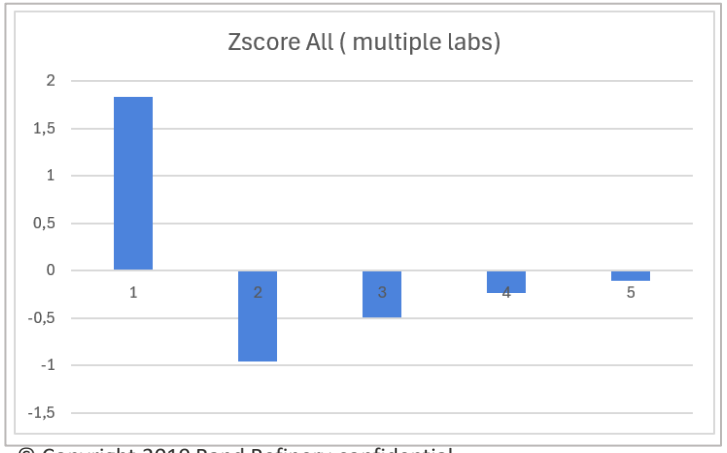
Average = 7078 g/t
Most Z score < 1.0

SUMMARY REPORT
ORG VS FACTOR (SINGLE LAB)

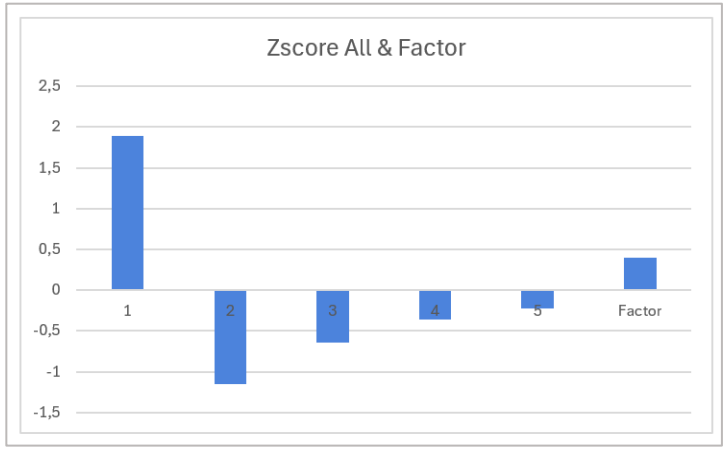


Abs diff = 96 g/t
Results = middle quadrant

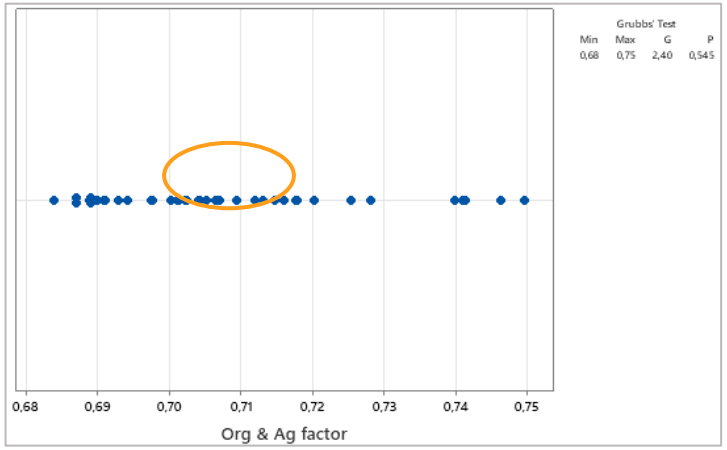
Z SCORE (MULTIPLE LABS)



Z SCORE (ALL)

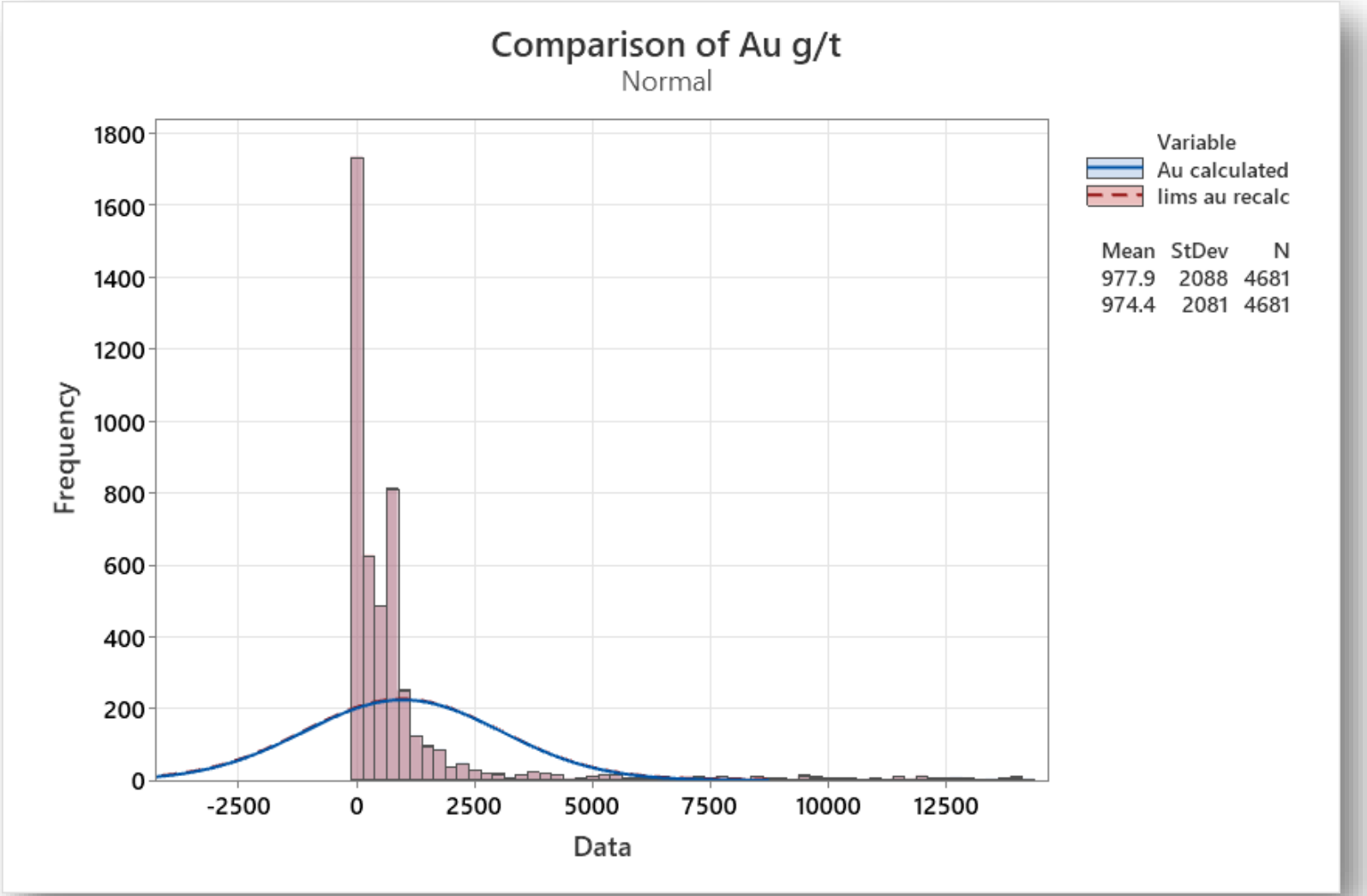


OUTLIER PLOT (ALL)



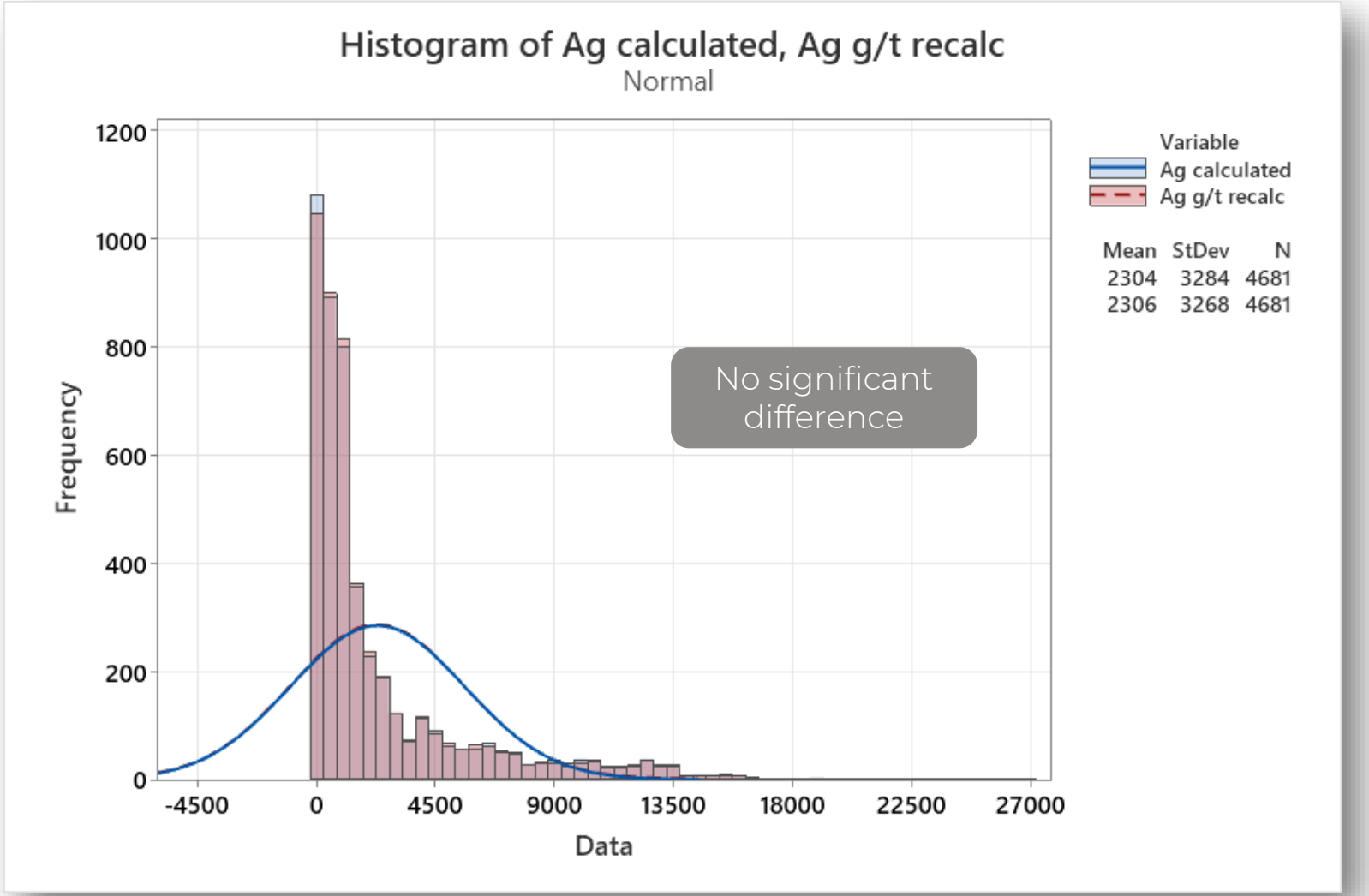
OVERALL GOLD COMPARISON

- 4681 data points
- Overall average of difference = 2.05
- Mean = 1.07
- >97% of difference lies within ±10g/t
- Au range reviewed
- 1 g/t to 14285 g/t



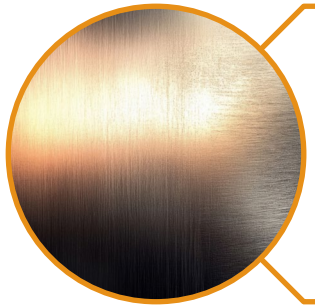
OVERALL GOLD COMPARISON

- 4681 data points
- Overall average of difference = 1.63
- Mean = 0.69
- >90% of difference lies within ± 20g/t
- Ag range reviewed
- 1 g/t to 27 100 g/t

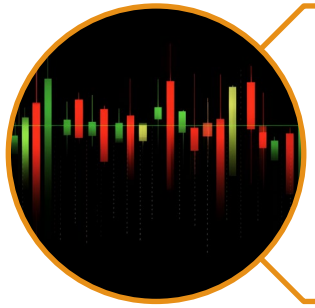


CONCLUSIONS

Within controlled process environment the combined absorption and volatilisation losses are within a linear relationship



Gold losses is significantly lower than Silver



Factor established for both Au & Ag that shows no significant difference compared to other refineries and synthetic control approach

ACKNOWLEDGEMENTS

Rand Refinery's Executive Team

Rand Refinery's Smelter assay team

Other Refineries

Praveen Baijnath
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ASAHI REFINING

ROYAL CANADIAN MINT MONNAIE ROYALE CANADIENNE

RAND REFINERY

THANK YOU