



CHROMATECHSERVICES

LEADING THROUGH TECHNOLOGY

Chromatech Accredited Laboratory Services
for the Analysis of Au & U₃O₈
ISO / IEC 17025 : 2005





X-ray fluorescence is a well established, and widely used technique for the elemental analysis of materials. However, the suitability of the technique is dependent upon the concentrations of the elements being measured. In particular, the X-ray fluorescence based instrumentation operating at photon energies below 35keV, is unable to provide sufficiently precise and rapid analyses for the extremely low concentrations of elements such as gold, uranium and platinum found in commercially viable ores. The innovative, and leading edge high energy K X-ray fluorescence (K-XRF) technology of the **AZTEC 4** analyser breaks through that barrier, and provides an instrumental technique capable of revolutionising the traditional fire assay techniques for these precious metals. Designed in conjunction with major gold mining companies, and employing the latest in electronic and computing technologies, **AZTEC 4** incorporates many major technological advances arising from years of intensive research and development since the instrument was introduced in 1987.

Advantages of K-XRF

This innovative, automated, high capacity assay technique is capable of:

- Providing precise, reliable and rapid analyses to support responsive decision making.
- Reduces sample preparation costs time and labour.
- Gold & uranium results are obtained simultaneously further reducing sample preparation and analysis time.
- Reduced charge out cost to client per analysis.
- Built-in automated analysis of quality control standards without destroying the integrity of the standards used.
- Offers retraceability of results with easy and fast conformation (LIMS).
- Faster turnaround time of sample results to the client.

Service Applications

The fast turnaround service provided by Chromatech Services have many benefits and make it well suited for numerous applications in the gold mining and mineral processing industry. The most common of these are:

Mining

- Grade control samples for mining control and ore reserve evaluation.
- Conveyor belt sample analyses for ore accounting and operational control purposes.
- Checks on assays to swiftly verify unexpected results or provide rapid support for key management decisions.
- Offers service to establish representativeness of sampling using clients existing sampling systems, techniques and laboratory sample preparation equipment.

Exploration

- Screening of geological and exploration samples to optimise assay information and costs.

Mill/Plant Operations

- Gold bearing carbon samples for control of the carbon-in-pulp process. Samples only require drying, and can be analysed to precisions of the order of 3% in under a minute.
- Gold plant or mill head samples for process monitoring and gold accounting

Commercial Laboratories

- Chromatech has the capacity to take on overflow work from commercial laboratories requiring gold & uranium and platinum analysis.
- The analysis method is of a non-destructive nature. Chromatech is able to assist in testing the homogeneity of higher grade standards with free gold particles. Gold in carbon standards can be prepared in granulated or in pulverized form.

The K-XRF Technique

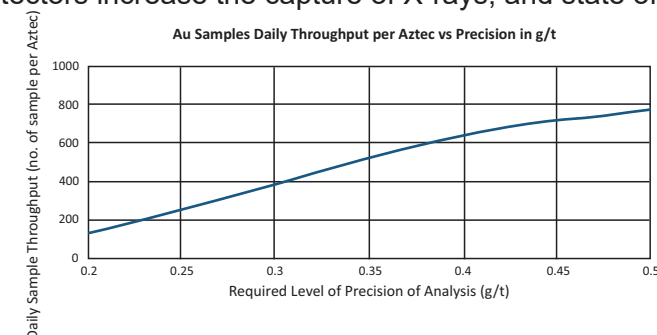
AZTEC 4 uses the well-known energy dispersive X-ray fluorescence technique to measure the concentrations of gold, uranium and other high atomic number elements.

X-ray fluorescence works on the basis of irradiating a sample of material with a beam of primary X-rays. The interaction of the X-rays with the elemental atoms in the sample causes secondary X-rays to be emitted by these atoms; a process known as X-ray fluorescence. The energy levels of the secondary X-rays are

characteristic of the emitting element, and the numbers emitted are proportional to the concentration of the element present in the sample. Conventional, low energy XRF instruments are typically limited to surface analyses, and elemental concentrations down to 10ppm. At these levels the uncertainty in the result arising from the statistics of radiation counting becomes significant.

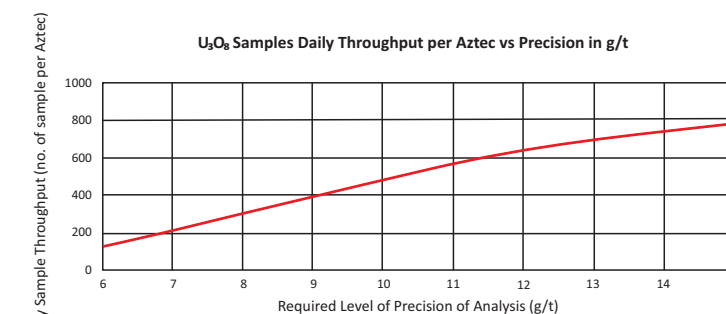
In contrast to conventional X-ray spectrometer systems, **AZTEC's** primary X-rays excite the high energy characteristic K X-rays of gold and platinum.

By virtue of using more penetrating, higher energy photons, a greater volume of sample is analysed, and the effects of sample preparation, presentation, and elemental interferences on accuracy are either minimised or greatly simplified. Multiple X-ray detectors increase the capture of X-rays, and state of



the art electronics allow X-ray counts of up to 750,000 counts per second per detector element, a factor of several times greater than conventional designs. The combination of effects ensures far lower levels of uncertainty in the result, and allows reliable measurements of elemental concentrations to below 1ppm.

The statistics of X-ray counting means that, the longer the counting period adopted, the better the absolute precision of a single measurement. This relationship allows the user to trade off precision against instrument throughput according to the sample type and the information required. Further flexibility in throughput is available by analysing sample batches, either to an absolute level of precision, or to a selected percentage precision.:



Au Analytical Precision (ppm)	Nominal Counting Time (seconds)	Nominal Daily Instrument Throughput
0.5	100	777 samples per day
0.4	120	648 samples per day
0.3	200	388 samples per day
0.2	600	129 samples per day

AZTEC Performance Specifications @ 1sd

U3O8 Analytical Precision (ppm)	Nominal Counting Time (seconds)	Nominal Daily Instrument Throughput
15	100	777 samples per day
12	120	648 samples per day
9	200	388 samples per day
6	600	129 samples per day

Benefits

The benefits that **AZTEC** can provide to both mining and commercial assay laboratories are considerable

- Accurate, precise, reliable and rapid assaying of powdered ore samples. **AZTEC** is capable of analysing ore grades in the range 0.5g/t to 500g/t, and a substantial body of experimental evidence demonstrates it to be in the above mentioned range as accurate and reliable as ICP MS and fire assay for the determination of gold.

Specific advantages over fire assay procedures include:

- The direct measurement of gold as opposed to bullion concentration, saving the costs of expensive silver parting techniques.
- The lower potential for error due to human intervention in the assay process.
- Reduced sampling error from analysing at least 50g to 60g of sample.
- Reduced errors from mineralogical and matrix element effects.
- **AZTEC** is an automated, high throughput, cost effective analytical instrument requiring little space and the minimum of supervision.
- X-ray analysis provides environmental and health advantages by eliminating the significant dangers from lead pollution inherent in fire assay.

Other potential pollution hazards inherent to fire assay are eliminated; including mercury and arsenic, driven off from the sample during heating as well as boron and fluoride compounds, present in the fluxing reagents.

- **AZTEC** power consumption of 15kW is a small fraction of that required for fire assay furnaces. The health hazards and unpleasant working environment associated with high temperature furnace operations are also eliminated.
- Highly flexible in meeting changing operating conditions. Samples can be analysed to any selected level of precision by varying the analysis time, so trading off throughput against level of confidence. Routine analyses can readily be interrupted for urgent assays with minimal disruption to the laboratory.
- Sample preparation is simple and inexpensive. No costly chemical reagents, consumable items or processing are required. Samples are presented to the X-rays in plastic tubes as dry powders, ground to less than 100µm. No pressing of powders is required.
- Operation of **AZTEC** is simple and training of new operators requires only 2 to 3 days.
- “Lost” assays are eliminated due to the non-destructive nature of the process and automatic, user defined, quality control of sample loading and instrument stability is incorporated into the operating software.
- The instrument configuration can be customised to meet specific customer requirements regarding speed, precision and price. Instrument configurations can also be easily upgraded to suit changing circumstances.
- **AZTEC** can be integrated into a wider automated network, and into a computerised laboratory information management systems (LIMS).

Principal of Operation

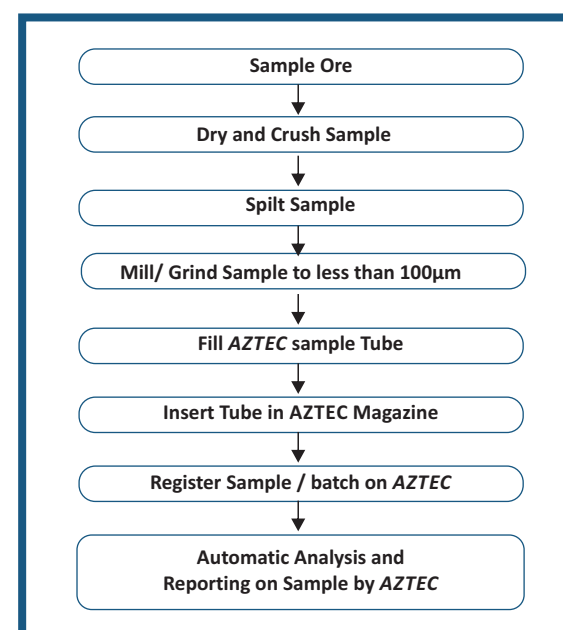
Sample preparation consists simply of grinding the dry sample to less than 100µm, and filling an 84cm³ sample tube. This provides about 100g of sample. Sample tubes are loaded into magazines which are inserted into the instrument. Samples tubes are automatically taken from their magazines, in turn, by a robot and inserted into the X-ray chamber. Approximately 50g to 60g of sample is irradiated by a primary X-ray beam to promote the secondary fluorescence. The resultant X-rays are detected and processed by an innovative proprietary system of solid state detectors and electronics. No residual radiation remains in the samples and they can be safely analysed further by **AZTEC** or other analytical techniques.

Data processing and control is effected by a personal computer employing the Windows operating system. The operational software is user friendly and allows considerable flexibility in:

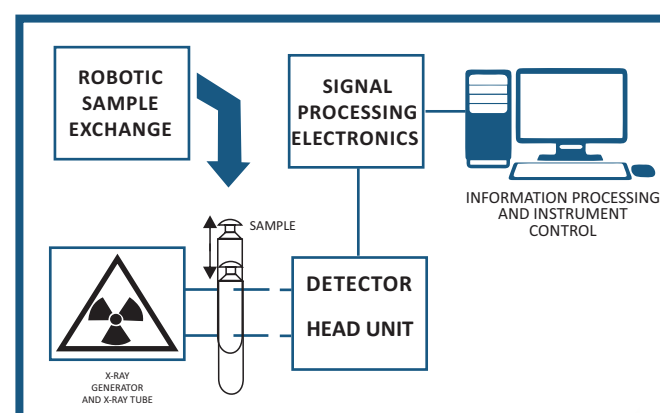
- How individual samples or batches of samples are registered for analysis.
- Specifying the analytical parameters for samples or sample batches.
- Specifying the automatic quality control systems required.
- Customising management reports.

The operation is designed to be continuous over a 24 hour period. No time is lost for calibration, as this takes place automatically while samples are being changed. Fault diagnosis is computerised and data-logged to facilitate maintenance and minimise down-time.

Chromatech Services (Pty) Ltd can provide guidance in the selection of appropriate counting time vs. precision to prospective clients where costs are known upfront and well defined.



System Description



- Sample transport module:- comprising automatic sample changing robotics with a capacity for up to 528 samples, extendible to 792 samples.
- Sample X-ray module:- incorporating an X-ray generator, and 160kV tungsten anode X-ray tube and chiller unit.
- Signal (X-ray) detector module:- comprising pure germanium solid state detectors housed in a vacuum and cooled by either liquid nitrogen, or a helium based cryo-electric cooling system
- Signal processing module:- pulse shaping and counting electronics housed in a temperature stabilised cabinet.
- Data processing module:- the latest specification compatible PC, Super VGA colour monitor, and printer.

Technical Support

All repairs are carried out by Chromatech Services(Pty) Ltd and no need for expensive service contracts all analytical costs are included in the sample charge out cost to the client.

In case of power outages a diesel back-up generator prevents the instrument from shutting down and reporting of results is not affected.

Servicing is assisted by the comprehensive fault diagnostic data logging system built into the operating software.

Specifications

Technique:

X-ray fluorescence using K X-rays for the simultaneous measurement of the gold and uranium content of powdered ore samples.

X-ray Detector Head Unit:

X-ray detector head unit containing innovative, high resolution, solid state detectors, cooled with liquid nitrogen to give optimised signal/background ratio.

Signal Processing Electronics:

Rack mounted Euro-card format for ease of servicing. Temperature stabilised to eliminate variations in results due to the effect of ambient temperature changes on the electronic components.

Sample Exchange:

Basic 6 dock configuration has a capacity of 528 samples. The capacity of the extended 9 dock

configuration is 792 samples. Each dock holds one magazine capable of containing 88 samples in an 8 x 11 array.

X-ray Module:

160kV HV Generator and X-ray tube with water chiller.

Power Supply:

10/20kVA single phase uninterruptible power supply, with a nominal 10 minute battery back up at full load, fed from 220/110 VAC 10%, 50/60Hz single phase supply. 66kVA Diesel back-up generator feeds the UPS and air-conditioning systems during power outages.

Computer:

Latest specification compatible PC, colour SVGA monitor, and laser printer. **AZTEC's** operating and control system employs the Windows operating environment.

Range:

Gold in Ore 0–500 ppm; Uranium 0-12,000 ppm.

Gold in Carbon 0–12,000 ppm.

Analytical Precision / Sample Throughput:

Dependent upon design configuration.

Accuracy/Bias (excluding interference effects):

Gold: Zero bias (100,000s count) better than 0.03 ppm. Sensitivity accuracy (100,000s count) better than 1% of gold value.

Specifications are invalid for elemental concentrations above 0.3%Pb, 60%Fe₂O₃, 2%U₃O₈. This would fall outside of the present calibration range.

[Chromatech Services (Pty) Ltd reserve the right to change the instrument specifications at any time, without notice.]

Contact



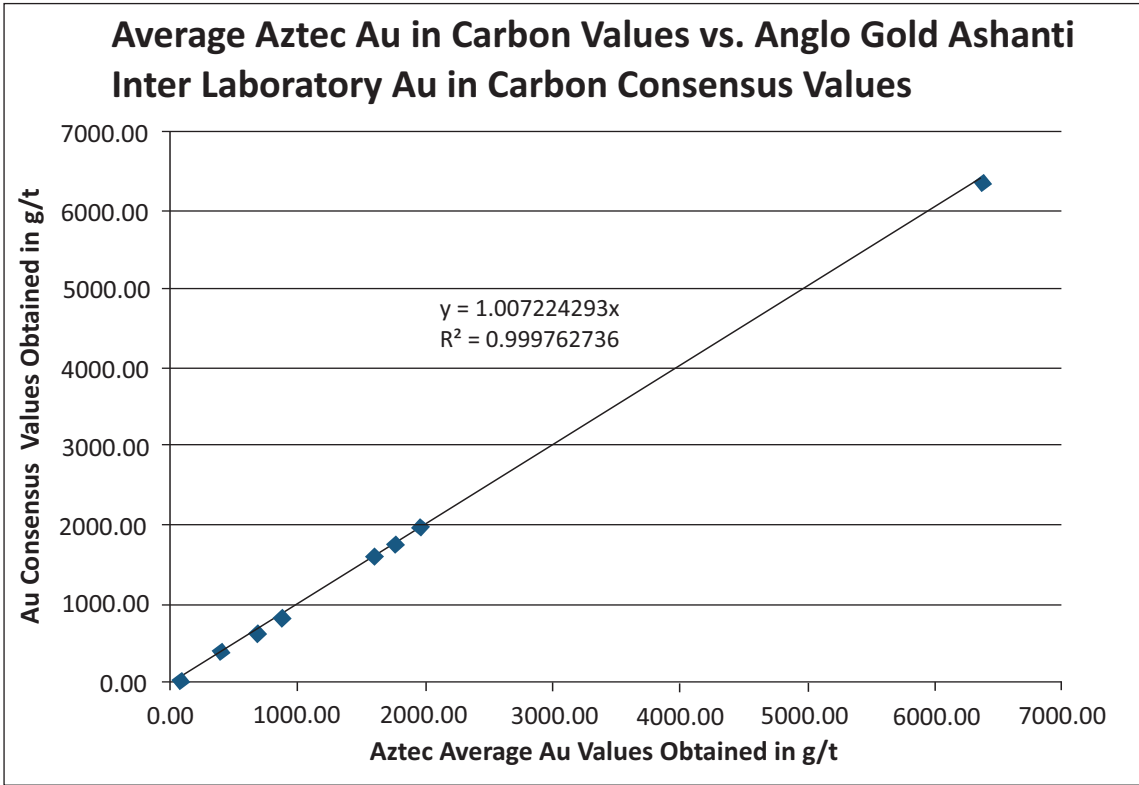
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Anglo Gold Ashanti Inter Laboratory Proficiency Testing - Round Robin Results:

Round Robin	Sample Type	Aztec Value g/t	Consensus Value g/t
Results Quarter 4 - 2012	Loaded Carbon	6356.9	6368.7
Results Quarter 1 - 2013	Loaded Carbon	851.7	848.5
Results Quarter 2 - 2013	Loaded Carbon	1939.0	2007.6
Results Quarter 3 - 2013	Loaded Carbon	1748.3	1786.8
Results Quarter 4 - 2013	Loaded Carbon	1593.4	1647.1
Results Quarter 4 - 2012	Eluted Carbon	67.7	61.2
Results Quarter 1 - 2013	Eluted Carbon	671.7	670.3
Results Quarter 2 - 2013	Eluted Carbon	49.7	51.0
Results Quarter 3 - 2013	Eluted Carbon	76.6	75.2
Results Quarter 4 - 2013	Eluted Carbon	381.6	414.7

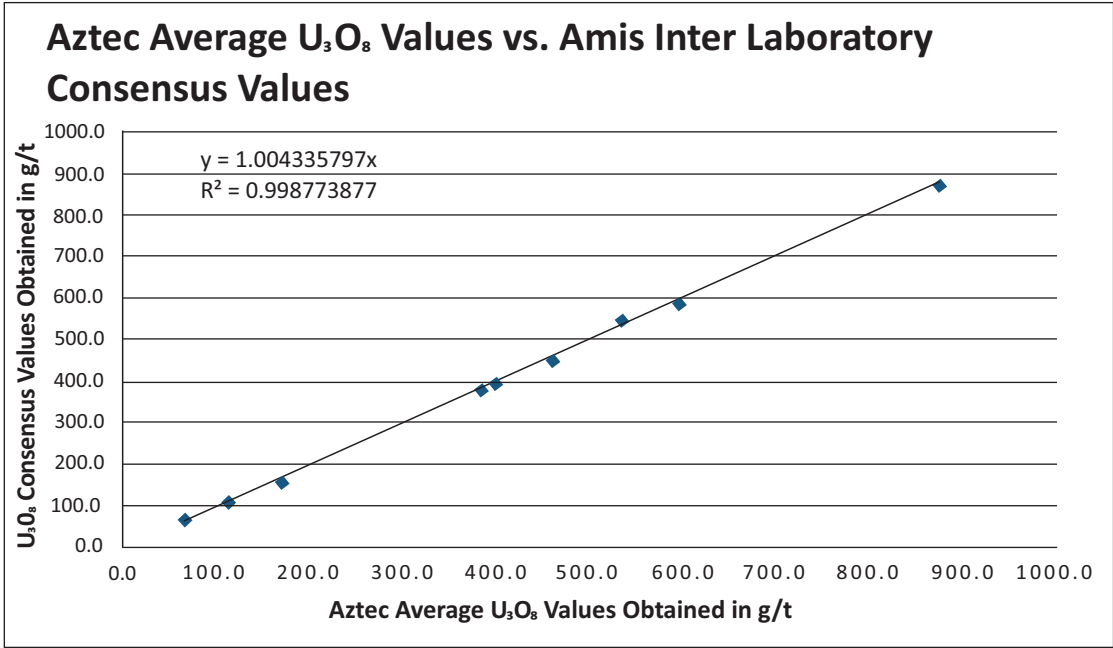
The following graph depicts the average Aztec Au in Carbon values obtained vs. the Anglo Gold Ashanti Inter Laboratory Consensus Values:



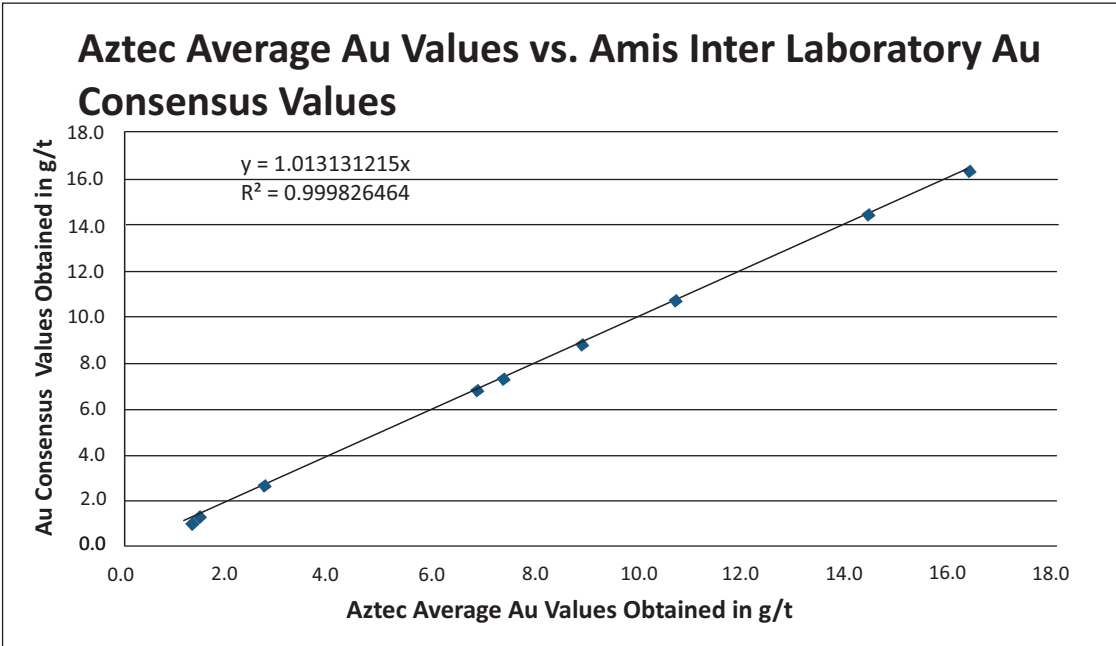
AMIS Inter Laboratory Proficiency Testing - Round Robin Results:

Amis CRM	Aztec	Consensus	Aztec	Consensus
Description	U ₃ O ₈ value in g/t	U ₃ O ₈ value in g/t	Au value in g/t	Au value in g/t
Amis0167	552.0	533.0	7.3	7.3
Amis0184	878.3	872.7	14.5	14.3
Amis0191	451.4	461.1	10.8	10.6
Amis0210	158.6	169.8	1.1	1.3
Amis0203	600.8	596.7	16.4	16.3
Amis0094	110.4	112.0	2.7	2.7
Amis0208	67.4	64.9	1.4	1.4
Amis0244	386.4	384.5	6.9	6.8
Amis0303	393.9	402.0	8.9	8.8

The following graph depicts the average Aztec U₃O₈ value obtained vs. the AMIS Inter Laboratory Consensus Values:



The following graph depicts the average Aztec Au value obtained vs. the AMIS Inter Laboratory Consensus Values:



Linearity Tests:

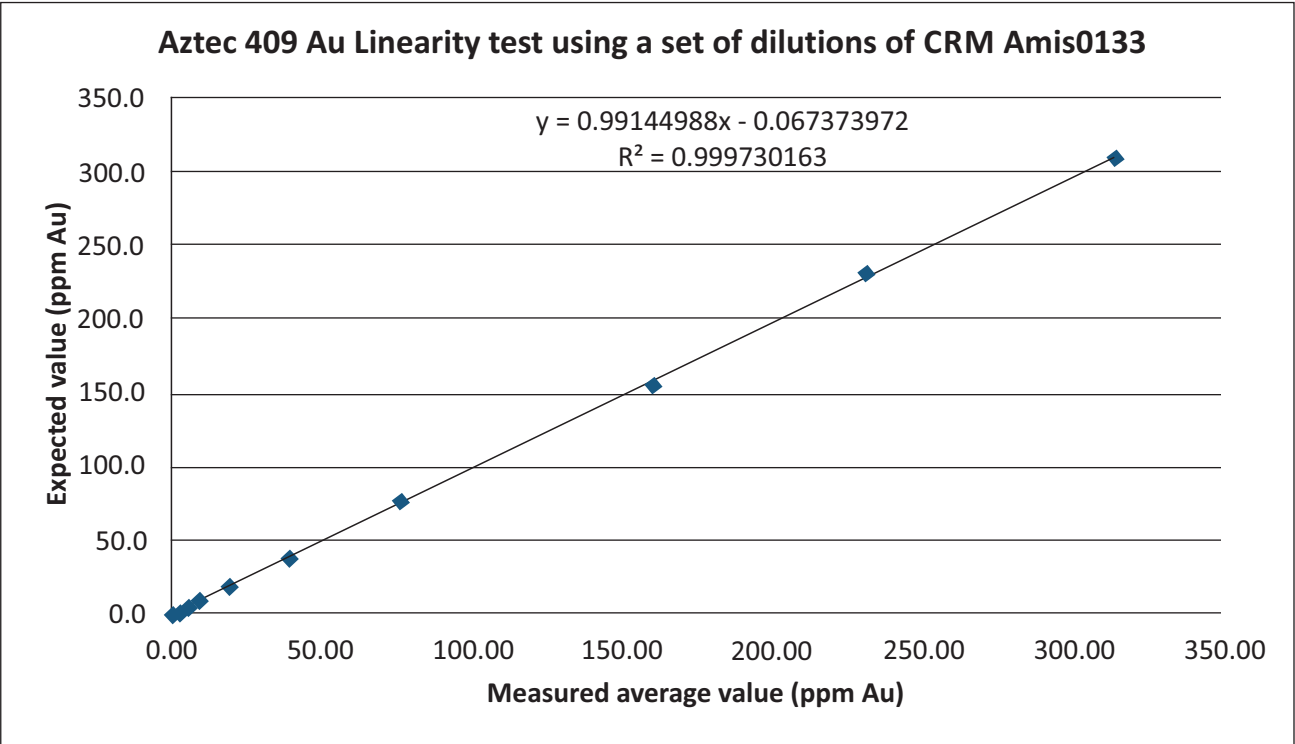
CRM AMIS0133 was used to make up a set of 13 samples using the method of standard additions. The first sample in the series is undiluted AMIS0133 (310 ppm Au & 3918 ppm U₃O₈), followed by successive dilutions in silica. Each sample was mixed by milling in a LM2 ring mill for 5 minutes, and then poured into a measurement tube. Each sample was measured 10 times for 600 seconds. The expected values and the average of the measurements are given in the table on the following page.

AZTEC 411 Au Linearity test Utilizing AMIS0133

Sample no.	CRM AMIS0133 mass	Silica mass	Expected value	Aztec average	Standard deviation
	%	%	ppm Au	ppm Au	ppm Au
1	100.000	0.000	310.00	312.88	0.67
2	75.000	25.000	232.50	231.36	0.36
3	50.000	50.000	155.00	158.55	0.26
4	25.000	75.000	77.50	74.50	0.21
5	12.500	87.500	38.75	37.92	0.18
6	6.250	93.750	19.38	18.68	0.13
7	3.125	96.875	9.69	8.70	0.20
8	1.563	98.438	4.84	4.59	0.20
9	0.781	99.219	2.42	3.32	0.21
10	0.391	99.609	1.21	1.81	0.26
11	0.195	99.805	0.61	0.84	0.19
12	0.098	99.902	0.30	0.49	0.18
13	0.049	99.951	0.15	0.15	0.18
Statistics	R-squared			0.99977	
	R			0.99988	
	Correlation coefficient			0.99988	
	Slope (intercept=0)			0.99497	

- The statistical data proves a near perfect linear relationship.

The comparative data is shown graphically in the following chart.

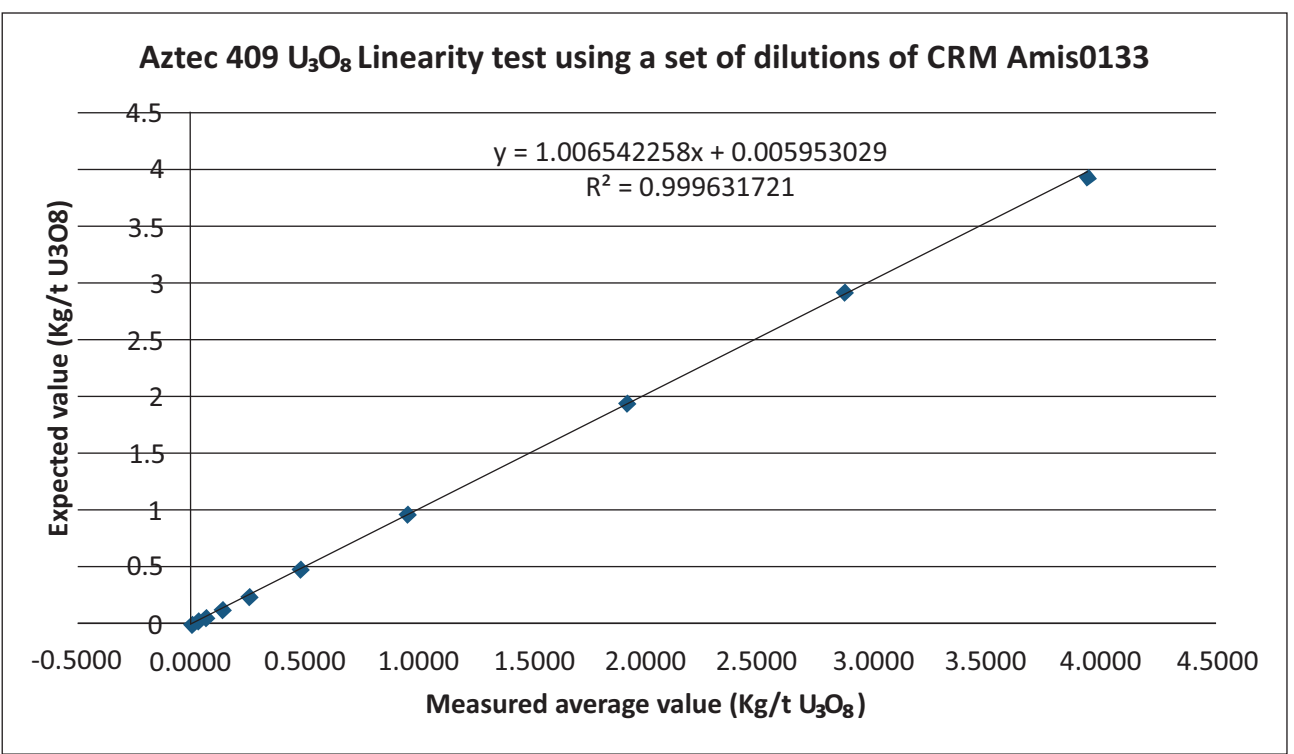


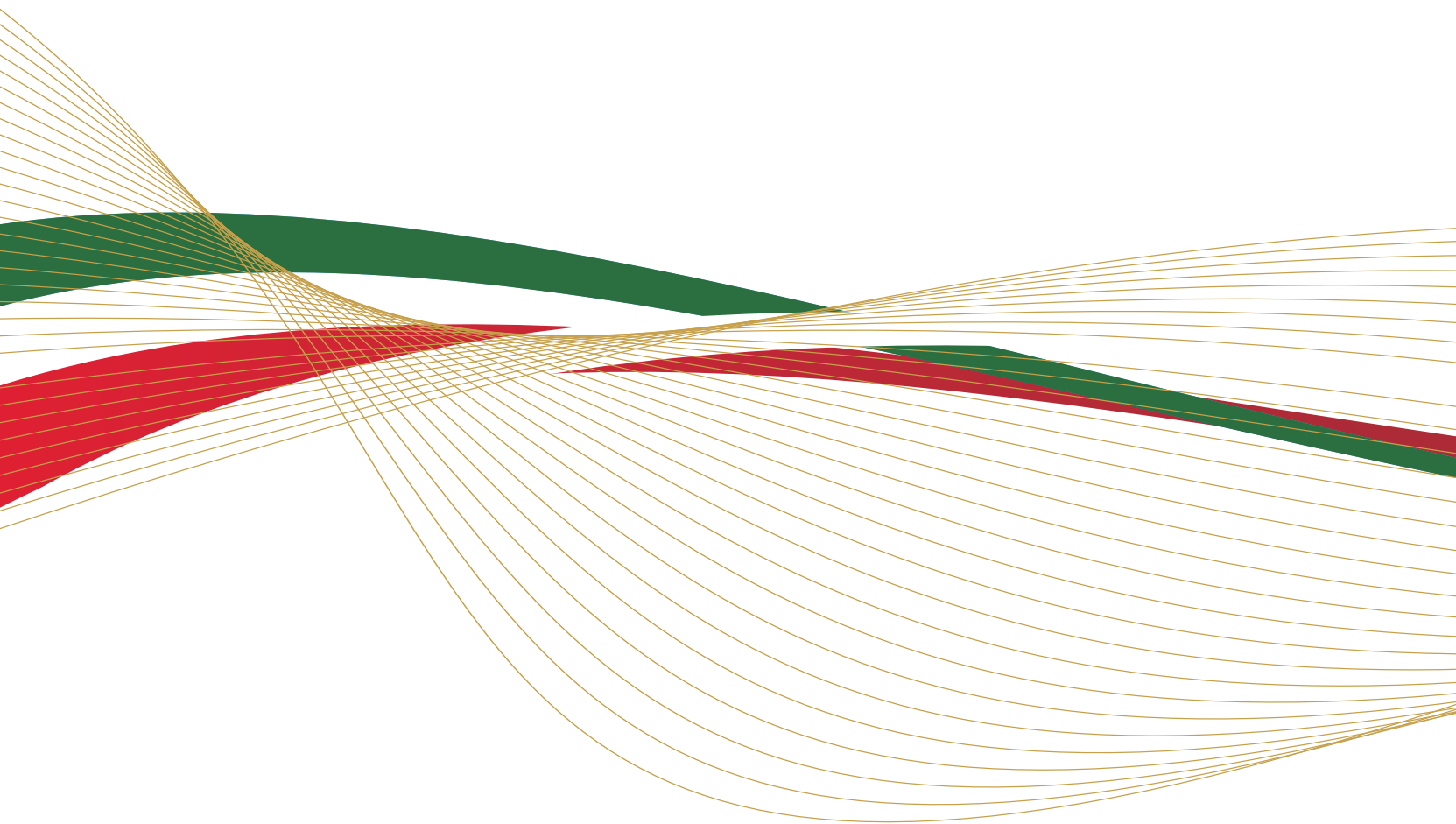
AZTEC 409 U₃O₈ LINEARITY TEST Utilizing AMIS0133

Sample no.	CRM AMIS0133 mass	Silica mass	Expected value	Aztec average	Standard deviation
	%	%	Kg/t U ₃ O ₈	Kg/t U ₃ O ₈	Kg/t U ₃ O ₈
1	100	0	3.918	3.942	0.008
2	75	25	2.939	2.864	0.015
3	50	50	1.959	1.909	0.006
4	25	75	0.980	0.946	0.010
5	12.5	87.5	0.490	0.477	0.005
6	6.25	93.75	0.245	0.244	0.005
7	3.125	96.875	0.122	0.122	0.006
8	1.563	98.438	0.061	0.059	0.006
9	0.781	99.219	0.031	0.035	0.004
10	0.391	99.609	0.015	0.015	0.007
11	0.195	99.805	0.008	0.007	0.005
12	0.098	99.902	0.004	0.005	0.007
13	0.049	99.951	0.002	0.000	0.008
Statistics	R-squared			0.99963	
	R			0.99982	
	Correlation coefficient			0.99982	
	Slope (intercept=0)			1.00875	

- The statistical data proves a near perfect linear relationship.

The comparative data is shown graphically in the following chart.





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