

## QOTHO CERTIFIED REFERENCE MATERIAL (QCRM)

### QCRM-1-185

#### FERROCHROME

#### CERTIFICATE OF ANALYSIS

CERTIFIED VALUES			
ANALYTES	UNITS	CONCENTRATIONS	EXPANDED UNCERTAINTY
Al	%	0.38	±0.03
C	%	6.66	±0.04
Co	%	0.054	±0.002
Cr	%	52.14	±0.08
Fe	%	33.88	±0.19
Mn	%	0.28	±0.01
Ni	%	0.172	±0.002
P	%	0.017	±0.002
S	%	0.042	±0.002
Si	%	3.43	±0.04
Ti	%	0.29	±0.01
V	%	0.30	±0.01
ASSIGNED VALUES (FOR INFORMATION ONLY)			
ANALYTES	UNITS	CONCENTRATIONS	EXPANDED UNCERTAINTY
Mg	%	0.33	±0.04

**1. Use:**

QCRM-1-185 is a certified reference material which is suitable for use as random control samples in routine analytical laboratory quality control, when inserted within a batch of samples and measured in parallel to the unknown. The QCRM can also be used as a control sample in the analysis of samples of a similar type, verification of analytical methods for Ferrochrome (Chrome Metal) and as a calibration standard for the calibration of equipment used for analysing similar materials.

**2. Origin of Material:**

This material was sponsored by ARM Machadodorp, South Africa.

**3. Mineral and Chemical Composition:**

The material is not naturally occurring, but it is a product of Pyrometallurgical processing of the chromite ore or foundry sand to yield a ferrochrome alloy. From the molten alloy state, this sample is cast and crushed into a lump size product of <2mm in size. The alloy has main phases of (Cr,Fe)<sub>7</sub>C<sub>3</sub>, (Cr,Fe)<sub>23</sub>C<sub>6</sub>, traces (Fe,Cr)<sub>3</sub>C carbides, Cr containing α-Fe, Cr-Si and traces of S, P, along with minor (<0,5%) amounts of Mn, V, Ti - all species are present in alloy form.

**4. Date of Initial Issue:**

29 April 2022.

**5. Packaging & Handling instructions:**

The material was packaged as 100g unit sizes, placed in geo-envelopes, within a vacuum sealed aluminum foil bag. Open the seal of the foil with care and shake or otherwise agitate prior to use. Normal safety precautions for handling fine particulate matter are recommended, such as the use of safety glasses, breathing protection, gloves, and a laboratory coat. Once opened, material must be stored in a cool, dry environment. Results on page 1 is presented on dry basis. Analysis should therefore be done on dry basis, after drying to constant mass, at 105 degrees Celsius.

**6. Method of Preparation:**

The material was sieved through a 75-micron screen and the oversize was re-milled to ensure 100% passing through the screen. It was then blended, systematically divided, and packaged into 100-gram zip-lock bags. Randomly selected samples, from the bags, were tested in-house via XRF, to confirm homogeneity. Once confirmed and certification completed, the items were placed in geo-envelopes and vacuum sealed in aluminium foil bags.

**7. Methods of Analysis used:**

- Sodium peroxide fusion with ICP-OES finish
- Multi-acid digestions with ICP-OES finish
- Chrome & Iron by sodium peroxide fusion with Potentiometric Titration
- Phosphorous by perchloric digestion and UV-VIS finish
- Fused beads with XRF finish
- Pressed pellet with XRF finish
- Carbon & Sulphur by combustion analysis.

**8. Analysis required:**

An instruction letter was sent to all participants. The analysis required was noted in the instruction letter and reporting template, including but not limited to Al, C, Co, Cr, Fe, Mg, Mn, Ni, P, S, Si, Ti and V.

**9. Participating Laboratories:**

NO	LABORATORY	COUNTRY
1.	AHK North West	South Africa
2.	AHK Richards Bay	South Africa
3.	ALS Inspection Richards Bay	South Africa
4.	ALS Inspection UK	United Kingdom
5.	ARM Machadodorp	South Africa
6.	Columbus Analytical Lab	South Africa
7.	Cotecna Richards Bay	South Africa
8.	Glencore Boshhoek	South Africa
9.	Glencore Lion	South Africa
10.	Glencore Rustenburg Smelter	South Africa
11.	Glencore Wonderkop Smelter	South Africa
12.	Mitra SK South Africa	South Africa
13.	Outokumpu	Finland
14.	PCL Rustenburg	South Africa
15.	PCL Steelpoort	South Africa
16.	RC Inspection SA	South Africa
17.	Samancor Dikwena	South Africa
18.	Samancor Ferrometals	South Africa
19.	Samancor TCS Laboratory	South Africa
20.	Samancor Tubatse Alloy Smelter	South Africa
21.	Samancor Tubatse Chrome	South Africa
22.	SGS Netherlands BV	Netherlands
23.	SGS Richards Bay	South Africa
24.	Zimasco Kwekwe	Zimbabwe
25.	Zimbabwe Alloys Chrome	Zimbabwe

**10. Assay Data:**

Data used for Assigning Values and Certification.

LABORATORY	Al	C	Co	Cr	Fe	Mg	Mn	Ni	P	S	Si	Ti	V
UNIT	%	%	%	%	%	%	%	%	%	%	%	%	%
LAB001						0.335							
LAB002		6.598	0.054	52.255	33.598	0.425	0.287	0.174	0.02	0.041	3.486	0.351	0.316
LAB003				52.333									
LAB004	0.442	6.61	0.056		34.37		0.285	0.192	0.017	0.042	3.35	0.33	0.305
LAB005				51.935									
LAB006	0.313	6.697	0.054		33.078		0.281	0.175		0.044	3.402	0.292	0.3
LAB007				52.345									
LAB008		6.705			33.755		0.29	0.173	0.017	0.046	3.36	0.302	0.301
LAB009				52.205									
LAB010		6.605				0.123			0.021	0.043			
LAB011	0.35	6.63	0.054	52.13			0.28	0.17		0.04	3.46	0.275	0.295
LAB012				52.17									
LAB013		6.645	0.054	51.885	34.06		0.277	0.172	0.017	0.043	3.44	0.295	0.303
LAB014				52.085									
LAB015		6.673	0.054	52.152	33.872		0.285	0.17	0.018	0.038	3.395	0.295	0.311
LAB016				52.189									
LAB017		6.655	0.053	51.805	34.31	0.31	0.27	0.16	0.02	0.04	3.21	0.295	0.32
LAB018				51.79									
LAB019	0.415			52.215	33.815	0.38	0.285				3.475	0.29	0.31
LAB020				52.24									
LAB021	0.398	6.745	0.055		34.18		0.29	0.175	0.017	0.043	3.37	0.31	0.305
LAB022				51.93									
LAB023	0.38	6.65	0.054	51.8	33.95		0.285	0.175	0.017	0.042	3.35	0.3	0.31
LAB024		6.615		50.83	33.3				0.018	0.044	3.39		
LAB025				50.64									

LABORATORY	Al	C	Co	Cr	Fe	Mg	Mn	Ni	P	S	Si	Ti	V
UNIT	%	%	%	%	%	%	%	%	%	%	%	%	%
LAB026		6.64	0.054	52.203	33.572	0.262	0.285	0.168	0.016	0.038	3.292	0.284	0.3
LAB027	0.442	6.655		52.11	34.065				0.021	0.039	3.395		
LAB028						0.29							
LAB029	0.17	6.525		52.34		0.325		0.151	0.011	0.035	3.45	0.29	
LAB030	0.365	6.69	0.055	52.025	34.17		0.29	0.17	0.019	0.044	3.455	0.305	0.305
LAB031	0.291		0.055		33.368		0.276	0.173	0.018			0.302	0.303
LAB032				52.415									
LAB033		6.61			35		0.297		0.013	0.04	3.46		
LAB034				51.9									
LAB035				52.55							3.595		
LAB036	0.414	6.634	0.05	52.195	33.679	0.313	0.296	0.175	0.017	0.042	3.417	0.293	0.314
LAB037	0.38	6.77		52.18	34.04	0.368	0.29	0.172	0.017		3.44	0.285	0.29
LAB038					34.18	0.365	0.287				3.565	0.3	0.3
LAB039				52.235									
LAB040	0.415	6.615		52.675	34.38				0.013	0.04	3.38		
LAB041	0.422		0.052	52.281	33.695	0.299	0.293	0.172	0.017		3.479	0.291	0.308
LAB042	0.43	6.765		52.14	34.72	0.26	0.27		0.02	0.05		0.31	0.31
LAB043	0.36	6.604	0.056	52.23	33.992		0.28	0.175		0.042	3.4		0.3
LAB044				52.196									
LAB045	0.374	6.48					0.272		0.015	0.045	3.26		
LAB046				52.1									
LAB047	0.411	6.715	0.053		33.665		0.295	0.165	0.018	0.042	3.38	0.29	0.285
LAB048				51.995									
LAB049	0.365	6.755	0.054	52.095	33.725		0.285	0.19	0.018	0.042	3.445	0.285	0.295
LAB050				51.99									
LAB051	0.414	6.725	0.053		33.995		0.267	0.171	0.018	0.041	3.44	0.295	0.3
LAB052				52.31									
LAB053	0.379	6.67	0.052		33.55		0.285	0.175	0.017	0.042	3.4	0.29	0.28

LABORATORY	Al	C	Co	Cr	Fe	Mg	Mn	Ni	P	S	Si	Ti	V
UNIT	%	%	%	%	%	%	%	%	%	%	%	%	%
LAB054				52.4									
LAB055	0.305	6.6		51.985	34.07	0.311	0.253	0.146	0.017	0.04	3.475	0.168	
LAB056				52.1									
LAB057	0.342		0.054		33.987		0.281	0.172		0.043	3.397	0.295	0.307
LAB058				52.285									
LAB059	0.335		0.054				0.275	0.169	0.019			0.295	0.298
LAB060				52.305									
LAB061		7.002	0.053	52.422	33.971	0.435	0.281	0.172	0.015	0.045	3.529	0.314	0.306
LAB062				52.175									
LAB063		6.615	0.054	52.06	33.65		0.283	0.171	0.015	0.042	3.46	0.292	0.3
LAB064				51.96									
LAB065		6.576	0.055	53.28	34.12	0.339	0.291	0.175	0.019	0.043	3.441	0.297	0.305
LAB066				53.2									
LAB067		6.589	0.053	51.918	33.864		0.29	0.168	0.02	0.042	3.497	0.302	0.304
LAB068				52.007									
LAB069		6.67	0.051	51.771	35.575	0.103	0.278	0.169		0.042	3.609	0.28	0.289
LAB070				51.85									
LAB071	0.37		0.05		32.75	0.32	0.285	0.17	0.02	0.035	3.34	0.285	
LAB072	0.371	6.935	0.049	52.212	33.644	0.319	0.306	0.189	0.016	0.049	3.516	0.275	0.298
LAB073		6.835			32.66	0.349	0.254	0.163		0.043	3.59	0.285	0.284
LAB074				52.185									
LAB075				52.35									

## 11. Method of Certification:

### QM is a SANAS Accredited Proficiency Testing Scheme Provider, No. PTS0012

This material was distributed as test items, in the Qotho Chrome PT Round 1 of 2021 and Round 1 of 2022. The participating laboratories were each given 1 randomly selected sample from the batch, to analyse and report on in duplicate. Some laboratories reported results via more than one analytical method. Obvious blunders were resolved with the laboratories (if any), after which the data was processed using Robust Statistics, through PROLab Plus.

Not all the participating laboratories were accredited. Historical performance in Qotho PT Schemes, as well as an evaluation of the CRM QA/QC data generated by the laboratories, during the analysis of this QRM, were considered, to evaluate the competence of laboratories. Where competence could not be confirmed, the affected data was deselected from the dataset. Certification of analytes was then done, provided that a minimum of 10 qualifying datapoints remained available.

Where analytes could not be certified, estimate concentrations were assigned, using all the data in the dataset.

## 12. Measurement of Uncertainty:

Standard uncertainty,  $u_{CRM}$ , was calculated according to ISO 13528:2015 (equation 6), and it includes the effects of uncertainty due to inhomogeneity, transport, potential instability, and laboratory uncertainty. Because of all the uncertainties under consideration, QM further applies an expanded uncertainty, for certification purposes. The measurement uncertainty of the certified value is therefore calculated as follows:  $U_{CRM} = k u_{CRM}$ , where  $k$  is a coverage factor, which is determined from the Student's  $t$ -distribution, based on the degrees of freedom, per analyte.

This presents a certified value, as follows:  $x_{CRM} \pm U_{CRM}$ .

Measurement uncertainty for Assigned values, are calculated in the same manner.

Laboratories which prefer to use the 95% measurement uncertainty, rather than the expanded uncertainty, all available information relating to measurement uncertainty of the certified/assigned values, are given below:

Analyte	Unit of measure	$s$ (Standard Deviation of Dataset)	$\nu$ (Degrees of Freedom)	$k$ (Coverage Factor)	$u$ (Standard Uncertainty)	95% Measurement Uncertainty	Expanded Uncertainty
Al	%	0.052	25	2.060	0.012	$\pm 0.02$	$\pm 0.03$
C	%	0.082	34	2.032	0.016	$\pm 0.03$	$\pm 0.04$
Co	%	0.002	27	2.052	0.001	$\pm 0.002$	$\pm 0.002$
Cr	%	0.26	56	2.003	0.038	$\pm 0.08$	$\pm 0.08$
Fe	%	0.44	36	2.028	0.09	$\pm 0.18$	$\pm 0.19$
Mg	%	0.061	19	2.093	0.016	$\pm 0.03$	$\pm 0.04$
Mn	%	0.01	36	2.028	0.002	$\pm 0.01$	$\pm 0.01$
Ni	%	0.005	32	2.037	0.001	$\pm 0.002$	$\pm 0.002$
P	%	0.002	33	2.035	0.001	$\pm 0.002$	$\pm 0.002$
S	%	0.003	35	2.030	0.001	$\pm 0.002$	$\pm 0.002$
Si	%	0.082	38	2.024	0.017	$\pm 0.03$	$\pm 0.04$
Ti	%	0.012	34	2.032	0.002	$\pm 0.01$	$\pm 0.01$
V	%	0.009	32	2.037	0.002	$\pm 0.01$	$\pm 0.01$

**13. Metrological Traceability:**

The values quoted herein are based on the consensus values derived from statistical analysis of the data from an inter laboratory measurement program. Traceability to SI units is via the accredited laboratories, as ISO 17025 requires laboratories to use CRM's traceable to the SI units, during the calibration of their equipment. Not all laboratories were accredited.

Fortunately, most laboratories reported on the QA/QC CRMs used during the analysis of this QRM and reported the values obtained during the sample run. Evaluation of their QA/QC performance serves as further evidence of metrological traceability.

Equivalence tests were performed on all analytes to determine whether the metrologically traceable data and those for which traceability evidence was not available, could be treated as equal (at a level of significance of  $\alpha = 0.05$ ). Where equivalent, all the data was used. Where not equivalent, only the metrologically traceable data was considered.

**14. Minimum sample size:**

The recommended minimum sample size for the use of this material is as per the participants method validation criteria.

**15. Period of validity:**

The certified values are valid for this product, while still sealed in its original packaging, for a minimum period of 5 years from date of Initial Certification. Stability monitoring of inventory will be done at regular intervals. Any concerns regarding potential instability of the material, will immediately be communicated to all consumers.

**16. Legal:**

This certificate and the reference material described in it were prepared with due care and attention. The requirements of ISO Guide 31, ISO 17043 and ISO 17034 were followed in the preparation of this reference material and certificate of analysis.

Qotho Minerals, however, accepts no liability for any decisions or actions taken following the use of the reference material. The company has a complaints procedure, which will be made available upon request, should there be any dissatisfaction with either the product or the CoA.

Certifying & Technical Signatory	
<b>Qotho Managing Director</b>	<b>29 April 2022</b>

*This Certificate of Analysis (CoA) has been electronically signed using an Advanced Electronic Signature (AES) in terms of the Electronic Communications and Transactions Act No. 15, 2002 (ECT Act). Any amendments to the CoA can be detected by reference to the Signature Panel displayed in the electronic pdf version of the CoA.*

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