

Implementing SampleManager LIMS Software to Support Metal Accounting Processes

Accurate and precise metal accounting processes are critical to the success of every mining operation. With operations increasingly spread across multiple companies, there are more points in the process where materials change hands and are bought and sold according to the values determined by laboratory analysis. The value is determined by the expected recovery of the materials, which requires the companies involved to have an accurate knowledge of this figure. Problems arise when there are issues with the sampling process, sample handling and storage or with the lab instruments and equipment being used to analyse the material and calculate the expected recovery. All of these could contribute to inaccurate results. If the calculated recovery is not achievable this could result in a financial loss for the company purchasing the material.

Aside from this clear financial impact, there is another consideration. The processes used to extract the valuable material can increase or decrease in efficiency, depending on multiple factors including the state of the materials being processed (whether it is damp, coarse, etc.), whether the machines involved have been properly serviced and calibrated, how much material is passing through, and other factors. By constantly and accurately monitoring the composition of the materials throughout the process and employing statistical analysis, any adverse changes to product can be identified and could potentially indicate an issue at some point in the recovery process. Adjustments or interventions could then be made to ensure optimum recovery is achieved.

Metallurgical accounting is under increasing scrutiny with stakeholders being more concerned about the origin and accuracy of reported results. As well as considering whether best practices have been employed to ensure the sampling process is correct, labs must also consider the processes that they follow to analyse the samples, process the data and report results. The AMIRA P754 code of practise outlines a list of metal accounting guidelines which address the importance of rigorous accounting systems and is a key focus of senior management in mining plants. Introducing data redundancy and the use of secure and auditable relational database systems enables the estimation of errors and drives data integrity, traceability and accurate reporting throughout all processes. A Laboratory Information Management System (LIMS) such as Thermo Scientific™ SampleManager™ LIMS, SDMS and LES software can be used to adhere to the AMIRA code - managing associated lab processes, driving best practices and ensuring unquestionable data management throughout testing processes.

The sampling process can be critical to ensuring real values are returned from physicochemical analyses without biased results. Once a fit for purpose method has been devised, a Laboratory Execution System (LES) can be used to take analysts step by step through the sampling process. Videos, images and detailed descriptions are used to show the user exactly how to undertake the tasks involved.

SampleManager software's LES links directly into the LIMS and can be accessed on a tablet, enabling the user to access the system during the sampling process and make any comments about the sample immediately while they work. This approach can eliminate bad sampling practices such as storage in inadequate containers which could be considered a cost saving, whereas the inaccurate results returned could lead to erroneous results with a more significant financial impact. Accessing the LIMS remotely also makes it possible to record results contemporaneously, enabling the lab to demonstrate data integrity.

The LIMS can be used to schedule the sampling plan and its locations, ensuring regular and accurate sampling and time stamping the exact moment at which samples are taken. Connections into external systems enable other data which may affect the sampling to be recorded at the same time, such as the temperature or humidity of the sample location.

Calibrations and maintenance of instruments and equipment used during the sampling and testing process are key to its integrity, just as the performance of any machinery involved in the recovery process is inherently linked to the final quantity of recovered material. SampleManager LIMS software includes a complete Instrument/Equipment Calibration and Maintenance System designed to help plan and execute a solid instrument management plan, ensuring that all the equipment used is working correctly, checked at regular intervals and any maintenance can be properly planned and prepared for. When instruments and equipment can be shown to be working to a high standard, the potential for errors in both the recovery process and the analyses to determine the amount of material recovered is significantly reduced. Calibration and maintenance plans may be applied to numerous items such as rotary sample splitters, sludge drying ovens, truck scale calibration and granulometry analysis equipment.

Statistical analysis such as Shewhart control charts are commonly used in laboratories to monitor processes and identify any issues as soon as possible. CUSUM charts are used less frequently but are an excellent tool for detecting bias or variance in an analytical procedure. SampleManager LIMS software's Statistical Quality Control package enables the creation and monitoring of Shewhart, CUSUM and other charts designed to highlight any process issues.

The statistical analysis of raw data also assists in the determination of metal recovery accuracy, which is a reporting requirement of any company's audit committee.

Data security is of great importance to the transparency and integrity of the data. Any system storing or processing data must have clear protocols in place to ensure that only authorized people can access the system. It should not be possible for data to be altered in any way, and there must be a full auditing service which records any changes as and when they happen, along with who made them. SampleManager LIMS software enables secure system access and can also be configured to request comments if details are changed, providing full data traceability based on ALCOA+ principles.

SampleManager LIMS, LES and SDMS software has been implemented to support Metallurgical Balance or Metal Accounting processes at various organizations, including Codelco in Chile. LIMS is now a central part of the MA process, managing product quality data and product movement through integration with other information systems, weighing systems, external laboratories and truck tracking systems across the organization. The LIMS is the data repository integrating the sampling and control information of truck tonnages, enabling timely report generation of all KPIs and providing information for other management systems, facilitating corrective action or investigation where necessary.

At Codelco's Ministro Hales site, SampleManager LIMS software is integrated with the truck weighing and tracking systems to receive tonnage, origin, destination and sampled date data for the reconciliation of wet and dry product tonnage WMT/DMT. Product from each truck is sampled to calculate the total tonnage reports of the lot and fine product weight based on moisture content. Product quality, moisture and particle size results are received in the system and the results of external laboratories are processed with SampleManager software's LES (parsing and mapping of flat files). Turnaround calculations for physicochemical analysis, truck weighing and sampling can also be managed using SampleManager LIMS software. The system enables statistical analysis to assess the mass measurement and accuracy in each sampling, weighing and analysis process.

The metallurgy analyst can generate reports by customer, origin, destination and tonnage of each truck in its plant. It's also possible to see how much product is in stock in a given date range, enabling reports of daily, weekly and

monthly metallurgical balance. Laboratory turnaround time is minimized due to the integration of the LIMS to external labs and site process optimization for result availability:

IdNumeric	Status	ORigen	CDestino	Patente	Pesaje	SampledDate	Hum	Peso	Neto	Tara	Posicion	ProductLink	JobNa
184037	Completed	SILO 5	DMH-BODEGA 1	XWC-21	451048	13-07-2019 9:14	11.9150	36120	18910	17210	1	Calcona Húmeda	LOTE_
184105	Completed	SILO 5	DMH-BODEGA 1	FXPB-38	451049	13-07-2019 9:35	11.9850	36920	20110	16810	2	Calcona Húmeda	LOTE_
184123	Completed	SILO 5	DMH-BODEGA 1	KWJC-94	450988	13-07-2019 9:51	13.2950	35900	20010	15890	3	Calcona Húmeda	LOTE_
184231	Completed	SILO 5	DMH-BODEGA 1	JPZC-90	451051	13-07-2019 10:07	12.4500	36460	20080	16380	4	Calcona Húmeda	LOTE_
184304	Available	SILO 5	DMH-BODEGA 1	FXPB-39	451209	13-07-2019 18:59		36150	19470	16680	1	Calcona Húmeda	LOTE_
184807	Completed	SILO 5	DMH-BODEGA 1	GZPZ-26	451154	13-07-2019 15:40	11.1700	34560	17650	16910	21	Calcona Húmeda	LOTE_
184952	Completed	SILO 5	DMH-BODEGA 1	JPZC-90	451156	13-07-2019 15:59	8.8800	34780	18490	16290	22	Calcona Húmeda	LOTE_
184973	Completed	SILO 5	DMH-BODEGA 1	KWJC-94	451157	13-07-2019 16:11	9.9750	36010	20210	15800	23	Calcona Húmeda	LOTE_
184974	Completed	SILO 5	DMH-BODEGA 1	FXPB-39	451160	13-07-2019 16:33	7.6950	36690	19980	16710	24	Calcona Húmeda	LOTE_
184992	Completed	SILO 5	DMH-BODEGA 1	KOHJ-79	451162	13-07-2019 16:49	7.0750	37310	20240	17070	25	Calcona Húmeda	LOTE_
184995	Completed	SILO 5	DMH-BODEGA 1	XWC-22	451152	13-07-2019 17:04	11.1600	36050	18710	17340	26	Calcona Húmeda	LOTE_
185086	Completed	SILO 5	DMH-BODEGA 1	FXPB-38	451176	13-07-2019 17:16	10.8900	37820	21090	16730	27	Calcona Húmeda	LOTE_
185087	Completed	SILO 5	DMH-BODEGA 1	XWC-23	451182	13-07-2019 17:34	9.8950	36810	20180	16630	28	Calcona Húmeda	LOTE_
185107	Completed	SILO 5	DMH-BODEGA 1	GZPZ-26	451191	13-07-2019 17:46	9.3600	34520	17760	16760	29	Calcona Húmeda	LOTE_
185108	Completed	SILO 5	DMH-BODEGA 1	XWC-21	451194	13-07-2019 18:10	8.3200	35830	18760	17070	30	Calcona Húmeda	LOTE_
185109	Completed	SILO 5	DMH-BODEGA 1	JPZC-90	451200	13-07-2019 18:28	9.2750	37240	20940	16300	31	Calcona Húmeda	LOTE_
185111	Completed	SILO 5	DMH-BODEGA 1	KWJC-94	451203	13-07-2019 18:40	9.1200	38420	22620	15800	32	Calcona Húmeda	LOTE_
185203	Completed	SILO 5	DMH-BODEGA 1	XWC-22	451047	13-07-2019 10:31	12.5800	35770	18830	16940	5	Calcona Húmeda	LOTE_
185210	Available	SILO 5	DMH-BODEGA 1	GZPZ-26	451069	13-07-2019 10:46		36870	19990	16880	6	Calcona Húmeda	LOTE_
185211	Completed	SILO 5	DMH-BODEGA 1	KOHJ-79	450971	13-07-2019 11:06	11.2600	36140	19100	17040	7	Calcona Húmeda	LOTE_
185212	Completed	SILO 5	DMH-BODEGA 1	FXPB-39	451085	13-07-2019 11:34	11.1000	37960	20890	17070	8	Calcona Húmeda	LOTE_
185231	Completed	SILO 5	DMH-BODEGA 1	XWC-23	451094	13-07-2019 11:49	11.3650	36810	20100	16710	9	Calcona Húmeda	LOTE_
185232	Completed	SILO 5	DMH-BODEGA 1	XWC-21	451089	13-07-2019 12:05	11.1900	36460	19360	17100	10	Calcona Húmeda	LOTE_
185233	Completed	SILO 5	DMH-BODEGA 1	FXPB-38	451096	13-07-2019 12:39	9.0800	37140	20320	16820	11	Calcona Húmeda	LOTE_
185234	Completed	SILO 5	DMH-BODEGA 1	XWC-22	451112	13-07-2019 12:41	11.1150	36270	19320	16950	12	Calcona Húmeda	LOTE_
185235	Completed	SILO 5	DMH-BODEGA 1	GZPZ-26	451116	13-07-2019 12:54	10.5400	36000	18650	17350	13	Calcona Húmeda	LOTE_
185236	Completed	SILO 5	DMH-BODEGA 1	JPZC-90	451108	13-07-2019 13:15	10.6000	37630	21290	16340	14	Calcona Húmeda	LOTE_
185238	Completed	SILO 5	DMH-BODEGA 1	XWC-23	451136	13-07-2019 13:57	9.9150	37170	20510	16660	15	Calcona Húmeda	LOTE_
185554	Completed	SILO 5	DMH-BODEGA 1	KWJC-94	451111	13-07-2019 14:31	10.9850	37060	21220	15840	17	Calcona Húmeda	LOTE_
185603	Completed	SILO 5	DMH-BODEGA 1	KOHJ-79	451127	13-07-2019 14:49	11.9100	39870	22820	17050	18	Calcona Húmeda	LOTE_
185615	Completed	SILO 5	DMH-BODEGA 1	FXPB-38	451142	13-07-2019 15:18	11.1400	37340	20560	16780	19	Calcona Húmeda	LOTE_
185648	Completed	SILO 5	DMH-BODEGA 1	XWC-21	451153	13-07-2019 15:32	10.9700	36150	19060	17090	20	Calcona Húmeda	LOTE_
185649	Completed	SILO 5	DMH-BODEGA 1	XWC-21	451145	13-07-2019 14:18	11.9500	35500	18440	17060	16	Calcona Húmeda	LOTE_
233771	Completed	SILO 5	DMH-BODEGA 1	FXPB-39	451134	13-07-2019 18:55	10.1000	39110	22340	16770	33	Calcona Húmeda	LOTE_

SampleManager LIMS software is configured to generate labels for each sample and product generated by the plant. The labels are scanned in external service laboratories and the results are sent back to LIMS. Raw data files are processed within the system, avoiding data/result manipulation or transcription errors.

In the screenshot below, two external laboratories, LQC and External Services Laboratory report results for the same sample. The metallurgy analyst can compare the results of different components and laboratories. This provides a double check of commodity purity and calculation of any accuracy/error/bias:

Entered by	Analysis	Component Name	Type	Entered on	Raw result	Value	Units
SYSTEM	EXT_N/1	H (Lab Externo)	N	8-JUL-2019 04: 18.16		8.1600	%
SYSTEM	EXT_CU/1	Cu (Lab Externo)	N	8-JUL-2019 06: 25.1303455177315		25.1303455177315	%
SYSTEM	EXT_S/1	S (Lab Externo)	N	8-JUL-2019 07: 34.065		34.065	%
SYSTEM	EXT_AG/1	Ag (Lab Externo)	N	8-JUL-2019 06: 589.881619193653		589.881619193653	PPM
SYSTEM	EXT_SB/1	Sb (Lab Externo)	N	8-JUL-2019 06: 9.05885535613799E-02		9.05885535613799E-02	%
SYSTEM	EXT_FE/1	Fe (Lab Externo)	N	8-JUL-2019 06: 18.7022053120553		18.7022053120553	%
SYSTEM	EXT_ASP/1	As (Lab Externo)	N	8-JUL-2019 06: 2.22380038494245		2.22380038494245	%
SYSTEM	EXT_INSO/1	Insolubles (Lab Externo)	N	8-JUL-2019 07: 5.97393177581245		5.97393177581245	%
SYSTEM	EXT_ZN/1	Zn (Lab Externo)	N	8-JUL-2019 06: 4.43788190568987		4.43788190568987	%
SYSTEM	EXT_GRANU/1	R48	N	8-JUL-2019 06: 10.1101304678386		10.1101304678386	%
DEFAULT	EXT_GRANU/1	R48	N	7-JUL-2019 05: 10.1101304678386		10.1101304678386	%
DEFAULT	EXT_GRANU/1	R65	N	7-JUL-2019 05: 10.1101304678386		10.1101304678386	%
SYSTEM	R100	R100	N	8-JUL-2019 07: 0.01998001998002		0.01998001998002	%
SYSTEM	R150	R150	N	8-JUL-2019 07: 0.03966033966034		0.03966033966034	%
SYSTEM	R200	R200	N	8-JUL-2019 07: 0.01698301698302		0.01698301698302	%
SYSTEM	R270	R270	N	8-JUL-2019 07: 11.3286713286713		11.3286713286713	%
SYSTEM	R325	R325	N	8-JUL-2019 07: 6.97302697302697		6.97302697302697	%
SYSTEM	RM325	RM325	N	8-JUL-2019 07: 78.3216783216783		78.3216783216783	%
DEFAULT	AR48	AR48	N	7-JUL-2019 05: 78.3216783216783		78.3216783216783	%
DEFAULT	AR65	AR65	N	7-JUL-2019 05: 78.3216783216783		78.3216783216783	%
SYSTEM	AR100	AR100	N	8-JUL-2019 07: 0.01998001998002		0.01998001998002	%
SYSTEM	AR150	AR150	N	8-JUL-2019 07: 0.03966033966034		0.03966033966034	%
SYSTEM	AR200	AR200	N	8-JUL-2019 07: 0.01698301698302		0.01698301698302	%
SYSTEM	AR270	AR270	N	8-JUL-2019 07: 14.7052947052947		14.7052947052947	%
SYSTEM	AR325	AR325	N	8-JUL-2019 07: 21.6783216783217		21.6783216783217	%
SYSTEM	APM325	APM325	N	8-JUL-2019 07: 100		100	%
SYSTEM	AF48	AF48	N	8-JUL-2019 07: 100		100	%
SYSTEM	AF65	AF65	N	8-JUL-2019 07: 100		100	%
SYSTEM	AF100	AF100	N	8-JUL-2019 07: 99.980019980002		99.980019980002	%
SYSTEM	AF150	AF150	N	8-JUL-2019 07: 99.6403596403596		99.6403596403596	%
SYSTEM	AF200	AF200	N	8-JUL-2019 07: 96.6233766233766		96.6233766233766	%
SYSTEM	AF270	AF270	N	8-JUL-2019 07: 85.2947052947053		85.2947052947053	%
SYSTEM	AF325	AF325	N	8-JUL-2019 07: 78.3216783216783		78.3216783216783	%
DEFAULT	APM325	APM325	N	7-JUL-2019 05: 100		100	%
SYSTEM	DWF_D50	DWF_D50	N	8-JUL-2019 07: 19.0223264636751		19.0223264636751	NOLUNIT
SYSTEM	DWF_D80	DWF_D80	N	8-JUL-2019 07: 46.8682296568302		46.8682296568302	NOLUNIT
SYSTEM	DWF_D90	DWF_D90	N	8-JUL-2019 07: 61.5462366537077		61.5462366537077	NOLUNIT

The system can also be configured to generate multiple reports for plant areas and high-level reports:

Reporte consulta Movimiento Camiones

ID OT: **LOTE_0000003200**

ID Producto **Calceina Venta**

Posición	ID	N Ticket	Turno	Patente	Origen	Destino	Tonelaje	Fecha Muestreo	Peso Muestra
0	230170	448204	Turno A	DJWF-29	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26120	01-07-2019 17:37:40	
0	230209	448160	Turno A	LJCV-32	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26830	01-07-2019 12:22:31	
0	230212	448154	Turno A	GHLW-41	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	27660	01-07-2019 12:01:14	
0	230214	448148	Turno A	CFRG-10	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	27670	01-07-2019 11:41:36	
0	230217	448146	Turno A	DPFR-82	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	27340	01-07-2019 11:13:03	
0	230218	448145	Turno A	DBLS-83	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	27110	01-07-2019 11:08:34	
0	230219	448139	Turno A	FHRT-61	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26850	01-07-2019 11:02:41	
0	230227	448124	Turno A	HHPT-68	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	24790	01-07-2019 10:08:27	
0	230521	448217	Turno A	JZSK-36	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	24720	01-07-2019 18:48:50	
0	230523	448221	Turno B	KZPL-84	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	25650	01-07-2019 19:05:04	
0	233161		Turno A		DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	421550	01-07-2019 18:41:20	
1	230163	448208	Turno A	HTVY-98	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26380	01-07-2019 17:55:33	
1	230520	448215	Turno A	CTVZ-18	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	25980	01-07-2019 18:41:20	
2	230519	448214	Turno A	HXPZ-40	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26630	01-07-2019 18:42:34	
3	230522	448213	Turno A	DRCK-98	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26060	01-07-2019 18:56:19	
4	230524	448228	Turno B	HRTV-62	DMH-BODEGA 1	PUERTO MEJILLONES-PUERTO ANGAMOS	26070	01-07-2019 19:13:02	
5	230525	448229	Turno B	DRBW-13	DMH-GENÉRICO	PUERTO MEJILLONES-PUERTO ANGAMOS	25690	01-07-2019 19:35:20	

The AMIRA metal accounting model aims to support mining plant managers in making better and more informed decisions and ensure operations information is reliably available. SampleManager LIMS software provides a centralized relational database and automatically transfers information to eliminate redundancy and reconciliation errors, providing the best possible report of plant performance. The system helps organizations to meet the AMIRA requirements for easy setup, configuration and auditing, enabling them to achieve maximum profitability.

References

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