



Achieving step change performance in copper ore processing

Exploit the potential of proven online solutions for sampling, elemental analysis and particle size measurement

Global efforts towards lower environmental impact and greater sustainability bring significant challenge for copper mines, while offering an unprecedented opportunity for innovation. With steadily increasing demand for copper, and institutional investors favoring enterprises with higher ESG (environmental, social, governance) scores¹, the economic case for transforming efficiency through new technology has rarely been stronger.

Growing demand...

Copper directly underpins society's planned transition to a lifestyle powered by renewable electricity. Electric vehicles contain between 4 and 8 times more copper than petrol/diesel alternatives; renewables use around 5 times more copper than conventional power systems². Factors such as these justify predictions of a copper supply shortfall of more than 15 million tonnes by 2034, based on current mine production³.

...tightening supply

Efforts to meet the increasing demand for copper are constrained by:

- The social license to operate
- ESG performance
- Net Zero emissions strategy implementation
- Decreasing ore grades and depleting copper deposits

Many copper mines lie in areas of low water availability making water consumption a pressing concern and a potential issue of contention with nearby communities. Power consumption is also a target for minimization with mining accounting for around 5% of global energy consumption. Mining in increasingly remote locations further intensifies energy supply pressures and the need for reduction.

As copper concentration in ores decreases to an average of below 0.5% in some mines, improving process efficiency becomes increasingly important, and at the same time, increasingly difficult. As conventional mining and metallurgical extraction processes are becoming unsustainable, the benefits of new and emerging technologies are evident.

The schematic below highlights well-defined strategies enabled by Thermo Fisher Scientific's technology that can make a substantial difference to the efficiency and profitability of copper concentrators.

Our proven solutions for copper ore processing include high availability sampling, elemental analysis, and particle size distribution data, providing accurate data in the timescale needed for sound decision-making and advanced process control.

Our minerals product line enables the step change performance required to optimize copper yield within the increasingly constrained operating environment. Ultimately, they can help to make clean energy greener.

Read on to find out what is achievable.

Bulk ore sorting: why process waste?

Block models, developed from drill core assay data, are essential for resource estimation and production forecasting but can hide substantial intra-block variation. As a result, many concentrators often process material that is in grade and mineralogical composition. Even more importantly, ore above the cut-off grade is routinely sent to waste, impacting recovery and profitability.

Effective bulk ore sorting preconcentrates the feed to the plant delivering:

- Improved grade control – less copper ore sent to waste pile
- Additional throughput of above grade ore with no plant expansion
- Lower water consumption per tonne of product
- Lower energy consumption per tonne of product
- Improved metallurgical recovery – due to the higher feed grade

Specific benefits depend on factors such as ore heterogeneity and mine/mill constraints. For example, in a new greenfield mine, the CAPEX required for the layout of the milling circuit and concentrator, can be reduced from the outset through the inclusion of ore sorting.

For an established 40,000T per day plant, a recent evaluation showed that effective sorting could reject sufficient low-grade ore to create the capacity to process an extra 20,000T of copper per year, generating additional profit in the region of \$100 million, with no mill expansion (assuming mining capacity exists). In either case the economic benefit is significant.

Technology that can rapidly and accurately differentiate material that is at or below cut-off grade is the foundation for ore sorting. It minimizes the loss of valuable material to waste, while at the same time ensuring that only economically viable ore is sent to the concentrator for processing, minimizing the amount of waste that is processed.

The Thermo Scientific™ CB Omni™ Fusion Online Elemental Analyzer meets this requirement, providing high frequency bulk analysis via Prompt Gamma Neutron Activation Analysis (PGNAA) or Pulsed Fast Thermal Neutral Activation (PFTNA).



CB Omni Fusion
Online Elemental Analyzer

Choose the CB Omni Fusion Analyzer for:

- Market-leading precision and accuracy, critical to ore sorting, especially for low grade ores
- Rapid analysis, less than 30 seconds
- A track record of reliability and performance in 18 other commodity industries such as cement and coal
- Local expert service and support delivered by our global network
- Real-time, accurate measurement of head feed grade for stockpile blending optimization

A demanding challenge – the economic benefits of accurate ore sorting

Ore sorting is a demanding analytical challenge, that requires a high-spec solution. Falsely accepting below cut-off grade material impacts the average grade of the feed stockpile, compromising recovery, while falsely rejecting above grade material sends recoverable copper directly to the waste pile. Both the precision and accuracy of a potential analyzer are therefore critical.

Compare a simulation based on the performance of a high spec CB Omni Fusion, with a high strength source and large detector volume, with that of an alternative analyzer with a single detector and smaller source, both sorting material with the same theoretical grade distribution, with a cut-off grade of 0.2% Cu.

The high spec CB Omni Fusion has a 3.1% false rejection rate and a 2.8% false acceptance rate. It rejects 24.6% of the material overall, capturing 93.9% of the Cu. The 3.1% of material falsely rejected has an average grade of 0.23% Cu.

The low spec alternative analyzer has a 7.2% false rejection rate and a 5.8% false acceptance rate. It rejects 25.8% of the material, capturing 92.2% Cu. The 7.2% of material falsely rejected has an average grade of 0.27% Cu.

The following example illustrates the importance of selecting an analyzer with the best specifications and performance. Starting with the scenario of a 40,000 tonne per day copper processing plant, the market value of an underperforming sorting application with a copper rejection rate of 200 kg/hr at an indicative price of US\$9,500* per tonne could equate over US\$5M per annum in falsely rejected copper.

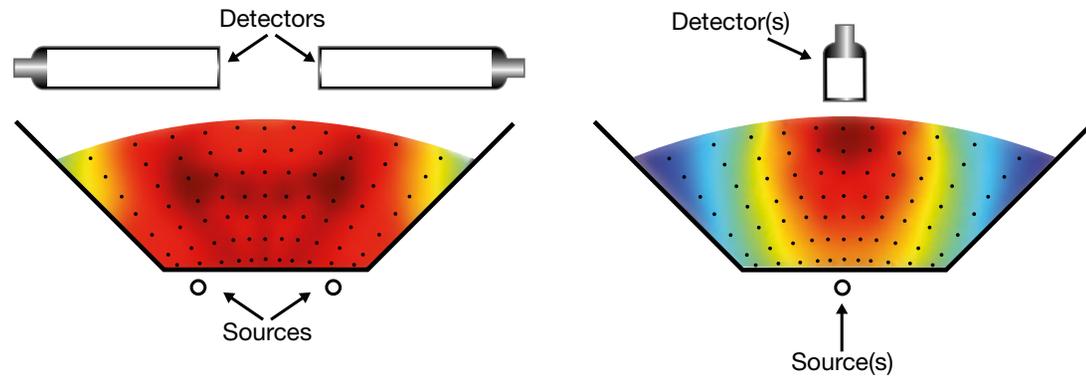
* August 2021

	False rejection rate	False acceptance rate	Overall material rejection
CB Omni Fusion	3.1 %	2.8 %	24.6 %
Low spec alternative analyzer	7.2 %	5.8 %	25.8 %

	Cu captured	Falsely rejected material with Cu	Average grade of Cu
CB Omni Fusion	93.9 %	3.1 %	0.23 %
Low spec alternative analyzer	92.2 %	7.2 %	0.27 %

Take a closer look: CB Omni Fusion Online Elemental Analyzer

The CB Omni Fusion delivers elemental analysis via neutron activation analysis - PGNAA or PFTNA depending on the excitation source used. Bombarding materials with neutrons causes the elements within them to emit secondary, prompt gamma rays which essentially create a fingerprint for an element. Thermo Fisher Scientific experts have pioneered the industrial application of PGNAA and PFTNA and the CB Omni Fusion offers features that clearly differentiate it from the competition.



Modelled uniformity for a CB Omni Fusion (left) and a centred geometry design (right)

These include:

- Higher neutron output – due to higher source strength
- Larger gamma ray captures due to larger, high quality detectors
- Optimized design for uniformity of analysis across the measurement zone

These features deliver highly accurate, precise, uniform measurement across the feed conveyor belt. Uniform measurement is critical because for ore sorting to have most value, material should not be blended prior to the ore sorting point. This means that high grade copper has an equal probability of being located anywhere on the belt. If only the center and/or the surface of the material is measured accurately, there is a high likelihood that high- or low-grade material will be missed. This increases the probability of low-grade material being falsely accepted or high-grade material being rejected.



Mining new commodity: digital data

To enable its digital transformation, the mining industry requires sensors and analyzers across the mining value chain that can deliver data in real-time with high accuracy. Monitoring and controlling the variability of the mining value chain include activities like metallurgical accounting, advanced process controls, digital twins and modelling of processes.



Metallurgical Accounting, or completion of a Metallurgical Balance, determines the amount of saleable metal in a mine and provides an overall assessment of plant efficiency, answering the question:

How much recoverable copper is coming out of the mine and how much of that copper reports to concentrate (product) relative to tailings (waste)?

Metallurgical Accounting metrics flow from operations, through site management, into corporate headquarters and onto the markets, making them critical performance indicators.

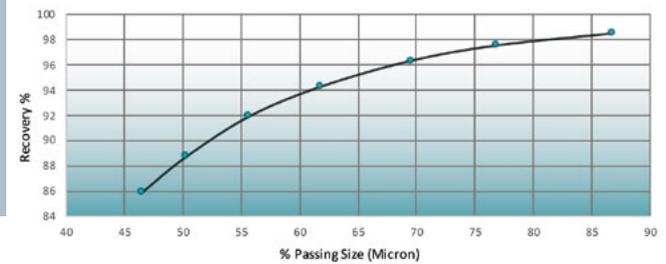
As technologies evolve and digitalization becomes standard, there is a growing need for tracking and optimizing recovery and accounting in real time, not just for reporting. Justifying an investment in technology to sample and measure the copper concentration of the concentrator feed, the concentrate and tailings is therefore easier than for any other stream. This is an application that typically demands a dedicated and/or higher specification sampling and measurement solution to meet the need for high frequency measurements, high availability, and robust, high-quality information.

Grinding control: Make every kW count

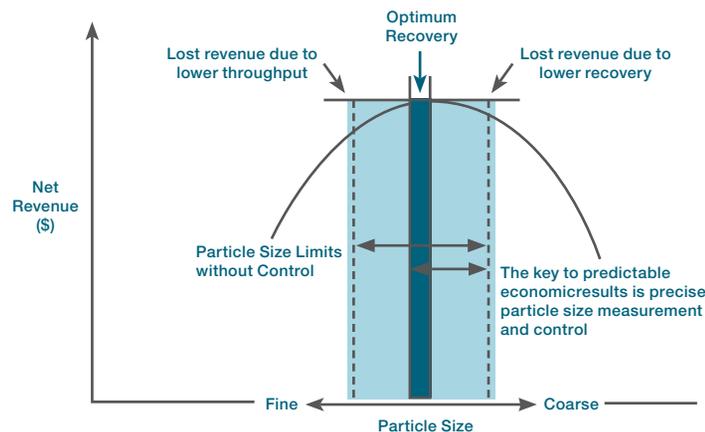


Crushing and milling account for over half of the energy consumption at a typical mine, making them a primary target for reduction (Source: ceecthefuture.org)

Recovery vs Size



The operational goal for the primary grinding circuit is to reduce the particle size of the ore for optimum copper mineral liberation in the froth flotation circuit. Meeting this target by inferring performance from parameters such as feed rate, cyclone pressure and density is inaccurate, since particle size is influenced by a wide range of parameters from the size and grade of incoming ore, to mill charge and cyclone pressure. Under- and over-grinding both result in operational and economic penalties.



Grinding just enough is critical – too fine, means lower throughput and/or higher energy consumption, too coarse and recovery suffers.

Online particle size analysis makes it possible to:

- Optimize energy consumption per T and increase mill throughput by minimizing over-grinding
- Maximize copper recovery and liberation, by minimizing under-grinding
- Reduce grinding media and flotation reagent consumption per T of product
- Instantly detect process upsets in the grinding circuit
- Implement automated mill control

Take a closer look: PSM 500 Particle Size Analyzer

The Thermo Scientific™ PSM 500 Particle Size Analyzer provides real-time in-stream particle size measurement and has a track record of delivering the high availability required for grinding circuit control.

Choose the PSM 500 to measure:

- Particle size in the range 1 – 1000µm with high accuracy, typically better than 1%
- In real-time, measurement update times are in the region of 10 seconds
- Large sample volumes, with no requirement for sample dilution
- % solids (an important metric for froth flotation control), in addition to particle size

The PSM 500 delivers particle size data via the technique of ultrasonic attenuation, continuously measuring up to eight size fractions. Particles subject to ultrasound waves dampen or attenuate their transmission to an extent that depends on the size of the particle relatively to the wavelength of the ultrasound. The directional dependence of ultrasonic detectors eliminates issues with multiple scattering allowing even high percentage solids slurry to be measured without dilution, a defining attraction for mining applications.

The PSM 500 offers market-leading ultrasonic attenuation technology for the mining industry with a range of valuable features including:

- New software and a contemporary user interface for simplified everyday use
- Simple and short sample transport with no requirement for pumping
- Capacity to measure up to 3 streams with a single analyzer



PSM 500 Particle Size Analyzer

Concentrator reagent consumption: Add just enough, and no more

In the froth flotation circuit, copper-rich particles are recovered in the froth while gangue is discharged to tailings. Adding collectors, frothers, and pH modifiers enhances this process by improving separability, stabilizing air bubbles, and improving separation selectivity, respectively. Optimizing reagent addition and process operation is a complex challenge with performance influenced by parameters such as ore mineralogy, feed rate, pulp density and particle size – excess fines can drive up reagent requirements.

Real-time elemental analysis provides the information required to:

- Adopt a knowledge-led, efficient approach to reagent dosing and the manipulation of process parameters such as aeration rate and pulp level
- Reduce reagent consumption
- Quickly detect changes in the feed material or process upsets, and take rapid, responsive action
- Ensure target concentrate quality
- Track copper, as well as other valuable and deleterious elements through the flotation circuit to assess process performance and maximize recovery

We offer multiple options for online elemental analysis delivering:

- Dedicated, online sampling and analysis for the continuous measurement of streams requiring high frequency analysis including Metallurgical Accounting streams
- Cost-efficient analyzers that measure up to 12 streams in user-defined sequences rotation for process control and monitoring
- The capability to measure important light elements such as sulfur by our industry leading PGNA technology

By combining our samplers and elemental analyzers it is possible to engineer an optimal solution for each stream and concentrator, whatever the constraints, to deliver the information required to improve flotation circuit efficiency and maximize recovery, with very low head loss.

Take a closer look: elemental analysis

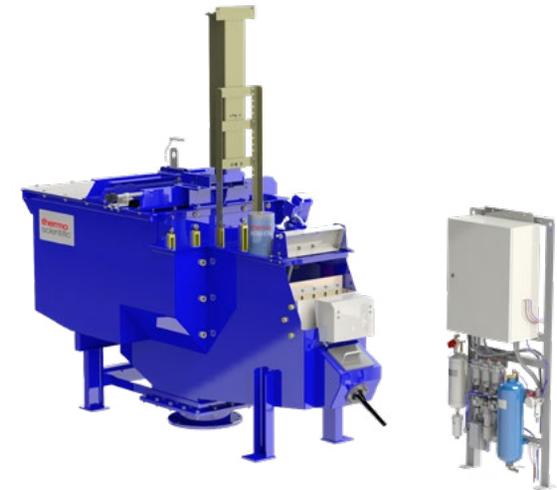
We offer three solutions for elemental analysis across the copper concentrator:

Thermo Scientific™ AnStat 330 Online Sampling and Elemental Analysis Station

The AnStat 330 is an integrated analyzer and sampling station providing dedicated real-time measurement for single streams via XRF. XRF analyzers measure the fluorescent X-rays emitted by a sample excited by a primary X-ray source, with each element providing a characteristic fluorescent fingerprint. The AnStat 330 is particularly suitable for Metallurgical Accounting applications or for critical streams where minute by minute analysis is needed.

Choose the AnStat 330 for:

- For the combination of sampling and analysis in one unit. This results in a low head loss solution, which can be integrated into a plant to lower its overall height
- The highest availability analyzer on the market
- Providing high frequency (continuous) analysis for demanding process control applications
- The elimination of long-distance sample transport saving piping design hours, installation and maintenance costs, and pump capital, operating and maintenance costs
- Proven technology for handling flows ranging from 4 to 50,000 m³/hr



AnStat 330 Online
Sampling and Elemental Analysis Station

Thermo Scientific™ MSA-330 Multi-Stream Slurry XRF Analyzer

The MSA-330 uses the same powerful MEP-300 probe as the AnStat 330 but is configured to measure up to 12 streams, with full stream separation retained throughout.

Choose the MSA-330 for:

- Cost-efficient, accurate, centralized elemental analysis for multiple streams
- No multiplexing or de-multiplexing
- The lowest head loss of any centralized analyzer system, less than 0.8 m
- Rigorously segregated analysis zones with no risk of cross-contamination



MSA-330 Multi-Stream Slurry
XRF Analyzer

Thermo Scientific™ GS Omni Light Elemental Analyzer

The GS Omni provides high frequency analysis of multiple elements for between 1 and 8 streams, via the technique of PGNAA which unlike XRF is suitable for measuring elements with an atomic weight of 20 and below.

Choose the GS Omni for:

- The capability to measure relevant lighter elements such as sulfur
- Measurements unaffected by particle size (up to 5 mm)
- Robust technology with a proven track record in slurry beneficiation plants.



GS Omni Light Elemental Analyzer

Real-time product quality control: Drive up concentrate revenues

Copper concentrate commands a price dependent on its grade, or copper content, which typically lies in the range 25 – 35%. However, penalties are imposed for impurities that impact the smelting process such as arsenic, bismuth and others. While smelters may be able to handle higher impurity levels via blending, they will charge for the inconvenience, in the worst case rejecting the shipment.

Online elemental analysis provides the information required to:

- Manage product quality /grade impurity levels
- Only ship concentrate that meets impurity level specifications
- Maintain a consistent, premium concentrate product
- Maximize revenues or Net Smelter Returns (NSR)
- Safeguard and enhance reputation

We offer multiple options for online elemental analysis that make it straight forward to:

- Measure impurities of interest
- At a frequency appropriate for the consistent concentrate production
- With a low maintenance, cost-efficient solution.

Take a closer look: Sampling

We provide alternative sampling options to meet varying requirements across the concentrator plant. Key criteria for the selection of sampling systems include:

- Accuracy – only unbiased, representative sampling can provide a foundation for accurate analysis.
- Availability – designs that minimize the risk of sedimentation and blockage are particularly critical for slurries, with access for maintenance and cleaning vital for maximum uptime
- Total cost of ownership – differences in capital costs can be dwarfed by installation costs and long-term expense of labor-intensive maintenance and excessive cleaning.

Sampling associated with Metallurgical Accounting is the most demanding application because of the requirement for excellent information integrity, and a high performance, system may be specified. Where measurements are driving process control there may be more flexibility to switch less expensive samplers in combination with multi stream analyzers.

SamStat-30

Representative Slurry Sampling Station

The Thermo Scientific™ SamStat-30 is a full-flow multistage slurry sampling station that provides composite and continuous samples. Delivering accuracy approaching that of a well-designed crosscut sampler, for a substantially lower capital cost, the SamStat-30 offers other important advantages including:

- High availability, > 99.5%* due to a small number of moving parts and with a cutter configuration that minimizes the risk of blockages
- An open, visible design for easy monitoring, cleaning, access, and maintenance
- Combining multiple sampling stages at one floor level with no requirement for sampling towers.
- Low head loss – enabling lower plant elevation and reduced construction costs
- Low flow velocity for reduced wear

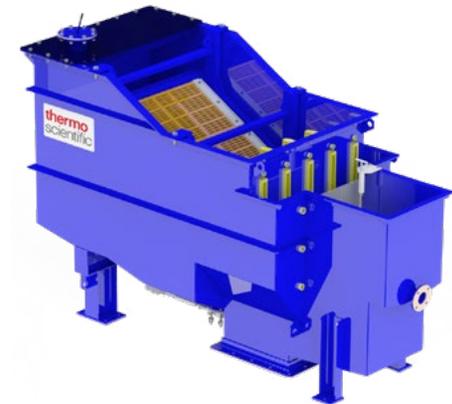
A range of optional features for the SamStat-30 further enhance its utility for mining applications. These include:

- Pebble screen – for cyclone overflow streams
- Outlet distributors and diverters – to evenly distribute or divide the incoming flow into two or more exiting streams
- Take-off point for particle size analysis
- Tank expansion for high/sticky froth streams
- Elemental analysis – with the AnStat 330

SamStat 30-CP

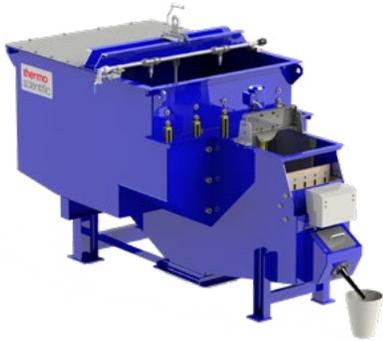
Continuous sampler with pebble screen for large particle removal

Reduced footprint, low head loss, easy to maintain solution for the flotation feed, with no requirement for a separate screen.



SamStat-30
Representative Slurry Sampling Station

Sampler Portfolio for the Copper Industry



SamStat-30 Representative Sampler

Provides a representative sample for lab analysis and can include an MEP-300 XRF analyzer for integrated sampling and analysis.



SamStat-30C Continuous flow

Feeds an analyzer with a continuous, representative flow.

SamStat-30CP Pebble Screen

Screens out large particles in flotation feed to avoid the need for a separate screen, reducing the need for additional footprint and head loss.



SamStat-30Ds Distributor

Can distribute flows at varying proportions to meet site needs while also producing a sample, avoiding the need for an additional product.

SamStat-30Dv Diverter

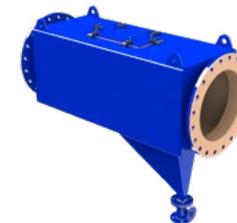
Can divert streams as required by site needs while also producing a sample, avoiding the need for an additional product.

Pressure Pipe and Gravity Samplers

We also offer Pressure Pipe and Gravity Feed samplers as a practical, compact, cost-effective solution for continuous sampling for process control applications.



Pressure Pipes



Gravity Samplers

Your asset, your concerns, our solutions

Putting in place optimal sampling and analysis solutions can be a challenge, whether you are breaking ground on a new mine, expanding an existing facility or simply looking for incremental gains. We have expertise and skills to complement yours and in-depth understanding of how to use our technology to maximize benefit.

Work in partnership with us to:

- Make your investment in analytical technology go further
- Produce solutions that are truly optimized within the constraints you face
- De-risk investment, installation, and commissioning
- Establish solutions that work for the long-term
- Secure a legacy of expert support
- Maximize ROI



Right from the start...

The technology we have is matched by experience and knowledge that can make a real difference.

For example, our experts pioneered PGNAA and we have more experience of its successful application in demanding commodity industries than any other supplier. Ore sorting has massive potential for the copper industry but it's new. Working with technologists and engineers that understand how to make it work can mean the difference between success and failure.

And our in-stream XRF analyzers have a reputation for delivering the highest availability of any on the market. Approx. 50 years of experience of implementing this technology in industrial plants gives us a commanding advantage, but it is arguably our expertise in slurry sampling, and integrating systems into plant layouts that sets us apart. Delivering the high availability and measurement frequency required for process control is demanding for slurries which block and sediment easily. With our technology, we can deliver representative sampling while at the same time lowering the height of your plant and eliminating pumps - saving capital costs, energy, ongoing maintenance and improve data availability.

We can help you optimize analyzer locations, minimize transport distances and where necessary group streams for long-term trouble-free operation.

Our philosophy for success:

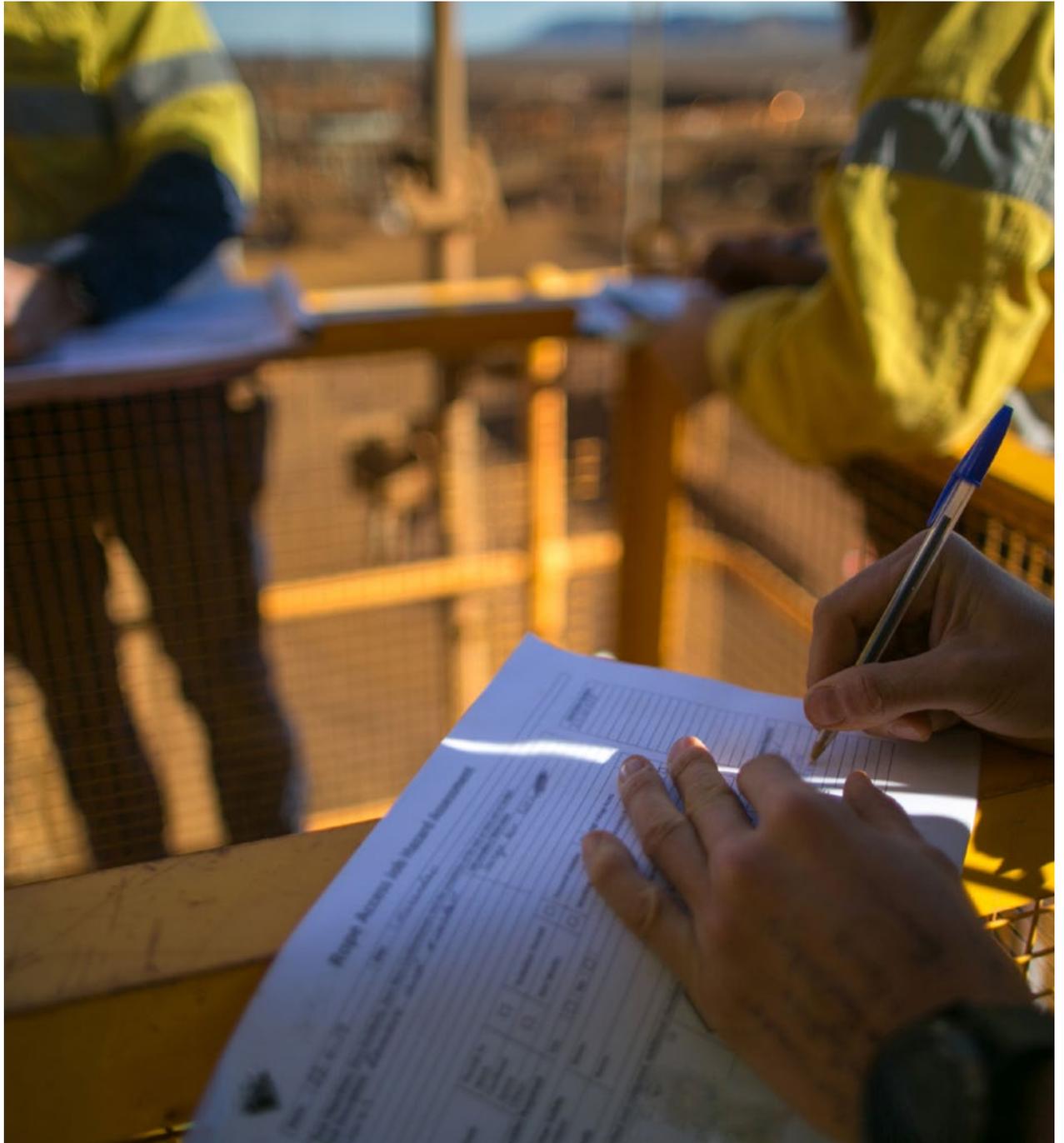
- Only measure what has value and do it well
- Don't take the measurement if you can't take a control action
- Install and engineer it properly taking into account factors such as location, pumping distances, elevation
- Every plant design or flowsheet is unique, each needs an individual sampling and analysis solution

... and for the long-term

While good design, installation, and technology provide a foundation for long-term success Thermo Fisher simultaneously offers the reassurance of exceptional service and technical support for maintenance and training. Delivered primarily by direct employees these services are available wherever you are located.

We offer:

- Guidance on establishing effective cleaning and maintenance schedules to keep equipment operating at its best
- Increasingly comprehensive access to remote calibration and maintenance services
- Expert input on data interpretation to support onsite calibration and safeguard information integrity
- Tiered levels of training, from commissioning to calibration masterclass
- Timely spares supply, via a network of regional factories and service centers, and advice on spares management
- Proactive technical support across all time zones backed up by remote troubleshooting



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*feedback from a customer operating 12 AnStat Online Sampling and Elemental Analysis Stations

Find out more at thermofisher.com/copper