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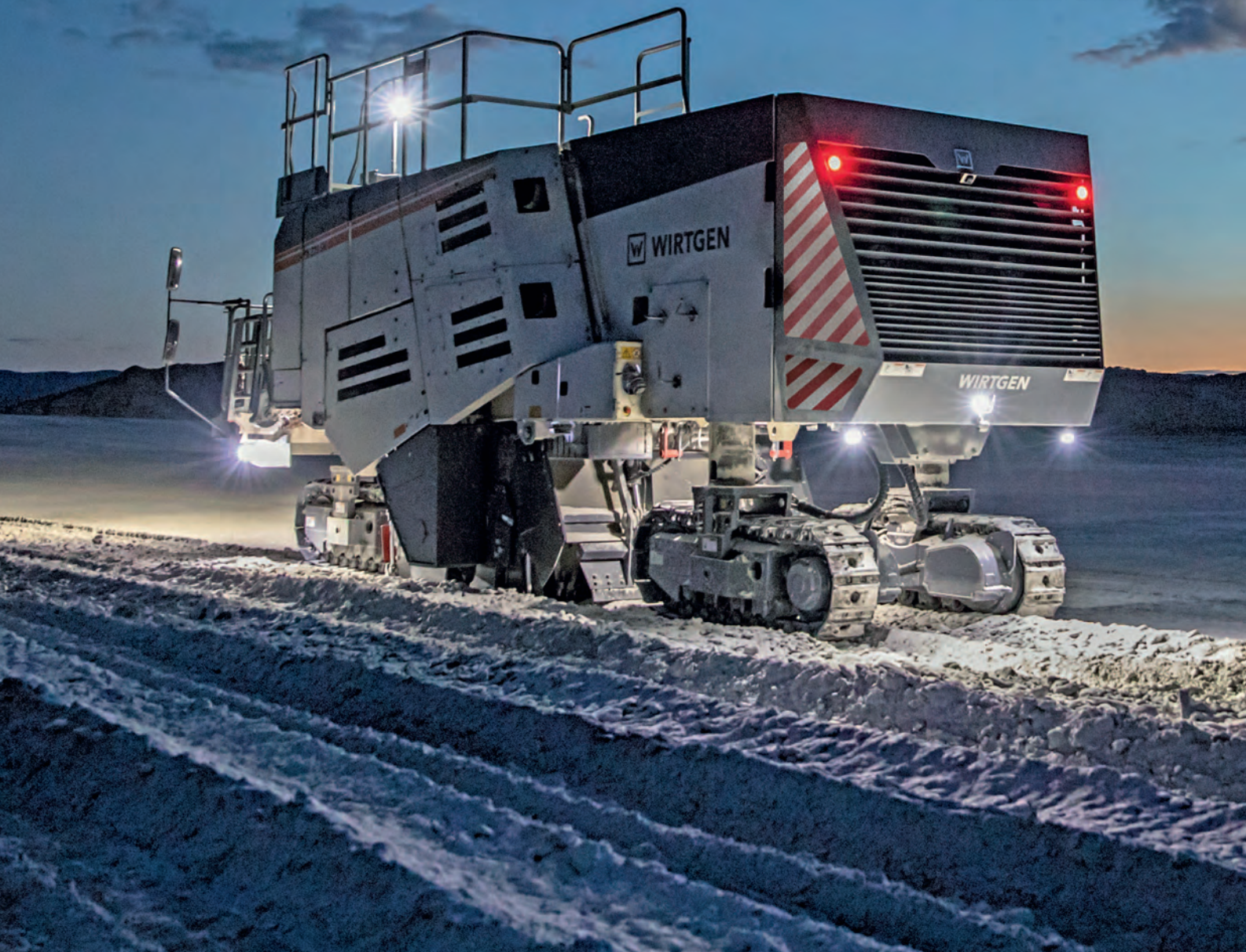

gone from being mainly used in diamond and industrial metal operations to potentially finding new homes in uranium, iron ore, coal, copper, gold, silver and phosphate mines, to name a few.

XRT

The ore sorting solution gaining most traction of late is XRT.

Most of the XRT solutions on the market recognise and separate materials based on their specific atomic density, allowing a high level of sorting purity irrespective of size, moisture or surface pollution, according to the companies manufacturing the machines.

In addition to a number of diamond case study examples (see *The ore sorting effect* below), tungsten and tin operations have also seen XRT machines work wonders.

For instance, Minsur's San Rafael tin operation in Peru repaid the $24 million capital cost that came with buying a TOMRA 3,000 t/d XRT ore sorter within four months of installation.

The use of sensor-based XRT ore sorting converted uneconomic waste material into economic ore, according to TOMRA's Robben, meaning material below the cutoff grade for the main plant, set at 0.9% Sn in 2014, was able to be treated with lower specific operating costs, thus bolstering reserves.

And, capacity of the San Rafael main plant freed up after the installation of the ore sorter, with nameplate rising to 3,600 t/d, compared with 2,950 t/d, Robben said.

Companies are also starting to realise the solutions can be applied at the front end of operations, too.

For instance, at a bulk sample trial in Western Australia for Novo Resources' Karratha gold project, a combination of XRT and electromagnetic induction (EM) sensors were recently used to concentrate gold.

The nuggety mineralisation witnessed at Karratha had, up until this point, proven tricky to separate from the waste materials, but recent studies showed a combination of XRT and EM sensor-based ore sorting could do exactly this.

Novo said the XRT identifies rocks containing particles of high atomic mass such as gold, while EM identifies rocks that become electrically charged due to the presence of metallic particles.

At Vista Gold's Mt Todd gold project in Australia the combination of XRT and laser-based ore sorting has shown a coarse fraction (+16 mm) high pressure grinding rolled product can

Vancouver-based **MineSense** is one of the few companies on the market with references that prove it can carry out precise and effective ore sorting on a bulk scale.

IM spoke with President and CEO, Jeff More, to find out more about the company's ShovelSense and BeltSense technologies and how the startup has been able to secure investment from the likes of ABB, Caterpillar and Mitsubishi.

IM: Can you explain in a little more detail how your ShovelSense and BeltSense solutions work?

JM: The base technology for both is XRF – a technology that has been around for some time. What we have done to this existing technology, which is quite unique, is three things:

- One, we have extended dramatically the range of XRF. Traditionally XRF would almost have to be held to the surface of a rock to get accurate measurements. The range extension allows us to work in the shovel environment where we are working across metres of volume;
- Second is speed. Our system is extremely fast. High speed analysis is required on our conveyor belt applications, but this is even more important in the shovel, where we're measuring dynamically; as the material is flowing into the shovel, to get a representative reading, you have to be able to take very fast readings of the material as it is moving past the sensors;
- The third is robustness. On a shovel, you are in a nasty environment from a shock and vibration perspective. We developed a system with sensitive components – the XRF itself, as well as the computing devices around it – that can stand up to that very high shock- and vibration-type environment.

IM: The most high-profile examples of the application of your ShovelSense technology have been at copper mines (Teck Highland Valley Copper (HVC), in particular); is the detection technology particularly effective in these ores? Is it being trialled elsewhere?

JM: The current sensing we have with the XRF is very effective in a certain section of the periodic table, which nicely covers the major base metals. We're focused on copper, nickel, zinc and polymetallic versions of those three. The fourth area of focus is iron ore.

We've selected copper as our first focus because of the size of the market and the geography. We have done most of our work in copper, but we now also have operating systems in nickel and zinc.

On a lab scale, the technology has been very effective in iron ore, but iron ore is a very different flow sheet, so we have purposely set it as our fourth market in what we call our primary clusters.

We have five mine site customers at the moment – three copper, one zinc-lead and one nickel-polymetallic.

We were very much focused on North America and, in particular, British Columbia for our first pilots and trials as it was quite easy for us to service in our back yard. The first international market was Chile, for obvious reasons in terms of copper production, and we now have a full MineSense entity and team operating in Chile and Peru

We're staggering the rest of our global expansion. We're now quite active from a business development perspective in southern Africa – South Africa, Zambia, DRC – and have activity in Australia.

We have systems installed at two different copper mines in British Columbia, one at a very large nickel-polymetallic complex in Sudbury, Ontario, and will have a fourth system operating in Alaska. We also have two mines, but four systems, operating in Chile. By the end of Q2, we will have another three systems operating in Chile.

We did all our development work for the system at Teck's HVC operation and we're now completely commercial there. We officially commissioned our first system in December, the second system is being commissioned as we speak and the third and fourth will be installed and commissioned in late-March. This will completely equip their fleet.

IM: Teck has previously said the use of ShovelSense has resulted in "a net measurable increase in the amount of ore (and the associated head grade)" it has available to feed its mill at HVC. Are these results in keeping with your expectations for the technology?

JM: Yes, absolutely. We base everything on, what we call, our value model. Very early in our engagement process, we set out a detailed model that calculates the profit improvement that mine will see – we did the same for Teck HVC. We agreed on a target at HVC and are actually exceeding that estimate. Most importantly, Teck is also seeing that value and is estimating a great overall impact at that mine.

IM: Can you explain the design rationale of creating an upstream shovel-based sensor system for loading operations and a conveyor-based sensor system for downstream analysis?

JM: Let's start with the value created. We look at the value in two different categories; the first one is the actual change to the mass flow in the mine. Our definition is much broader than ore sorting and looks at the change in the way material flows. That is a very black and white calculation around profit improvement.

There are several different use and value cases for this, but almost all the mines have this basic one. That is, by working at the face, we're able to identify waste that is in the ore and remove that waste right at the pit

efficiently be separated into waste and ore piles. The laser sensor, in this case, detects quartz in the ore after it has already gone through an XRT-based process.

Robben was quick to dispel the opinion that existing mines are reticent about using XRT ore sorting in fear of underfeeding their follow-on processing plants.

"As the application of sensor-based ore sorting often leads to a reduction of total cash costs, it turns resources into reserves and actually increases the life of the mine. Marginal resources are turned into reserves, for example, at Wolfram's Mittersill mine in Austria, Coeur Alaska's Kensington gold mine in the US or Minsur's San Rafael tin mine in Peru."

Kroukamp, who with Cronimet has overseen the installation and running of several XRT ore sorting solutions, explains why there may be a need to apply more than one sensor-based solution at mining projects in the future.

"Once you start going into finely disseminated tungsten ores, especially scheelite, you get these little spots throughout the rock...When you start going too small, the [XRT] machine fails as a result of detection. The signal coming back is

TOMRA's Sorting Solution division installed nine of its TOMRA COM XRT sorting units, each with an operational width of 2.4 m, to process a 1,850 t/h sorter feed at Ma'aden Phosphates' $560 million processing plant at the Umm Wu'Al project in Saudi Arabia

before it incurs any extra cost. Then, when the shovels are working in waste, we can identify the ore. Every mine is aware of this – they call it 'losses' and 'dilution'. By identifying this, we are exchanging tonnes of waste for tonnes of ore, which increases the average head grade that goes to the mill.

It's very complicated to achieve it, but the math is simple.

This, in turn, can have a positive effect on the recovery curve by providing richer feed to the mill. Then, the last element from a profitability perspective, is you are putting more metal units into the front end of your mill and getting more metal units out of the back end of the mill. With the same infrastructure, you are getting more metal units and revenue so your NPV and ROI on infrastructure go up.

In terms of the importance or working at the face on shovels, the only opportunity you have to identify the ore that is in the waste and recover it, is in the pit before it gets hauled to the waste dump. After that, that ore is lost forever. That is one primary reason we are there with ShovelSense.

In addition to the mass balance, we're providing tremendous information on the orebody that the mine has never had before. If we're working at a mine, the mine plan may have one grade per shift based on this plan. We're now providing the mine with roughly 1,000 datapoints per shift on each shovel operating in the pit, which allows them to have a much more precise view on what is actually in the orebody.

Connecting that back to the BeltSense, there are mines that want to be able to pursue that precision mining concept and track selected mining units throughout the process. Not all the time, but often, our BeltSense is used in conjunction with ShovelSense so that what we're identifying at the rock face can then be measured at different downstream points. This tends to be for companies that have a more complicated downstream process – perhaps where blending is going on.

Most of our focus on BeltSense is on run-of-mine material, or primary crush, but we can work with any production size belt out there. One of the copper mines we are in discussions with has pretty much the fastest and largest belt out there; there are no limitations there and we offer a much more rapid measurement, enabling more precise selective mining units, than any other system out there.

The beauty of our technology is that the calibrations and algorithms developed specific to the mine for both ShovelSense and BeltSense are the same in terms of the ore properties.

IM: How do you envisage both systems working in a mine of the future where processes are automated?

JM: As I mentioned, we view ourselves as part of the smart mining and

By working at the face, ShovelSense is able to identify waste in the ore and remove it right at the pit before it incurs any extra cost, according to MineSense's Jeff More

digital ecosystem. We are in three different industry sectors – the mining space, the CleanTech space and IIoT area.

In the language of IIoT, we're very much an edge product; it is a complete hardware and software, machine-learning system that operates on its own, but there is tremendous value to be had by connecting that product into the rest of the digital ecosystem. The first step is integrating into software like fleet management systems, but a lot of the partners we are working with are primarily focused on how we can connect into and add additional value to their overall digital platforms. Another area is the automated systems and that is where our commercial agreement with Siemens is focused.

IM: Will you look to incorporate additional sensors into the ShovelSense and BeltSense packages to expand your metal and mineral reach?

JM: The answer is yes. We think there is tremendous market potential with what we are currently commercialising, but we do have other sensing types in R&D that we plan to introduce in future years. This could extend metal types, other elements important in the mine decision making process, and also non-grade characteristics. Our platform has been set up that we can add in additional sensors as we need to.