Kevin: Hello, everyone. I'm your host, Kevin Gordon. And today we are joined by Garry Noble. He is Thermo Fisher's senior application specialist. He's been dealing with PGNAA for a long time. I'll let him get into that. But his background is in physics. And welcome today, Garry.

Garry: Thanks very much, Kevin. Looking forward to the discussion.

Kevin: Very good. So, today's session, we're going to talk about PGNAA technology and how it fits in different applications and things like that. PGNAA is not a new technology. It's been around for a long time. So, Garry, tell us exactly what is PGNAA?

Garry: Yeah, so I guess just to touch on my background. As Kevin said, I'm involved in physics. That's my tertiary background. I've been working in PGNAA for over 25 years now. So PGNAA—it stands for Prompt Gamma Neutron Activation Analysis. It's an elemental measurement technique. It's not one that you learn about in university. It's certainly not something I heard about before I joined the industry. That's very much industry technology.

Garry: Like other elemental techniques, it's exploiting the nature of elements, bombarding with some radiation. In this case, it's in the form of a neutron. So we have a neutron source. We emit neutrons into a sample, and then those neutrons interact with the nuclei in the center of the atoms, the center of the elements, and that interaction results in some excess energy being generated. That energy gets released very promptly—hence the name prompt gamma—and a gamma ray is emitted, or multiple gamma rays can be emitted. If we measure those gamma rays, it tells us something about which elements are in a sample and based on the number of gamma rays that are emitted, it tells us something about the concentration of those elements.

Garry: It's a really powerful measurement technique because unlike a lot of other techniques that you may be more familiar with—like XRF—XRF is a surface measurement. The energy of the X-rays is enough just to penetrate a millimeter or so into a rock or into a sample. Whereas neutrons can penetrate through half a meter of rock or a belt loading of material on a conveyor belt or many tens of centimeters into slurry.

Garry: And then the resultant gamma rays are also highly energetic, and they can also penetrate through rocks. So you can actually see right through and within rocks on a conveyor belt. It's not sensitive to particle size variability or variation. You can see

through the entire layer of rock on a conveyor belt and provide a real-time analysis. So that's in a nutshell is what PGNAA is.

Kevin: PGNAA, big difference between that and other techniques is that bulk measurement technology, right?

Kevin: Yeah. That penetrative ability - really enables you to measure your ore, or whatever you may have on the conveyor belt, a lot more efficiently, or a lot more accurately than techniques like XRF.

Garry: And what's surprising is, I've been involved for 25 years, but you speak to people today and they've never heard of it. But it's actually had a really long history. It's been used in industrial applications for 40 years now. In fact, the first PGNAA analyzer that was installed into coal was deployed in 1985. So, there might be some people around that were informed then.

Kevin: I guess it's celebrating a 40-year birthday today—or this year. Yeah, so it's definitely not new.

Garry: Kevin, you started off in coal. Tell us a bit about your experience and how PGNAA really made itself known, if you like, in coal.

Kevin: Well, I think when we think about technologies like this, we always think about there's an adoption period, right? And not only customers, but like me—when I first started 23 years ago, I remember being at a coal-fired power plant, installing the analyzer. And we were getting ready to run coal for the first time. So I asked the operator, "What percent ash are you expecting?" And he said, "Oh, it should be around 47, 48 percent ash," which was kind of surprising to me because where I come from, it's a 10 to 12 ash product in terms of coal. So, I thought, huh, I've never seen it really measure this high.

Kevin: So, then we started running coal through it and the first analysis was like 47 and a half percent ash. At that point, I was a believer, 100 percent believer at that point. In coal, it's basically a blend-sort application. You might sort the coal out of the preparation plants and then you blend those together to meet your train target at the loadout. In a power plant, you might blend a high and a low sulfur coal to make sure you want to meet the spec of the sulfur from the boilers at the power plant. So very strong application in coal.

Garry: Yeah, so I didn't delve too much into the coal industry. When I first started in PGNAA in 2000, my first entry was into the cement industry. Back then, when I commissioned my first cement PGNAA analyzer, it was just sort of squeezed in between the raw mill feeders and the mill. A bit of an afterthought. And it's been really amazing to watch the journey of PGNAA in cement nowadays.

Garry: When new cement lines are built, the PGNAA lines are designed in from day one because it's been able to deliver so much value into the cement process that it's a

standard measurement technique now and it's a standard process control technique. In cement, they want to measure what's coming out of the quarry. Typically, you've got a limestone quarry. They want to measure the quality of that limestone and make sure that what they're delivering to the stockpile is on target.

Garry: It enables the mining operation, the quarrying operation to maximize the life of mine by being able to measure lower grade pockets within the quarry, blend it with some of the high grade to hit their target grade and maximize the life of mine or life of quarry. And then once they've built that stockpile closer to target, it means they don't have to add so many higher cost additives downstream when they have to blend in the silica, alumina and iron with the calcium from the limestone to hit the target chemistry for the kiln to produce the cement.

Garry: That blending of those additives is something that PGNAA now does as a routine application to ensure consistent feed and saving energy. I mean, you know all about the energy savings that cement plants get at the kiln.

Kevin: Yeah, and I think it's interesting when we talk about the adoption of PGNAA in certain markets. Now we see where the cement industry is utilizing PGNAA and it's a standard. It is designed into the flow sheet, but that has taken an adoption period as well, right?

Garry: Yeah.

Kevin: But that adoption period is pretty much over and it's just a standard in the industry. And I think another application too, Garry, is sintering for basicity control. I know you have a lot of experience in that if you want to expand a little bit on that application as well.

Garry: Yeah, so that application is well over a decade, probably getting closer to 15 years old now. In an integrated steel plant, the blast furnace is king. They need to make sure that they're feeding the blast furnace with the right grade iron, either lump iron ore or pellets or the other product that they manufacture in an integrated steel plant called sinter.

Garry: Sinter is an agglomerated iron ore product where iron ore fines are blended principally with limestone because the iron ore naturally has silica as an impurity and they need to blend in limestone to get the right calcium silica ratio. And it's that ratio control that PGNAA enables in real time where historically they would take a sample and it would take many hours to get a lab result back and then they could make a change. Well, now they're providing—or they're measuring in real time and making real-time control changes to dose the limestone and reducing variability by a factor of two typically.

Garry: And so it's a technology that's—yeah, we talk about 40-year birthday of PGNAA. It's over—1993 was the first cement cross-belt analyzer that went in. So, there's over 30

years of PGNAA in cement. It's at least 15 years since the first sinter one went in. And there's been probably 20 or so different commodities that I've had personal experience in calibrating analyzers and helping commission analyzers and support customers to use PGNAA in a broad range of different applications.

Garry: So yeah, there's this huge potential. Anytime your process has variability and your only window into that variability is some drilling that you might've done when you're trying to evaluate the resource and the grade within the mine. And typically, there's nothing until you send that material into the plant and you start processing. You crush it, you mill it, and then you get an assay in the process. And in between there's traditionally nothing.

Garry: We know that talking to process engineers and hearing stories about the mines not sending what we want them to send, or they're telling us one thing, but we're getting something else. And I just can't believe that there's mining applications and mineral processing applications where they have this problem of variability. It impacts the process. It impacts the recovery. It impacts the costs. And there's a technology that's been around for 40 years that can help solve that problem of understanding what they're sending to the plant.

Kevin: Yeah, one thing that I wanted to touch base on that you had just mentioned in terms of sampling. There are processes out there that are difficult to sample, maybe because of the high tonnage and the particle size and things like that. But it's also about representative sampling, because if you get a sample, if you just take one grab sample every eight hours, you really don't have anything. You don't understand your variability at that point.

Garry: You're putting a lot of faith in that one sample. Yeah. And that's where I think PGNAA has a huge opportunity to add value to any process where you're mining and either primary or secondary crushing, but still much larger particle sizes than it's practical to actually physically sample. And when there's variability that is impacting your downstream process, that if you have no idea what's coming, then you can't do anything about it.

Garry: There's a saying that I've been familiar with for a long time: if you can measure it, you can control it. If you can control it, you can optimize it. And the first step is being able to measure it.

Kevin: If you think about sampling, you're taking a picture. But an online analyzer using PGNAA technology is like taking a video.

Garry: Exactly. Yeah. So, you're flying blind. You've got the blindfold on really. You're trusting what you may have sampled or assayed a long time ago, being representative of what's still hitting the plant.

Kevin: One application that I see that is probably very difficult to sample is in copper.

Garry: Yeah, copper—you generally, you've got less than 1 percent copper in the ore. So, they've got to put a lot of tons into the plant, into the mill and into typically a flotation process or it could even be a leaching process. But yeah, there's a lot of tons and we've actually got some experience in PGNAA in copper. And it's been a real eye-opener to see the amount of variability we're getting on measuring the rock on a conveyor belt.

Garry: Typically, plants might be used to looking at the granularity of a block model or their mine plan, what they expect, their grade control on a daily basis or even a monthly basis. And everything's pretty stable. But when you put an analyzer on a conveyor belt and start measuring minute by minute—we can measure less than a minute, if need be, if the application demands it.

Garry: Typically, on a minute-by-minute basis, this operation—we've got an installation at Red Chris, Newmont's Red Chris mine up in Canada. The average truck load is about six minutes' worth of analysis. We're getting six analyses within each truck. And your truck is what you term your selective mining unit. When you load up the truck in the mine, it either goes to the process, or it goes to waste. But within that truck, we see variability that's not blended out through the material handling or through the crushing, but there's variability within each truck.

Garry: Now that information at a truck-by-truck level, if you integrate that and provide feedback to the mine on a truck-by-truck basis, you can identify things like misrouting of trucks. You can use that information to validate the mine plan, the block model or the grade control plan. And not only can you provide that feedback to the mine, you can also provide that feed forward to the process. You can start to understand exactly what you're sending to the stockpile.

Garry: Depending on what you've got in terms of stockpiling at your plant and what you can study and model and predict about the material flow through that stockpile, you can start to provide feed forward to the mill and to the flotation process. There are many locations within a flow sheet that you could utilize PGNAA.

Garry: One other application is on the mill feed belt after the stockpile because sometimes the material flow through the stockpile is not FIFO—first in, first out. There can be a lot of residence time that's hard to predict. And so, what you think you've got on the pile and what you think is going to be hitting the plant may not be exactly what is hitting the pile, what is hitting the plant.

Garry: Often a lot of these coarse stockpiles are sort of cone shaped. Larger particles roll to the outside, finer stuff sort of falls into the middle. And so, you get some variability that you can't predict or control. And putting an analyzer on the mill feed belt could give you that insight that gives you direct feed-forward information about what's about to hit the mill.

Garry: We're seeing some interesting applications of this elemental analysis in using it to predict things like rock hardness. And also, one of the challenges with any sort of

sulfide mineral process is potential acid-generating tailings. And being able to measure sulfur directly with PGNAA and measure some other elements that might be associated with the neutralization of sulfur in the tailings—you can start to use that feed-forward information to adjust your process to control reagents.

Garry: Other deleterious gangue that might be associated with the host rock like clays or talc—these are elements that we can measure with PGNAA that can provide important feed-forward information. That's opportunities. And then leaching is another one—measuring copper, sulfur, looking at different ratios to assist with the acid dosage. There are a lot of applications where just putting that measurement into the existing flow sheet provides incredible insight.

Garry: And once you've got that insight, you can start to make decisions about what you're sending to the process, how you're managing that material from the mine to the mill to reduce variability. Or it's an early warning system. It gives you insights to what's coming and then you can do something about it. If you have no idea what's coming into your process, you just can't respond.

Kevin: Yeah, I've always thought of PGNAA—when it's implemented into a process, it's kind of like putting a magnifying glass on the process. You might be going from getting a sample every eight hours or so, that sample may not be representative, but then you utilize PGNAA and it basically just changes the game. It tells you things that you've never known before.

Garry: Yeah, and that variability that we see even on an intra-truck basis—so within that six minutes of that amount of ore that's being dumped from the truck into the crusher and then spread out over about a kilometer of conveyor—we're measuring that one kilometer of material and there's potential to use this measurement technique to actually do bulk ore sorting. It obviously requires the infrastructure to be available, but this is where the opportunity exists to design plants of the future to take advantage of this analysis that's available, it's mature, but it's just not been implemented as effectively and as readily into mining applications compared to other processes.

Garry: In a cement process or a sinter process, what they're trying to produce is their actual product. They're trying to produce clinker in a cement process; they're trying to produce sinter in a steel plant. That's an actual product that's going to be mixed to a certain recipe. So, it's not quite the same, but that's where the technology has been really leveraged to the full. And it's a combination of the measurement technique and the infrastructure enabling the control.

Garry: That's where if PGNAA is going to deliver the value that I believe it certainly can in copper mining and mineral processing, there's got to be some co-evolution of implementing the technology with changes in the process flow sheet. It's a bit like the adoption of electric vehicles has to go hand in hand with the introduction of infrastructure that supports electric vehicles.

Garry: So, if you just have PGNAA as an afterthought—and my first commissioning in cement, it literally was an afterthought—and nowadays it's designed into the process. And I think that's the opportunity in copper mining and mineral processing: if the technology can be integrated into a flow sheet that enables that measurement, that real-time measurement to provide a level of control that the existing flow sheets just don't allow for, that's where the real value comes in with this measurement technique.

Kevin: Yeah, I can certainly see that. I think one thing that copper mining customers ask is, how do you calibrate the analyzer? Because they're running a belt that is 6,000, 7,000 tons per hour at 5 meters per second. That's a lot of material. So what would you say to that?

Garry: Yeah, well, that's the real critical aspect of designing and supplying an analyzer, a PGNAA analyzer, into any process. The prior preparation and planning—with anything in life—is critical to success. To deliver an analyzer into the field that hasn't gone through a robust factory calibration, you're passing the buck.

Garry: You're delivering a lot of problems to the customer because to try and do any kind of calibration in the field using any kind of samples in the field or expecting the customer to send certain grade material to try and do some sort of field calibration, it's time-consuming, it's onerous, it's costly, and it's just not the right way to go about it. So there's variability, as we talked about, in the material that's delivered to these processes. And it's not practical to try and calibrate in the field with field material.

Garry: You've got to do some preparation, discuss with the customer, get some data about their life of mine, the variability they're expecting to see, and actually design a calibration suite of samples. So, when you factory calibrate, you're calibrating across the full range of elemental composition you're expecting to see.

Garry: The other thing—I mean, essentially you need the measurement on the belt to account for all the variation that you're likely to see in the process. So, we talk about elemental ranges and elemental variability. The other thing that varies is the belt loading, amount of material on the belt. Tons per hour changes. And so, the amount of material that's on the belt does have an influence on the measurement.

Garry: You've got to incorporate that into your calibration, and you can do that far more effectively in a controlled manner in the factory. We do that. We have a calibration—part of our calibration is what we call the automatic belt load calibration, where we can load up material at different belt loadings in the factory and build that into the calibration. So when the analyzer ships to the customer, installed on the belt, it's ready to go from day one, producing analysis that's representative and accurate.

Kevin: That's critical. If we go back to the adoption thing—if you put it in day one and you're working, that adoption is going to take a lot quicker process. I certainly see a lot of advantages for the copper industry basically adopting this technology. We're starting to see a lot of interest from the copper mining sector. So, I think that's a good sign.

Garry: Yeah, I mean, there's a few interesting differences between copper and other commodities like cement and coal where PGNAA has, I guess, had its longest history. Trying to measure something that's only half to 1 percent of the rock is different to measuring something that's 50 plus percent of the rock. And so, the same analyzer design can't be expected to deliver the same performance in copper as it's had traditionally in cement and coal and sinter.

Garry: Yeah, we've had a—I guess, had a process of analyzer evolution and analyzer innovation over the years where we've identified what the needs are for different markets and developed the right configuration of analyzers that are going to be required to deliver the measurement that's needed in different applications. And that's certainly the case in copper. You've got to design and deliver an analyzer that's been configured to deliver the right analysis that's needed in that process.

Kevin: Yeah, very good. I guess to wrap up, Garry, we had mentioned a couple of times that 2025 is the 40th birthday of PGNAA. And I think that's wild. And if you think about it, I think the technology is still scratching the surface of its capabilities and industries, whether that's copper or refractories or what have you. Any kind of elemental blending process, PGNAA can help. And I think it's got a fantastic future.

Garry: I hope so. I think it's got massive potential, but there needs to be—there's a conversation that needs to be had. People have to be receptive to introducing measurement techniques that haven't been traditionally utilized in their industry. It's a proven, robust measurement technique that can add value if it's done in the right way.

Kevin: Well, fantastic, Garry. I really appreciate you joining today's podcast and we look forward to bringing you back later to talk about PGNAA. There's also an option for PGNAA in slurry. So, in future podcasts, we'll bring you back on and discuss that. So, I really appreciate you being here.

Garry: Thanks for the opportunity. Thanks, Kevin.

Kevin: Thanks, Garry.