AIME

Founded 1871

AMERICAN INSTITUTE OF MINING, METALLURGICAL, AND PETROLEUM ENGINEERS

ORAL HISTORY PROGRAM

Peter Hayes:
How a Meeting at the Pig and Whistle Influenced My Life Part

2018

TABLE OF CONTENTS

PART 1

PART 2

PART 1

00:00 Introduction

Mackey:

Hello. Today is Tuesday, August 28th, 2018. This is an interview with Peter Hayes, who is a professor of Metallurgical Engineering at the University of Queensland, Brisbane, Australia. Peter was Founding Director of the PYROSEARCH Centre at the university. My name is Phillip Mackey, and this interview is being conducted as part of the American Institute of Mining, Metallurgical, and Petroleum Engineers oral history project. We are sitting in the Westin hotel in Ottawa, Ontario, Canada, where we have been attending the Peter Hayes symposium, being held in honor of Peter. So, I thought we'd start, Peter, tell me a little about where you grew up and a little bit about your parents and what they did for a living.

00:57 The Early Years - Stourport-on-Severn, Worcestershire, England

Hayes:

Thanks, Phil. Yes, actually, I was born in England in a place called Stourport-on-Severn in Worcestershire. It's in the West Midlands. Stourport was a center for glassmaking for the 19th century. It was part of the manufacturing industry, industrial revolution, and also not far from Coalbrookdale, which is the site of the first iron blast furnace that used coke.

Mackey:

Interesting.

Hayes:

And, there's a bridge there called the Iron Bridge.

Mackey:

Yes.

Hayes:

And, it's still standing today.

Mackey:

Yes.

Hayes:

It was built by Abraham Darby (III), the younger in 1779.

Mackey:

Interesting.

02:02 Family - Link to Mining - Early Schooling

Hayes:

So, that's where I was born. My parents were, my mother's from Welsh stock, I guess. She's from a farming family, and my father came from Staffordshire. The history there was he worked in the coal mine as an electrician, and my grandfather worked in the mine as a train driver. So, we have a bit of history in the mining industry, and I would say the metallurgical industry and how far that goes.

Mackey:

Okay. So, your high school, your primary school, you could tell us a bit about primary and high schools and then what, or who influenced you to study engineering or study metallurgy in particular?

Hayes:

Okay. I'll start with the primary school. My father, after he was initially an electrician in the mine, but, during the war, he actually joined the Royal Air Force.

Mackey:

Really?

Hayes:

That was a career change for him, and he became a pilot and instructor. That meant, after the war, when I was conceived, we moved around quite a bit because, if you're in the forces, you don't stay in one place too long. You move every two or three years, usually. So, we moved around a lot. When I was very young, we went to what was then Southern Rhodesia, then back to England on the farm. I went to a primary school near the base, which was called Ewelme primary school in Oxfordshire. It's actually the oldest primary school in England established, I think, in 1437, around that time, and still operating today. The buildings are still there. It's quite remarkable, and it's still doing a good job.

Mackey:

They certainly did a good job back then.

Hayes:

Oh, I enjoyed that time, probably too much. Later on, I went to high school in Germany. My father went to Germany as part of the posting. It wasn't a German-speaking school. It was an English-speaking school for forces children. I picked up some German there, and I got to see a fair amount of Europe while I was there. That was a game-changer for me in that I didn't do that well in early exams. There was a system in England called the 11 plus, a gateway to decide your future education, and I think I must have been having a rough day because I failed the exam for this gateway. That meant I would not have been able to go to what was then called a grammar school in England, which is basically where you do high-level style academic courses. So, going to Germany was important for me because the school system was different, and that enabled me to develop progressively. So, I worked my way out from, I guess, under-achieving to probably achieving my potential, I think, by the time I finished. That was pretty important from an educational perspective to get that opportunity and time to develop.

06:19 Influence Toward Engineering

Mackey:

So, there you were, I think you went to the University of Newcastle on Tyne? How did it turn out that you chose to go there and you chose to do metallurgical engineering?

Hayes:

Yes, that's another interesting story, too, in that not that many people at the school I went to attended a university, partly because I think the children associated with the forces, they were moving school every three years, and that was very unsettling for most people. I was lucky in I spent six years in one school in Germany. I'm also lucky because I had a roommate who was actually very smart. He eventually went on to get a double first in physics and electronics at Manchester. He was very smart, and I guess we worked together as a bit of a team back then. What persuaded me to choose metallurgical engineering or metallurgy at that time was a book that I read. It was called Metals in the Service of Man.

Mackey:

I remember that book.

07:42 University System Expansion - Opening Opportunities

Hayes:

Yes, there were many editions to that; it was so popular. I think there were 10 or 11 editions, at least. That book gave an overview of the potential for developing new materials and how society would use them. And so, I got enthusiastic, I guess, about how I could use my maths and science knowledge because I wasn't brilliant in any of those. I was okay at maths, physics, chemistry, but I wasn't outstanding in any one of them, so there was no clear point at which direction to move. Metallurgy seemed to fit the bill, and it covered all of those things. I could use all of that knowledge. So, I decided to give it a go. Also, that was a fortunate period in time because that was a period just after the expansion of the education system in England. If I'd been born five years earlier, I would never have gone into this because a number of places or the percentage of the population that went to university was very low. Probably about three percent of the population went to university in that day. There was an expansion university system in the U.K., and Newcastle was one of those newer universities which were trying to encourage increased enrollments, I guess. So it all worked out for me in terms of timing.

Mackey:

I remember that book, Metals in the Service of Man. A little Penguin Book, blue cover. I think I still have it, by the way. So, then you moved to Newcastle and you finished your bachelor's degree. So, maybe you could tell us a little bit about university, Peter, during those three, four years and then what did you do after that?

10:05 Newcastle on Tyne, Northumberland, England

Hayes:

Yes, actually, there is a connection there to Canada and to Newcastle. Bert Raith was one of my lecturers; he taught me fluid dynamics.

Mackey:

He was good at it.

Hayes:

He was good at it and, eventually, came to Canada. So, there's a connection there to McGill. The other person who was there was a guy called Paul Grieveson who came from U.S. Steel fundamental labs. He worked with E. T. Turkdogan and Larry Darken. So, there was a tremendous pedigree there behind the teachers. Also, I worked with one of the professors. It was Professor Ken Jack; he was a Fellow of the Royal Society. He'd been in industry as well as being an excellent crystallographer. So, there were some really good guys on staff at Newcastle. It was really a good foundation, a traditional metallurgy course. It wasn't engineering; it was an Applied Science course in those days. It was a mixture of what we call physical metallurgy and extractive metallurgy, I guess, is the best way to describe it.

11:00 A Change in Direction

Mackey:

Right, so, Peter, then you graduated, probably with honors. What did you decide to do then? At that crosspoint?

Hayes:

I was lucky enough to get the medal for the graduation, as the top students graduating. I was pretty proud of that. I had only just managed to get into university, you know, managed to graduate. So, I still have that medal. But, yes, a number of things changed the direction of my career, I guess. I did have some experience working in the summer vacation, as most students do. They try and get a job to get some experience. I went to a company in Hereford not far from my mother's family in West Midlands. There's a company there called Henry Wiggins. I remember that Henry Wiggins was owned by Inco at the time, International Nickel. That company developed Nimonic alloys, which were used in gas turbine engines. So, I got to work in the processing development lab and to write some reports about reactions and performance of these alloys in gas turbines. I had to write out a critical report or review of what happens and select the test procedure, which would be most appropriate. It gave me a nice background, delving into reaction mechanisms and interactions between fluxes, metals, and things like that. So, that was a great experience.

13:51 Broken Hill - Bumping Into a Bit of History

Hayes:

The next year,1969, I went to Australia. This was, again, a bit unusual. At that time, the Australian government was looking to recruit graduates or students from the U.K. to emigrate to Australia. They were trying to encourage people to come to Australia, and, with the English Speaking Union, they put on a charter flight from the U.K. to Australia. I managed to save up a bit of money from working on the farm, and I just managed to scrape up enough money to buy the ticket to get on this charter flight to Australia. The other great thing about the scheme was the English Speaking Union had arranged with a number of companies in Australia to find employment. So, I actually went to work at Broken Hill in New South Wales. When I got there, I found out I was working on the south mine, the original mine, BHP, Broken Hill Proprietary. It was established way back in the early 1900s. So, I bumped into another bit of history there.

Mackey:

So, there you were, just about to graduate. Broken Hill, middle of the outback, digging up concentrate or a sampling concentrate, zinc. I think it was zinc concentrate. So, I guess you went back to the U.K. Did anything happen there that was of interest?

16:01 How a Meeting at the Pig and Whistle Influenced My Life

Hayes:

Yes, actually. I was working with a maintenance crew most of the time. I didn't go down the mine. I was working with the maintenance crew, which was pretty good because I got to see the difficulty in maintaining a working mill and doing maintenance on some pretty big machines. It wasn't like normal size screwdrivers; it was sledgehammers. I was lucky there to work in a job where I actually got paid. I got more money working there than I'd ever seen. It was a very rich mine at that time, and everybody was on the bonus, depending on the metal price. So, yes, I had some great experiences there. I got to see how the mill worked and how operations worked. I got to do some sampling around the plant. One of the things I managed to do was- there was an incident at the plant one Friday evening. I was seconded to level out the lead concentrate on the truck that was going down to Port Pirie to the smelter, and the weigh machine broke down. They had to stop loading the trucks. This was early on Friday evening. I was on the night shift, and so we got an early ticket. We all had to go home. So, it was Friday night, and everybody went down to the pub on Friday nights. So, I went to the pub - threw my clothes on. I didn't have time for a shower, so I was looking a bit grimy.

Mackey:

Lead concentrate everywhere.

Hayes:

Lead concentrate, lead sulphide, this black stuff, not quite like coal dust, but it looks a bit like that. So, I was looking a bit rough, and I went to the pub, and I recognized someone on the other side near the bar, a lecturer in geology. He was seconded to the mining department, to Broken Hill. I knew this fellow from a previous meeting, and he happened to have a couple of very nice looking girls in tow. So, I introduced myself to him in the way of getting to know the girls, which turned out to be quite fortunate because that relationship went on for quite some time. I had to go from Australia to England to finish my degree. And so, there was a long-term relationship started at Broken Hill at the Pig & Whistle, and after several years that lady became my wife and still is my wife now.

Mackey:

Fantastic. What a nice story.

Hayes:

I guess that influenced my future career and why I came back to Australia.

Mackey:

Right.

19:56 Research - Investigation and Problem Solving

Mackey:

We'll continue. Maybe tell us a little bit about; I guess you went back to the U.K., you graduated. Then, tell us a little bit about the next period.

Hayes:

I graduated in 1970, and, yes, I had this experience in Australia, I had experience in Wiggins alloys, and, at that point, I wasn't quite sure what to do. I went to some job interviews, obviously got an offer to work in the blast furnace in south Wales with the British Steel Corporation. Then Paul Grieveson, who taught me thermodynamics at Newcastle University, he was my mentor at the university, and he asked me if I was interested in doing research, doing my masters. I was quite surprised, but I'd done a project in the final year at the university using an electron microscope. That was my thesis project. I was looking at aluminum alloys and growth and precipitates of aluminum alloys as part of a project. I liked that idea of investigation and problem solving, and I really got on well with Paul Grieveson. He was quite an inspiration. Not everybody got on with him because he asked questions. He taught you to think about what you are doing and what you're investigating. He was an excellent teacher. So, he and Ken Jack, they had a high-temperature group. They were working on nitriding steel, and they asked me if I'm going to do a master's. I said, "You know, I'll give that a go." That sounded like good fun, and I really enjoyed that. So, I was doing that for about a year, and then I was told Grieveson was offered the Chair in metallurgy at Strathclyde University. Strathclyde University, at that time, the metallurgy department was actually very active in extractive metallurgy, quite well known.

Mackey:

Yes, quite well known.

Hayes:

A number of eminent people came through that system, and so, I had a choice. I could stay at Newcastle with Ken Jack, or I could go with Paul Grieveson to Strathclyde. I decided to go to Strathclyde. I was Paul's first Ph.D. student. That was a new adventure for him, I guess.

Mackey:

And you.

Hayes:

So, what I did was I wrote up my work in doing my masters and got that out of the way quickly and then went up to Strathclyde to do my Ph.D.

23:43 Strathclyde - Stockholm - the Million-volt Microscope

Mackey:

Okay. So, by that time, it's about '74. We could talk a little bit about Strathclyde, but then we'll keep going. You can talk a little bit about the Ph.D. work, the research topic. Fantastic university and great background. And so, then brought you to the end of your high degree. You could tell us a little bit about what happened then and how you decided.

Hayes:

Yes, I finished my Ph.D. in '74, so, I did it in two years, because I had a bit of a head-start on the experimental stuff on my masters. So, I was able to accelerate through the Ph.D. and did it in two years. As I was doing my Ph.D., I also had another break in England. I was able to go to Stockholm; we had a contact in Stockholm. When the Swedes were on summer break, they left the lab with a million-volt microscope. It was one of the few million-volt microscopes in Europe. There was one at Imperial and one in Stockholm. So, I designed an experiment as we had the microscope for, I think, a week, while the Swedes were away. So, we got on the ferry and went over to Stockholm, and, in two days, I did a chapter of my thesis by designing this experiment, which worked out like a dream. It was perfect. It showed more work, all I wanted to know in two days. It helped me grow and finish my Ph.D. When I finished that, I actually was offered to apply for a postdoctoral fellowship at Cambridge, the Goldsmiths Fellowship, which was pretty prestigious at that time.

0:00 Heading Back to Australia - University of Queensland

Hayes:

I had other priorities; by that time, my wife, Penny, and I were married. We got married in Glasgow. She'd come over, and I was looking to go back to Australia. So, I looked at the job ads, and there were two positions going. One was in Kalgoorlie, the School of Mines, and another was at the University of Queensland. I had no idea where Brisbane or the University of Queensland was.

Mackey:

East or West... [Laughs]

Hayes:

I had to do a bit of map reading, but I got offered the job as a lecturer at the University of Queensland in '76. My role there was quite interesting. I was hired as a lecturer in ceramic materials. That came about because the then professor at UQ, Geoffrey Chadwick, was trying to build up materials in that department, and he knew I had worked with Ken Jack and Paul Grieveson back in Newcastle as well as nitriding of steel. They had a group working on ceramic materials, and Ken Jack and Paul Grieveson had developed the Sialon ceramic materials so they could nitride base material, which is used quite widely commercially these days. So, they were at the forefront of that ceramic development, and I guess I got the benefit of the doubt since I was in the lab. I must know something about ceramics. So, I got the job with teaching ceramics at the University of Queensland.

Mackey:

And so, Peter, then in 1976, new Ph.D., new wife, new city, a new country. Actually, the second time you've been there. So, then you've remained at Queensland ever since and [had a] fantastic career. What were some other staff people there that had worked in various extractive metallurgy like copper and so on? So, you had to establish yourself, and I'd say it wasn't easy; you had to get recognized. What were some of the early experiences at Queensland, and how you decided to map it out?

29:15 Just Making Bricks

Hayes:

Yeah, it's quite interesting, though I'd say. When I started, I was a lecturer in ceramic materials. Part of the brief was to build up research and materials. But, unfortunately, in Australia, we didn't have a strong ceramics industry, relatively small country.

Mackey:

I guess you're just making bricks.

Hayes:

And, the only ceramics around were bricks. Actually having recently probably only been in Brisbane for 20 years.

Mackey:

The brickworks.

Hayes:

Although there was a strong thrust in North America to develop ceramic materials and in the U.K., that didn't translate to Australia.

Mackey:

Hard to imagine.

Hayes:

So, I had a tough time getting things off the ground. Well, I did manage to get a research grant from the Australian Research Council in my first application, was actually Sialon glasses, but I couldn't hire anybody I ever taught. There were no postgraduates, no postdoctoral. Eventually, I gave the money back. My first grant, my first research grant, I gave it back because I couldn't do the work. I felt it's not right to keep all the money if I couldn't do the work. I'm probably the only person who's given money back to the Australian Research Council. It sounded a bit strange at that time. I remember a professor who said, "Do you really want to do this?" In those years, I had to teach quite a few courses. In the first ten semesters, I think I taught ten different courses. As a junior lecturer, it was pretty full-on. There wasn't really much time for research. And, I had no hands to help.

31:24 Dramatic Changes - Teaching Ceramics and Extractive Metallurgy

Hayes:

But, there were some dramatic changes; I guess happened. One of my colleagues on the academic staff was a guy called Anil Biswas.

Mackey:

Yes, I knew him.

Hayes:

Anil Biswas wrote an excellent textbook on the iron blast furnace, published himself, which, at that time, was an unusual thing to do because most people would go to established publishing houses. Anil had also co-written a book on extractive metallurgy of copper with Bill Davenport. So, Anil was teaching extractive metallurgy, and I was teaching ceramics. One day Anil got very sick, and he ended up on the floor of his office with a heart attack, and he had to eventually retire. He had a heart operation. He lived a few more years, but he didn't teach any more at the university. So, that was on a Friday afternoon, and on that Monday, I was teaching Extractive Metallurgy.

Mackey:

Replacing?

Hayes:

Replacing Anil Biswas. I had to teach extractive metallurgy.

Mackey:

Plus Ceramics?

Hayes:

Plus Ceramics. So, it was a step change for me. I guess I had some background because I forgot to say between finishing my Ph.D., I did the British Steel Corporation Fellowship for a couple of years. So, between '74 and '76, I forgot to mention that. But, that's when I started looking at iron oxide reduction, kinetics, all of that.

Mackey:

Blast furnace iron-ore processing.

Hayes:

Yeah. So there was a connection. That's why I was interested in what Anil was doing, and he understood what I understood.

Mackey:

Right.

Hayes:

But anyway, I had to teach Extractive Metallurgy, and I was looking around for materials to teach the course and textbooks to guide the students. And, it started me, I guess, towards extractive metallurgy. At that point in time, I said to the head of the Department, "I've got to change direction here. Ceramic materials are not going to work for me. I have to go back to extractive metallurgy and to engage in that."

34:34 The Idea of a Book on Extractive Metallurgy - CSIRO

Mackey:

So, could you tell us a little bit about how the book, the idea of a book, whether you did a book and, and how the university, the work of the university progressed at that point, and when you went to any places like CSIRO?

Hayes:

It's funny you should mention that CSIRO was very active at that time. I guess after Anil left, then I was looking for a research direction because I know people in Australia. So, I actually went down to CSIRO in Melbourne.

I actually went to a Sabbatical leave to Imperial College in 1982. I remember distinctly that I was trying to write notes based on the fact that I had to teach all these courses, which I didn't actually know much about, to be honest. It was a very steep learning curve for me. So, I was gathering information about the teaching about that time, but then I went down for two or three months to CSIRO. I worked with Bill Denholm. At that time, he was in charge of the development of extractive metallurgy after John Floyd had developed the top submerged lance, SIROSMELT technology.

Mackey:

Yes.

36:22 Learning About Liquid Phase Systems

Hayes:

So, I had some experience with Bill. We did some experiments in the lab. I was helping him to do stuff there and started to realize that these were quite complex systems. There was a lot of technology changes taking place at that time, starting to get some awareness of that. I already had some experience with high-temperature experiments because during my sabbatical Paul Grieveson back at Imperial and I did some work on steel, and Paul was doing research on slag metal reactions and kinetics. So, I used that time at Imperial to learn a bit about liquid phase systems as opposed to gas-solid systems, which iron oxide reduction, which I had studied previously, and then came along working with Bill. We were looking at the reduction of lead oxide from slags. You've seen cases in slag reduction. So, my interest in slag systems, I took that design, that mini SIROSMELT smelter one-kilogram unit, that design back to Queensland and started building some apparatus.

Mackey:

Let's see, you brought it back in the car [[[crosstalk]]].

Hayes:

No, no, I brought the design back. I had to build it in myself. Luckily, we had an induction machine a large induction 25-kilowatt induction machine in the lab, which had been left over from foundry work. I adapted that to do some work in the lab. There wasn't much equipment out there, to be honest. There were a few furnaces, not much research equipment at all. It became clear that the extractive metallurgy couldn't move forward without knowing a bit more about the fundamentals of these complex solutions as these lead slags contained just about everything.

Mackey:

Yes

38:48 Reaching Limitations - The Need to Learn More About Complicated Systems

Hayes:

We were doing calculations, one-line equations on the back of an envelope. That's about the level of the technology that we had, and I got to think, “We're hitting a brick wall here. We're not going to develop any further until we know more. These systems were pretty complicated, and techniques people were using those days really couldn't get on further; we reached the limitations, especially in things like lead and zinc. Extremely difficult to characterize because of the high vapor pressures associated with those slags at high temperatures.”

Mackey:

Things would keep changing as you put them in the furnace. So, doing any measurements at equilibrium, chemical equilibrium, was basically not achievable.

Hayes:

Very difficult - impossible. After my experience in CSIRO, I went back to University, back to teaching. I managed to finish writing up my lecture notes and put them together in the form of a book.

Mackey:

I see that's how the book came about.

Hayes:

Yes. So, I had to get my thoughts together. I didn't really like the textbooks I was using for their approach. I wanted a different approach, and I wanted to integrate these ideas. In a way, because I was thrown in the deep end in teaching, I had to teach areas which I knew nothing about, hydrometallurgy, mineral processing. I only had the barest of background.

Mackey:

From the lead concentrate at Broken Hill.

Hayes:

Yes, and a very rudimentary bachelor's degree.

40:57 Writing and Publishing Process Selection in Extractive Metallurgy

Hayes:

So, in a way, I was a student. I was learning, so while I was teaching, I was asking questions, which I would hope that the students would ask and that helped to shape the structure of the book. So, instead of writing the book as an expert in the field, which most books are written by people who have been working a long time and, in the field, eminent researchers. I was writing the book from the point of view of someone who was trying to learn and understand how these things got connected. The way they were teaching things, I couldn't see how one reactor was connected to another. Why would we choose this combination of technologies to get to this endpoint? Why don't we go this way? Why don't we go that way? So, the structure of the book was really to try and explain why we do the things we do and why we choose a different technology. That was my first shot at it. I know my first trials were pretty awful.

Mackey:

The book is successful, has been since the 30, 40 years.

Hayes:

The book was successful. I had to go and try to find a publisher, and nobody was interested because the market was pretty small. Since Anil Biswas had published his own textbook, I said, "I'm going to do it. I've done all this work; I'm going to do it, I'm not going to waste this." So I published and marketed it myself. I wrote to all the universities I could, metallurgy departments around the world, and said there's this book here, and I got some reviews organized.

Mackey:

This was all before the Internet?

Hayes:

No Internet.

Mackey:

No Internet. Hardly faxes.

Hayes:

This was before computers. We didn't have a computer.

Mackey:

You wouldn't have.

Hayes:

Everything was typeset. We had no computer word processing.

Mackey:

Using lead from Broken Hill for the typeset.

Hayes:

Probably.

[Laughs]

43:31 Setting Up the Minerals Process Engineering Degree

Hayes:

So, that went well. Then, I managed to persuade the head of the department to put on some extra staff. So, before then, some other event happened. 1985 was another event because, up to then, the metallurgy program and being a single degree program, and they decided, some of the staff decided, to set up a materials and manufacturing degree. So, that meant half the class, or 50 percent of the class, were going to go to materials and manufacturing. And, there were two academic staff members left to teach process metallurgy, John Kleeman and myself. Coincidentally, John Kleeman was the plant metallurgist at Broken Hill south when I did my vacation work. It's remarkable; it was such a small world there. There's no way I knew John was going to move to Brisbane, and there's no way I knew I was going to Brisbane. So, we ended up together, the two of us teaching the whole of the metallurgy program, and that was a tall ask. At that point in time, I said, there's no way we can teach all of this. I started to look around about how else we could still deliver the metallurgy program, at the level that we need to teach, because I knew there was stuff that I wasn't good enough to teach. At that point in time, I enlisted the help of the chemical engineering department. We were in separate departments at that time. We were in mining and metallurgical engineering, and chemical engineering was another world. So, I approached the then head of chemical engineering and said, "Look, I want to set up a program where our students come to your department and take your courses in mass and energy balances and even mass transfer and those types of courses." So, at that point in time, I set up what was called a Minerals Process Engineering degree. That was a crisis point. We could have gone then. The whole metallurgy program could've been shut down at that point. So, that happened. I managed to recruit, at that time, Hae-Geon Lee, who came from Korea. He was a visiting postdoc. I had gotten some money to do research by that time, and so, Hae-Geon helped to teach some of the Thermodynamics, and we got a helping hand. We started to progress with the research, still looking around at where the focus might be. I did a lot of work on fluid flow and gas injection. We were looking at refining systems. But, I hadn't cracked this problem systematic problem.

Mackey:

Complex slags.

Hayes:

Yes, I got some money to start some work. I thought initially that we might be able to do this using a Knudson cell mass spectrometer type system.

Mackey:

Right.

Hayes:

Which had been used to measure activities?

Mackey:

Yeah.

Hayes:

In alloys. Vapor pressures.

Mackey:

Yeah.

Hayes:

So, I actually got some money to send a postgraduate student to France, to the university there where Chatillon was doing some work. He was an expert in that technique. He had a multiple cell, Knudson cell mass spectrometer facility. It turned out that that wasn't going to work because the systems we wanted to study actually had aggressive slags and pressures that were too high for that system. And, they were very aggressive, and so they attacked all the crucibles, and it just didn't work. So, my first attempt ended in abject failure. And so, we had to start again, look around.

48:44 Development of a Thermal Quench

Hayes:

Some of the work I'd done on gas-solid reactions in the '80s, I'd done some work for BHP and Rio Tinto on the reduction of iron oxides, particularly in kinetics and mechanisms. And, what we designed there was a reactor where we took some very small, single crystals of iron oxide and dropped them into a furnace and held them in the hot zone of the furnace and then quenched them out after a specific reaction time. This design was using small samples, so they'd come to temperature very quickly. I was able to do the partial reduction. Then, we had this device which released the sample, and it dropped into liquid nitrogen. That produced a twofold effect; it was a thermal quench, so it went from six or seven, 800 degrees centigrade to minus whatever. And, at the same time, because of the liquid nitrogen, it gave off nitrogen gas, so any residual hydrogen or CO got quickly diluted in the reaction system. So, that was a thermal quench that we developed, and we were able to see what the reaction mechanisms were and look at the interface between the growth of the iron and iron oxide on reduction. That idea of the quenching, we thought we might be able to utilize that to try and capture some of these equilibria. So, moving on now into the early nineties and, at that point in time, Mount Isa mines had a very active process development group. Roger Player was heading up; he had a team of very good engineers in the process development group. And, part of what they were doing is developing the lead Isasmelt. They had a pilot plant at Mount Isa, which Roger helped build, and these guys and Steve Matthew, one of my Ph.D. students, was actually on the team. So, we persuaded Roger to give us some funding to solve this problem about the liquidus temperature on these lead slags because nobody had a phase diagram.

Mackey:

No, too complex for the phase diagram that existed.

51:55 Lack of a Phase Diagram

Hayes:

It was lead, zinc, iron, lime, silica, everything in there, and there was a problem because the viscosity of the slag was critical to being able to tap the slag, obviously in the end of the smelting phase. The temperatures they were running at, they had solids in the slags. It wasn't a fully liquid slag. It was a solid-liquid mixture; it was a slurry, and controlling the percent solids was critical to running a smooth operation. With no phase diagram, you couldn't predict at what percent the solids were. There was a big argument about whether these solids actually formed on cooling because people would take samples from the furnace. So, are these solids formed on cooling, or were they there in the furnace? Nobody knew.

Mackey:

They didn't know.

Hayes:

At that point, I had gotten some funding, and I was able to recruit a recent immigrant to Australia, a guy named Eugene Jak. He'd just recently come over from Russia. And, I had this money; I'm on my way through Sydney airport. I said, "Eugene come out of we'll have an interview. Let's have a talk." At that point in time, I said, "Do you want to come and work on this project?" So, that's how Eugene Jak started.

Mackey:

That's '90-'92 about?

Hayes:

Yes, and so, Eugene went to Mount Isa, and we took samples of the slag, and then we started. I had some previous experience looking at lead and zinc sinters in the blast furnace, and there my understanding of metallography and material science actually was very important because I'd started using phase analysis, and we started using an electron microscope to identify the phases present in lead and zinc blast furnace sinters. And, we had a very old electron microprobe to do that earlier work; it was just about on its last legs.

Mackey:

Not many of those.

Hayes:

This was in the department, and there was nobody to look after it, and sometimes it would work, and sometimes it wouldn't.

54:30 Cracking the System - Changing the Technique - Constructing the Phase Diagram

Hayes:

But, the university at that time, in a very important initiative, they decided to set up the electron microscope facilities as a central facility rather than having them in separate departments with separate researchers. These were expensive equipment items. So, the university decided to invest in this microprobe. And, I said, "Let's use it, okay, and see if we can identify these phases?" I've already started some work with another student on some of the slags in trying to identify, I guess, the phase formation from lead blast furnace sinters, a student, Jason Nairn. That was the first time we started to think about how we can put these complex systems together, how would we could simplify them down in a way that we could understand them and use them on the plant. Anyway, Eugene was an excellent student, and we managed to crack this system and develop this technique where we took small amounts of material and then quenched them. Because they were so small, we were able to cool them, and we changed the technique from what people had previously used. It was a complete 180 degree, turn around about the technique. Previously people had made up mixtures of certain bulk composition and then equilibrated them and then quenched them. But, if you tried that in the lead-zinc slag, you couldn't do that because of the composition change. So, any sample that you had bore no resemblance in composition to what you started with. We turned things on its head, and so, we equilibrated these samples at a fixed temperature. So, we knew what the temperature was accurately, and then when we quenched the material, we analyzed the individual phases, the solids, and the liquids, and that gave us the solidus and the liquidus. And, from that, and doing a series of experiments, we were able to estimate the liquidus surface and the solidus and construct the phase diagrams. And then, we put that together pseudo-ternary phase diagram, and we're able to deliver to Mount Isa, the first phase diagram for lead zinc smelting slag. And, it all went from there. The PYROSEARCH Centre was subsequently established.

Mackey:

It began about then.

Hayes:

Well, it followed after that.

Mackey:

Sorry, Peter, to go back. You started then to collaborate with Art Pelton and Chris Bale, about that point?

57:53 Working with the Coal Industry

Hayes:

Yes. What happened was, after Eugene was finishing his work, we had an opportunity to work with the coal industry. There were several large research centers being set up, Cooperative Research Centre for Black Coal Utilisation. One of the major problems in coal utilization was what happens to the ash? When you burn coal, you're left with the mineral matter. And, one of the key properties in marketing coal was the ash fusion temperature. Up till then, they'd be using very empirical approaches. They would take samples of the ash and do cone tests, softening tests. Okay. So, they have a softening point, melting point, a hemispherical temperature. It was very empirical, and, to a metallurgist, it looked pretty awful, to be honest. And, I approached them and said, "Look, we know stuff about slags, and let's have a go at this. I think we need to take a new approach. This is a complex slag." I'd also, at that time, thinking about how we've described thermodynamics, and I was starting to look around, say, ”We've got all this data now, which we didn't have before, how are we going to describe it?” Because I wasn't a modeler, I'm not a thermodynamic modeler. So, I looked around the world at who's doing this stuff? I went to the U.K. National Physical Laboratory, and they were doing some modeling and approached them to see if they were interested in a collaboration. But, they had an arrangement with another set of companies sponsors, and there was a no go there. And then, I went over to Canada to talk to Art Pelton, and I said, "Look, Art, we're going to be producing a lot of experimental data. It could be useful to provide that basic data to help develop these thermodynamic models." So, that's how the collaboration with Art Pelton started. And, I went back to the Coal Utilisation, CRC, and said, "Look, we can start modeling stuff and give you a new tool to be able to predict the slag liquidus and solidus temperatures, you don't have to go into these techniques." So, I got the funds to send Eugene to CRCT (Centre for Research in Computational Thermochemistry) in Montreal for a year.

Mackey:

He spent a year there?

01:01:04 Developing FactSage Databases

Hayes:

He spent a year there, and, during that time, he put together that data on the lead-zinc database that was the first lead zinc database in FactSage, and he did that while he was there. When he came back, then he had a whole new system to work on because the coal ash slags are really iron oxide, silica, lime, and alumina, which is the basis of metallurgical slags. And, that was the basis for setting up another database for FactSage. So, again, that was a major project. Eugene then spent several years putting together that database, and we sent all of that database back to Montreal to FactSage, and they're still using the basis of that database today.

PART 2

00:21 Developing Techniques for Characterizing Complex Slag Systems - Synergy

Mackey:

Well, good morning, Peter. Well, it's now Wednesday, next day, and we're continuing with the discussion. Peter, I think yesterday we stopped off was around 1992 or 1993. Eugene had spent a year at Ecole Polytechnique with Art Pelton and Chris Bale and then he came back to Queensland. So, maybe we'll pick it up there. Eugene comes back.

Hayes:

Yes. So, Eugene had done his postdoctoral work at the CRCT in Montreal, and that was funded principally by coal companies at that time who were looking to see how they could predict the properties of ash resulting from coal combustion. But, that basic system, the alumina, silica, iron, lime system is really the basis of a lot of metallurgical slags. And so, there was a clear synergy between coal ash systems and what we wanted to progress in terms of developing the phase equilibria and developing techniques for characterizing these complex slag systems. So, there was a synergy there. Eugene started work on the FactSage databases. He had already, during his time in Montreal, prepared the lead slag database with Art and Sergei, and he went on to do the base system for the coal ashes and then build viscosity models based on the thermodynamic models. So, that's the basis of extending the thermodynamic database into physical chemical property modeling that also started at that time. That was an important growth period for us, and strong relations with Montreal helped us develop that. At the same time, the experimental techniques that we started to progress with Eugene started to produce some really good results. So, we'd extended our range of systems from originally the lead smelting slag systems at the Isa smelter at Mount Isa. We went on to do zinc blast furnace slags, which nobody previously characterized because of the difficulty in handling those zinc, high zinc slags, and extending it into other systems. So, there was a period of progression into a whole range of different systems - Cerro Matoso, nickel smelting slags, and it just grew. The list grew, and it turned out to be [a] very successful development. And, as we went along, the techniques that we expanded the range of chemistries and started to push into areas which people hadn't been able to measure previously. And, I think industry then started to take notice of that and say, "Well, we're getting close to the slags that we're using in our plants rather than idealized binary or ternary systems, which are a long way away from metallurgical practice." And so, I think we gained traction with the industry. And then, industry support started to come to keep the momentum going in the development. So, things were going quite well into the early two thousands, and that also led to the establishment of the Pryometallurgy Research Center, which we call PYROSEARCH.

05:04 Establishment of the Pryometallurgy Research Center - PYROSEARCH

Mackey:

So tell us a bit about that, Peter? How that began?

Hayes:

Yes, the then Head of the Department of Mining and Metallurgical Engineering, Don McKee, clearly, he's supportive of the fact that we were being successful there, and we also had an entrepreneurial vice chancellor that time, Paul Greenfield. He was previously Head of Chemical Engineering, and I knew him quite well. The climate was right, I think, to progress to the next level, and not just being an academic working with a research group but to actually expand the activities. And so, the university had embarked on this policy of establishing centers within different departments and within the University (of Queensland) to enhance the profile of those research activities. So, the opportunity came up to establish a center. Eugene and I worked together, we're I guess cofounders of what was then called Pryometallurgy Research Center. We gave it the acronym PYROSEARCH to try and give a commercial edge to it, and we've used that ever since. And, I think that's been quite successful; as of 2018, it's still going. We changed the name slightly to Pyrometallurgy Innovation Center, recently, for a number of reasons. But, that's going well. And, I was the founding Director of the center and Eugene was the Research Director. And, subsequently, Eugene has become the Director, and I stepped aside, so he's driving that process.

07:23 Cerro Matoso – Work on Complex Slags

Mackey:

Peter, tell us a little bit more. You did lead slags, zinc blast furnace slags, in between, I think, copper slags, ferrite slags. And, tell us a bit more about the nickel laterite slags. Cerro Matoso was interested in some work. On a complex slag?

Hayes:

Yes, Cerro Matoso is nickel laterite process and, that particular operation, BHPs operation Cerro Matoso, the slags were in the silica primary phase field, which is a bit different from most of the other laterite deposits in South America and other places. And, there really wasn't much information about that. There was only one previous study on that system. I think it was Bowen and Schairer, you caught me there a bit on the reference.

Mackey:

I think it was a Billiton study.

Hayes:

Yes. BHP Billiton at that time, and they were in the silica primary phase field. There were issues about understanding the liquidus temperatures of those slags and how the impurities might affect that. And, the technique that we'd developed enabled us to measure those liquidus temperatures. So, this was important for furnace integrity because of the establishing the cooling characteristics in the furnace and the super heat between the alloy and the slag knowing that information and we were able to show the effect of alumina. For example, one or two percent alumina in the material had a dramatic effect on liquidus, 50 degrees (Celsius) drop in liquidus temperature for every one percent alumina, and I think we did a pretty good job in characterizing that system and extended that further out into the olivine and pyroxene fields. So, I think that was very personally, I was quite satisfied with that study. And, I think it turned out to be quite useful.

Mackey:

Yes. Okay.

10:02 Technical Contributions to the Industry and Recognition - Reaction Kinetics and Mechanisms and Development of Experimental Techniques

Mackey:

So, Peter, we've just talked about the various slags and metal systems lead, zinc, copper, nickel, significant work in nickel. And, that work continued with some other systems. Maybe we might sort of discuss some of what you think the technical contributions to the industry and perhaps any recognition that this work has identified within the community.

Hayes:

Yes. Thank you. So, I think my contributions have been in a couple of areas. One, my on-going interest in reaction kinetics and mechanisms. So, something I started way back when I was doing my British Steel Corporation fellowship, and I still have interest in, those gas solid reactions. I'm still doing research on that and characterizing that. So, I feel I have made a contribution in that area, I'll come back to that in second. And, the other area is really the development of these experimental techniques to provide us with this additional information on the phase equilibria. I'm not personally a modeler, thermodynamic modeling. That's not my expertise, but I can bring my knowledge of micro structure and relationship to phase equilibria in thermodynamics and bring that connection and help to identify what the important things that we should be measuring. And, I think that's led to the development of the techniques and now the development of the modeling. I think that's laid a platform for us going forward to develop these tools, which are now being incorporated in computer packages. So, at the time we set out the computing capability that we had in the world, it's a bit hard to comprehend now, but when we started out, the models were very simple. And, computing power was very limited. So, now 20 years on, everybody uses computers, the speed and capacity of the computing systems are so much greater. And, that means the potential for use of these databases as predictive tools instead of being something that's just an academic interest is now becoming a mainstream tool that the industry uses every day. And, I think it's been satisfying to see that transfer of fundamental knowledge into practical tools that the industry can use. I remember talking to members of the coal industry back in the early nineties and saying we could develop this tool, and there was quite a bit of resistance about why do we need this stuff, and we're never going to use these esoteric approaches in our industry. And now, the reverse is true that everybody goes to the thermodynamic models and data that's available as a routine part of the planning and development of their technologies. So it's a complete reversal. To be part of that I think has been quite encouraging and some of our work has been acknowledged. Yes, I'm happy and quite proud to have received some awards from TMS, science awards from Extractive Processing Division for some of the papers we produced in Metallurgical and Materials Transactions. I'm quite proud of that. We're at three awards from TMS and also from CIM and Institute of Metals and Materials in London as well. So it's good to have some acknowledgement from peers, and I've been lucky enough to get some acknowledgement this year in the symposium here in Ottawa in my name. I feel quite humbled by those acknowledgments.

15:27 Changes in the Australian Industry and its Influence on the Center

Mackey:

Yes, I agree. The symposium has been a remarkable event, and it's still going on. So, Peter, you're working in Brisbane, support from Mount Isa. I think you mentioned we could, perhaps, cover that a little bit. Mount Isa was several hours flight away from Brisbane. You did a lot of work there, I think work with Kalgoorlie and so on. So, what about changes in the Australian industry, how you saw that influencing the work of the Center and then you were reaching out to Canada, you worked in Columbia, and possibly perhaps some of the Japanese industries? So, how did that all mesh together, and how did you will those changes?

Hayes:

Yes, that was part of management on my part, I guess. I had to find sponsors, I guess for our research. At that time, in the 90s, there was still active research going on at the University of Melbourne, there was the G. K. Williams Research Center, and-

Mackey:

And Port Pirie I guess [cross talk]

Hayes:

Pasminco and Port Pirie Associated Smelters, South Australia. The establishment of the research center in Melbourne attracted support from most of the Australian smelting community. We weren't part of that Center. And, because of limited funding available from industry at that time, there wasn't a lot of scope for us to do research and to have a research funded. So, basically, to survive or to expand, I had to go and seek an industry outside Australia, and so, I traveled to South Africa and Europe, around the world to get research sponsors. We also had difficulty getting government sponsorship at that time. The fact that we had difficulty in getting funds internally meant that I had to go overseas and help us to internationalize our operations, which, in the long run, that was a good thing to do rather than looking internally and relying on local support. So, we started with very strong support from Mount Isa Mines. I focused on the lead and zinc, and then that continued with the Xstrata. But, we broadened our base, if you like, internationally. So, that's really how we extended operations. And, I think that helped us in the long term, as I say, to broaden the range of systems that we studied.

Mackey:

So, Peter, how do you - you're now global, and what sort of changes in the industry have you seen and how does that affect the work of the center, and where do you see some of these changes going? How will the center react to the various changes, mergers, acquisitions, a rise of China, and so on and so forth?

Hayes:

Yes, so there's been quite a big change in Australia, the number of smelting operations has decreased, a relatively small number, and they've increased other places in the world. So, Australia's becoming more an exporter of concentrates rather than the processor of those minerals into refined metals, which personally was a bit disappointing. I would like to see Australia do more with the mineral wealth that it has.

Mackey:

I agree with you.

20:10 Importance of Predictive Tools

Hayes:

But, that's not my decision. On the other hand, we are able to support other operations, and it's heartening to see the resurgence of process metallurgy in Europe because of the realization of the need for recycling of metals. As time has gone on, we've actually moved more into those areas and support, metals recycling. So, we have strong support from European metallurgical companies now and helping those companies to handle the diversity of the elements in more complex systems, chemical systems, more elements, and different combinations of elements coming into metallurgical operations. And then, for the need for these predictive tools is becoming more and more important because we can no longer deal with systems which are relatively simple coming from the ore, but we're adding into the mix all sorts of combinations of primary and secondary materials. So, there's a broad spectrum of elements which need to be recovered. And the predictive tools, as I say, are becoming more and more important. And, I think in the future, not only help us in process development but, ultimately, we'd like to see those tools incorporated in actually in the operations, in determining the optimum conditions in the processes and in the optimization of those complex flow sheets. So, where the partitioning of the different elements between process streams to be able to predict that and to design and to operate the different unit operations at optimum efficiency. So, I see the application of the basic data now flowing back into the industry. And, as my colleague, Eugene Jak was saying in the symposium today that he'd like to see a predictive virtual reactor type of model so that industry can predict what's going to happen. So, we can use, basically, feed forward control in our process systems rather than reacting to things which had happened half an hour or two hours ago, in which we've got no chance at all in controlling.

Mackey:

No, I think this is fascinating, Peter and I guess that's where you see the work of the center moving. I think somebody said yesterday, one of the presentations, something like 80% of the gold that has been mined is still in circulation. And, I suppose that's a similar figure for copper. So, that all connects with what you're saying about the circular economy that's commonly used today.

23:54 Changes and Making Improvements in Education – Establishing a Strong Research Presence

Mackey:

Peter we- very interesting discussion about how the center was internationalized, working globally, but meanwhile, back at the university, another primary role is education and education of undergraduates and, I guess, postgraduates. So, maybe we can go a little bit back in a parallel kind of activity, how you saw changes in the education and how you made improvements and how it's seen, and maybe we'll cover it towards the end of this little segment. How can we attract more students into mining and metallurgy?

Hayes:

Yes. So, in the late '90s and early 2000s, the focus was on establishing a strong research presence, and I put a lot of effort into that. In 2004, the university, and particularly the (Engineering) faculty at UQ, was faced with financial difficulty. There was essentially a 10% cut in budget that had to be made. Metallurgical engineering was one of the smallest programs in the faculty, so, we were in the firing line to whether we would continue to exist. In fact, we'd lost one of our senior professors because there was a 10% cut in staff in all schools. So, that threatened the life of the metallurgy program, and, to be honest, we were within two weeks of being shut down by the university. The Executive Dean or the Dean of the Faculty, he was very sympathetic to what we were doing, but he had a job. He had to balance the budget, I mean, that was his job. But, I managed to persuade the Dean to talk to some people in industry and say, look, this is a very important program for the industry. If you shut this down, this is going to have a major impact. And, there was a person, one of our former graduates, Joe Pease, who was with Xstrata, previously Mount Isa Mines. I contacted Joe and said, "Look, Joe, we really need to get someone talking to University about the potential impact of this change." Joe then made contact with the industry and the Australasian Institute of Mining and Metallurgy (AusIMM), and we managed to persuade the then dean to set up a working party between the university and industry to look at the future metallurgical education at University of Queensland and also mining because there were some questions about the mining program at that time. So, they set up a joint working party. I was asked to be on that working party representing the metallurgical industry, and the education potential, I guess, from the university side. And, the industry came to the fore, the panel was chaired by the president of the AusIMM, and out of that working party, they analyzed what was necessary to keep the program going. At that point in time, I proposed a dual major in Chemical Metallurgical Engineering as the way forward to provide the skillset for the industry and to provide pathways to attract people into the program.

28:47 A Radical Departure - Keeping the Program Going

That was a bit of a radical departure from the then types of structures conventionally offered in metallurgical engineering. But, that was taking into account, I guess, what the industry needs were in terms of skills and attributes, but putting together a program that we could actually deliver. The other point was that, there was no way in the world, with the numbers of students or graduates that the industry wanted in Australia, there was no way that that was going to be economic from the university's perspective. In fact, the maximum we could possibly achieve was maybe 50% of the cost of putting on these programs. The minimum class size would have to be 50 students for every year (to be economically viable). And at that time there was no program in the world that produced 50 students in metallurgical engineering a year. It was an impossible target. Then, industry came to realize that, and so, there was an agreement that, if our target was about 25, that represented half of the costs. The industry would contribute in various ways to make the other half. So, a partnership between university and the industry was established and that led to support from the Minerals Council of Australia, essentially supporting the equivalent of one academic position. Then Xstrata also contributed a position, the chair in metallurgical engineering, and BHP, through BMA, also supported a position. So, we had three academic positions, which were essentially supported by industry funds and the other three were contributed by the university. And so, both sides were happy. The university was happy that they were getting some support to keep the program going, and that gave us the potential to hire staff because at that stage, I was the only person left in metallurgical engineering.

Mackey:

Plus Eugene.

Hayes:

Eugene was a part of the research center. He was not funded by the university. That was all funded by external funds. I was the only one left standing. It was one of those periods in time where, as you said, it could have gone quite easily. So, the fact that we had support from industry meant we could go out and hire people again. And, that's what we set about doing. The duel major in chemical metallurgical engineering is still going now. It's been quite successful in attracting students into the program. Flexible entry into the program, but we haven't thrown out the specialist metallurgical engineering components. We combined the core metallurgical engineering with the process engineering from chemical engineering, and we have a good working partnership with that branch of the discipline now.

32:33 Mining and Minerals Industry – Part of the Solution to Environmental Problems – Attracting Students

Mackey:

So, Peter, that is continuing, and, perhaps, we could talk a little bit about that, and, then, how do you see continuing to attract students in terms of the fact that mining is often seen as an environmental problem? I liked the comments that were made yesterday in some of the presentations that, in terms of climate change, recycling, circular economy, that I think the comment was, mining is part of the solution rather than causing the problems. So, do you want to comment on some of those aspects and attracting students and so on?

Hayes:

Yes, I think if we go back 30 years ago, 40 years ago, that mining and metallurgical engineering were seen as specializations. With this dual major program, we've tried to broaden that context so the students have more flexibility in their career paths because they come out with a degree in chemical engineering as well as metallurgical engineering. Flexibility in career paths was the important factor at that time when we set up the program. Also, the industry was conscious of the environmental impact of mining in Australia, maybe 20 years ago, and I think that was an important environment to recruit students. Unfortunately, I think we've had a regression over that period of time in the attitude of some of the major companies who've walked away from the environment. And so, there's been opposition to and denial of the impact of CO_2, for example, on the environment. And, we've also seen a decline in support from the major industries. So, I think if we're going to attract people back into the industry, we have to have a climate change from the industry to get back to the message that they were promoting 20 years ago; that is, they're also taking care of what they do with their resource; that they're going to rehabilitate that land and the mine. They're going to take care what they do with their waste.

35:20 Metallurgists - Guardians of the Elements

In Europe, it's very encouraging that that is taking place. I think we have to spread that message to other parts of the world, if we're going to attract students back into the discipline and give them this challenge about being what I call the guardian of the elements because that's what I think metallurgists are. Eighty-five percent of the elements in the periodic table are metals and, as metallurgists, we should be looking after that resource. The other thing I think industry needs to do more to attract students is to get them involved. There's been a disconnect between the industry and their recruitment. So, the industry assumes that there is a ready supply of graduates coming through and, essentially, since the financial crises, the emphasis has been on cost cutting, and I think we have to give our young engineers experience on the operations to show them really what the potential is, where the career paths are. So, I think getting employment vacation, employment experience to first- and second-year engineers is critical to attracting those young people into the industry, so we can show them what the possibilities are, show them what impact they can have on the industry.

Mackey:

Okay. Yes, because the center is working internationally, but the day to day lecturers and students come into the university by working more nationally, so I guess you've got a dual kind of function, and I think you're right. The industry needs to be re-educated on how they can get the people to run the plants that they want to run to keep them in business. So, that's a very interesting point.

37:44 Working to Internationalize in the Undergraduate Program

Hayes:

There is a follow on now, which I'm embarking on the sustainability of our program. Now, what's happening recently is that those supporters from industry who I said supported half the cost of the academics, those supporters have gone away now. Minerals Council has now withdrawn its funding. So, we've lost the funding for that academic position. Glencore has stopped funding the Chair in metallurgical engineering. BMA has also stopped that funding. So, we're now back in the situation which we were back in 2004. So, it's another of those cycles, and, now, we are looking to how we can support ourselves and how we can support these metallurgical programs. One of the things I'm working on now is internationalizing in the undergraduate program. There is a great demand for education in China, so there is an incredible investment in education. I'm setting up agreements between Chinese universities and Indonesian universities and other places to take their engineers, after the first or second year, and have them transfer to the University of Queensland to complete their specialist education in metallurgical engineering. So, we're looking to internationalize the undergraduate teaching as well as the research now. And, I think that's, well, that's the only way forward I can see at the present time, and it fits into, I guess, the needs of the community in those societies who are developing the technologies in extractive metallurgy.

Mackey:

I can just see the CEO of a major company coming to Queensland and saying, ”What are you doing? Where are my Australian graduates?” Well, he didn't support it. So, you've got up to dual challenge.

Hayes:

Yes, that's right. I'd like to see more Australian undergraduates in our programs.

Mackey:

But they're not there.

Hayes:

But, I would like to see Australia industry saying, “Well, we need you guys.” And, not just when we need them, but all the time. We're building processing plants, which are lasting for decades. We need an education plan, which has the foresight to see what the educational needs are for those decades, to keep those plants running and to keep improving the technologies and efficiencies of those plans.

40:55 The Role of AIME and its Member Societies – TMS and SME

Mackey:

I think Peter we're near the end of the discussion on the career, attracting people, milestones in the industry, and the impact. We might just talk a little about the role of AIME and perhaps the different member societies, TMS, SME, and so on. How has been your involvement with TMS, AIME, and SME?

Hayes:

Yes, I've been a member of TMS since 1980 and also the AusIMM and that corresponded to the time in which I, essentially, changed from focus on ceramic materials to extractive metallurgy. And so, that was a way which I could become familiar with the industry, to make contacts within the industry and learn about what the priorities were within the industry. So, that networking is very important, a way of getting me in contact with people across different branches of the industry. Otherwise, you're stuck in silo in a particular university, in a part of the world, which is a long way from everywhere else. So, having this connection with professionals, metallurgists in different parts of the country and different parts of the world has been important. And, that gives me an opportunity, through international conferences, such as the Extraction 2018 program that we have here, of bringing people together and sharing experiences and trying to work out a way forward and to establish collaborations with industry. That's one of the focuses of metallurgical engineering at the University of Queensland, which has been going now for more than 60 years. And, University of Queensland has a strong focus within this dream collaboration. So, keeping those connections and having opportunities to meet those people is very important.

Mackey:

That's excellent. Well, I think we've covered the areas we wanted to talk about Peter. Is there anything else you'd like to bring up or mention before we close the interview?

43:54 The Need to Promote the Vision of the New Era in Metallurgical Engineering

Hayes:

Yes, I think an important part of the message we have to get over to potential graduates if we're going to attract people is to promote the vision of the new era in metallurgical engineering. I feel like, I think we've been through the down cycles economically. Metallurgical engineering is changing dramatically. The technology is changing dramatically. The focus on a broader range of elements, elements that people hardly heard of a couple of decades ago, are becoming critical to supporting our technological society. The number of elements we use in computing systems and our communications, iPhones and new energy generation. This is new metallurgy, it's the next generation of metallurgy. And, I think that's the thing that we should be promoting to attract the new generation of metallurgist and expand and build on the technologies and tools that we've been developing in traditional branches of metallurgy. So, I see that the last 50 years has been developing a platform for development to this next stage. Because we all need metals, we'll continue to need metals, and we're going to continue to need metallurgists into the future.

Mackey:

No, I think that's very, very interesting. Peter. They're good comments and let's hope you can continue that role.