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ORAL HISTORY PROGRAM

Raymond Decker: A Life Full of Serendipity and Discovery

2022

PREFACE

The following oral history is the result of a recorded interview with Raymond Decker conducted by Eric Nyberg on **DATE**. This interview is part of the AIME and Its Member Societies: AIST, SME, SPE, and TMS Oral History Project.

ABSTRACT

Raymond Decker, a leading researcher in superalloys, has had a 70-year career progressing the advancement of knowledge and technology in the field of metallurgy. Decker's inventions have had significant contributions to some of history's most notable discoveries. His development of maraging steel played a role in both the exploration of the Titanic and the Apollo 11 mission to the moon. An entrepreneur, influenced by his mother and father, Decker started the company nanoMAG to progress the healing of bone fractures by manufacturing human bones from magnesium alloys. Following the three-legged career stool analogy he adopted from his mentors, Decker built a successful career by having supportive research partners, staying healthy through exercise, and being a part of technical societies for continual learning. Serving as ASM president from 1987 to 1988 and an active member of TMS since 1950, Decker states that these societies have served as his learning machine through the years. Through his university appointments and society contributions, Decker has become an influencer for the next generation of material scientists.

Readers are asked to bear in mind that they are reading a transcript of the spoken word, rather than written prose. The following transcript has been reviewed, edited, and approved by the narrator.

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55:00 A 70-year Career Progressing the Advancement of Knowledge and Technology

00:20 Introduction

Nyberg:

Hello, I'm Eric Nyberg. I'm a Product Engineer with Kaiser Aluminum in Spokane, Washington. I'm also the current TMS Light Metals Division (LMD) chairman. And, today, I am pleased to be able to interview Dr. Ray Decker, who is going to give us an oral history of his career and background. And, we're very excited about that. Ray, could you begin by giving us a little bit of career background, and where you're at today?

Decker:

Yes, thank you very much, Eric. This is Ray Decker, and I'm currently Chief Technical Officer of nanoMAG LLC and an active member of the TMS LMD Magnesium Committee. I'll give you some background here, and I hope to cover six topics: early background, my college and military service, technical inventions, continuing university activities, technical society activities, and national activities. But, I'll start out with the early days in the family.

00:46 The Yearn to Learn and Earn – Influence of My Parents

Nyberg:

Well, why don't you give us a little bit of background about your family, and how you all got started in the field of metallurgy to begin with, Ray?

Decker:

I'm not going back to 1869 but back to 1930. Growing up on our family farm in upstate New York – Afton, New York, on the Susquehanna River – a small dairy farm under 140 acres. And, as far as family goes – my parents and siblings – my mother was an English, history teacher, and she imparted a yearn to learn. And, my siblings, Charles, Sylvia, and Martin, and I all did learn. We all went to grad school. In contrast, my father dropped out of school at eighth grade to become a farmer. But, he also became an entrepreneur, and he taught us a yearn to earn: to work hard with objectives, endpoints, with productivity, applications, as a result of our hard work.

Nyberg:

So, Ray, it sounds like your mother and father both influenced you quite a bit in the way that you're definitely an entrepreneur, and you've had a very successful academic and education career as well. So, it sounds like both of your parents had quite an influence on you as an adult?

Decker:

That's very true. They had a real influence. More and more, I realize that as I age, as I mature. One part of this was farm boy, and we had chores very early. Once we reached about 10 years of age, we had assigned daily chores and responsibilities, things we had to get done every day. And, one was I had a few cows to milk before school and after school. Then, we produced cabbage for the New York City grocery market, a yearly crop. Another crop we produced was maple syrup. We had many maple trees. This is a sap bucket in which we gathered the sap to be then boiled down to maple syrup. So, again, earning and producing.

Nyberg:

Excellent.

04:13 Following My Uncle's Career and My Coach's Advice

Decker:

Then, high school was in the Afton New York High School, and it was quite diverse, Eric. All the way from sports, music, journalism, and, then, leadership of the student councils. And, here you can see that I already planned to be an engineer, that was following my uncle who was my model. He was a Lehigh engineer graduate who became a Colonel in the Ordnance Corps in the Second World War. So, I wanted to follow his career.

Nyberg:

That's amazing.

Decker:

My favorite sport was basketball. Here I am, a skinny kid. But, here's the key guy. I had a mentor [Tubby Crane] who was my gym teacher and coach all the way from K through 12.

Nyberg:

Ray, what ways did he mentor you in that regard?

Decker:

He was very rigorous on ethics. You don't cheat, you don't lie, and you take a straight line there. And then, secondly, you're part of a team. Always work with the other players, assist everybody working with you, socially be a team in your endeavors. Very influential in what I did. After this, I followed on in exercising. I went into softball in the Army, then played squash later, and today still go to the weight rooms, and do a little bit of running even today to keep up the physical exercise, which I recommend to everybody.

Nyberg:

That's good advice to us. We should all take a bit more of that advice with us every day. Well, thanks for that background.

06:18 From Metal Working with My Dad to The University of Michigan and Growing My Family

Nyberg:

How about as you moved into the university era?

Decker:

Eric, I chose the University of Michigan, which was a surprise for a New York upstate boy. But, Michigan offered low costs. It was a top-notch engineering school in metallurgy, and it offered a job. I got a part-time job insured, and then I was able to take ROTC following the pattern of my uncle, Jim Bisbee.

Nyberg:

What led you to the field of metallurgy at the university there?

Decker:

Well, my father he had a shop. He did welding, metal bending, built things out of metal. So, I had a taste for hands-on metallurgy, and that turned out to be a strong department of engineering at Michigan. And, I got a part-time job, which I'll describe, which really nailed me into metallurgical engineering. So there, I started off in 1948, four years of excellent training. But, midway through that, serendipity came into play in 1950. I joined TMS and ASM, both technical societies, as a sophomore. Then, I got a real good part-time job, double the pay, now at $1.35 an hour. And, that's when I launched my alloy design career with a great mentor, Professor James Freeman. And, the other serendipity, I got engaged to my eighth-grade friend, Mary from Afton, and that was a real good, lucky move.

After finishing my bachelor's, I was called into the service during the Korean War, and I served as an Army Ordinance Lieutenant for two years. And, the first assignment was on metallurgy of the atomic cannon. And, my leader there was Colonel Jack Wallace, who later became the Foundry Prof at Case Western University. My second year was spent in France in the army headquarters in La Rochelle, France, the administrative office in the ordinance department of that headquarters. Real good, two years of schooling. I'll mention some family first. We had four daughters, Mary and myself: Susan, Betsy, Cathy, and Laura. Then an extended family with our daughters and husbands: Stewart, David, and Rick, and then 16 grandchildren that you see here, but five are missing. Bill La Croix and Emily and since this picture, Betsy and her husband, Dave, adopted three more kids: Mattie from Africa, Josie from Haiti, and Josiah from China. So we ended up with 19 grandchildren, and, not seen here, of course, are eight great-grandchildren. So, a great family.

Nyberg:

Well, congratulations on that, Ray. That's an amazing family that you have there, and I'm sure it keeps you busy every day with things going on in the family. That's incredible.

Decker:

I'm now known as Pa-pa-pa.

10:29 My PhD Thesis Discovery – The Cause of Broken Turbine Blades and A New Superalloy

Nyberg:

Oh, that's great. How about your career as you started moving into the professional world?

Decker:

Yes, Eric. So, after the Army, back to grad school at the University of Michigan, Dr. Freeman guaranteed me a job when I got out after the Korean war, in 1954. So, my first assignment was to study nickel-based superalloys and the variability of turbine blades in jet engines. There was a lot of problem at that time with broken turbine blades in the hot end of the engine, which ran at 800 degrees centigrade. And so, I undertook trying to find out the secret of all the variation. And, I was very lucky; serendipity struck again. And, I found out that during processing of the alloys, one called Udimet 500, the base, no trace elements, a life of only 50 hours, poor ductility, which was the reason for the broken blades. But, during processing, we picked up boron and zirconium, which we then added in minute amounts. We got 10 times the life and seven times the ductility and very good performance on turbine blades at that time. So, that was my discovery on my PhD thesis with Professor Freeman, 1957.

Nyberg:

That discovery led you a long ways after that, I think?

Decker:

Yes, and we had technology transfer very quickly. Before I even finished my PhD, the University of Michigan and NACA had a symposium in 1957. That was the precursor to NASA. And, we had attending GE, Westinghouse, Universal Cyclops, Allegheny, TRW, Special Metals, and International Nickel – all producers of nickel-based superalloys. And, we did a tech transfer at that one-day meeting, and the practice boron- zirconium went into commercial use in less than a month. The secret was cleaning up the crystal boundaries of the alloy, the nickel-based superalloy, by large zirconium atoms and small boron atoms, which accumulated at the grain boundary. So, that was real fun.

Nyberg:

Ray, who was the company that commercialized your alloy?

Decker:

All these companies commercialized it.

Nyberg:

Oh, amazing.

Decker:

They used that technology very quickly. I got job offers.

Nyberg:

I bet you did.

13:28 A Career of 24 Years at International Nickel – My Colleagues' Notable Inventions

Decker:

With International Nickel, it was international, and that was, at that time, a Dow Jones company. So, it was quite attractive, and I took a job there in 1958.

Nyberg:

I bet they were very happy to be able to hire you after that discovery. You were the expert in the field.

Decker:

I certainly was happy with that situation. So, I had a good career, 24 years, at INCO, starting 1958. And, this is a picture of our Sterling forest staff in the 1970s. Here I am. Later in the seventies, I became the corporate vice-president of research, managing a lot of research at Inco. But, there are several notable inventions by my colleagues, not me, but by my colleagues, and I thought it'd be good to list some of those inventions. For nuclear tubing, Al McElree and Harry Copson, Cast Inconel 713 IN 100 for turbine blades, Clarence Bieber, Mechanical alloying by John Benjamin. US coins, we now use laminate dimes and quarters by Jere Brophy, Bob Gibson and Bob Trapp. Compact graphite cast iron by Bob Schelleng. Processing for manufacturing cisplatin cancer drug by Gaylord Smith. INMETCO recycling of steel mill waste by John Pargeter.

Nyberg:

That's quite a bit of development work that was happening at that time and under your direction.

Decker:

And then, in addition, nickel battery electrodes by INCO Canada and Europe labs. Nickel alloy weld wires, Charles Witherell. Super plastic stainless steel, Jere Brophy, Bob Gibson and Wayne Hayden. Stir cast aluminum nickel graphite composites for wear resistance by Frank Badia, Hydrogen storage for autos by Gary Sandrock. Genetic engineering for bio-leaching nickel ores by Cal Cupp, Nickel rounds for electroplating decorative coatings by Bert Knapp. Now, those were all other colleagues. I was not the inventor on these, but I had the pleasure of sharing a lab with these great inventors. But, onto my invention of maraging steels in the early part of my career at Inco.

16:16 The Invention of Maraging Steels and Clarence Bieber, the Great Superalloy Inventor

Nyberg:

So, where did you head after that period of time with Inco?

Decker:

I went on to Michigan Tech University as Vice President of Research. I'll get to that a little bit later in the talk here, Eric.

Nyberg:

Okay.

Decker:

The maraging steel was the upside-down steel, quite different than conventional steel. It was a concept of Clarence Bieber, who was the great superalloy inventor. Clarence did not have a college degree, but he was very inventive. His first lesson he taught me was to use the best hypothesis, plan at your desk, and get out in the lab. Watch and observe the experiments as much as you can. Get out and watch the melting, the working, the tensile testing, etc., and you'll run into serendipity. You'll see things you didn't expect that you wouldn't see sitting at your desk. So, I followed that, but here was the concept.

Rather than conventional steel quenching to a hard, brittle martensite, then tempering back to a softer martensite with up to 280,000 PSI, have enough nickel so that you can air-cool a soft, workable iron-nickel martensite with no carbon and then age up to a very strong, tough martensite with up to 350,000 PSI.

Now, the first composition Clarence developed was hardened by aluminum titanium, and it turned out to be a bottleneck. It was poor in toughness, poor in corrosion, and poor in weldability. So, Inco set up a project team to try to solve the problems. INCO had a creative research program where you could try wild ideas without a lot of need for approvals from management, and serendipity hit me again there. And, we came up with a cobalt-moly-hardened version which had higher strength with toughness, good stress corrosion, and good weldability, invented by myself, Alan Goldman – a summer student from NYU – and John Eash, a cast-iron metallurgist.

We discovered this with small, two hundred-gram melts in two weeks by hardness tests. By luck, one of those six compositions today is still the commercial Fe-18-Ni-7-Co-5-Mo 250 grade. This was scaled up to commercial heats of 20,000 pounds in six months, went to commercial use in less than a year. And, here are some of the markets that were developed by Inco's market development department: aircraft jet engine drive shafts for GE, wing hinges for the French Mirage, aircraft production tooling, and aerospace rocket motor cases spun out of the soft martensite and aged. Then, Apollo 11, Apollo applications that I'll talk more about. Then, finally, into hydrospace, in the CIA clamshells, and the MIR 1 and MIR 2 hulls that I'll talk about.

20:04 The CIA Game – An Operation for Maraging Steel to Recover a Russian Submarine

Decker:

First, the CIA steel clamshells. This was thought to be an operation to gain nodules from deep in the ocean, iron-nickel nodules under the auspices of Howard Hughes and the Glomar Explorer and clamshell operation down to 16,000 feet. With Allegheny Ludlum Steel Company, we developed this maraging steel clamshell. It was supposed to scoop under the nodules, pick them up, and bring them back to surface.

The true game, the CIA game, was to recover a sunken Russian submarine, the K-129, deep off Northwest Hawaii, that was successful. The maraging steel clamshell brought a portion of a Russian submarine to the surface. I didn't find out the real meaning of this cover until 2010. I still thought it was mining nodules until it was openly revealed, in 2010, that it was a superb CIA operation.

Moving further into sub, Mary and I visited Finland for the opening of the ASM Finland chapter in 1988. At that meeting was the Vice President of a steel company, Locomo Steel Company. He invited us to see their plant the next morning. He picked us up in the limousine, drove to the plant. We went through guarded gates into a new building, and he said he would show us something that the Russians were doing in that building, on behalf of the Russian Academy of Science.

22:09 Exploring the Titanic and Apollo 11 – My Steel Below 16,000 Feet to 240,000 Miles Out

Decker:

They were building the Mir-2 and the Mir-1 submersibles in that building. Here you see the plastic streamlined plastic of the Mir-2, but inside were two cast maraging steel hull hemispheres, eight feet in diameter with welded on flanges and then maraging steel bolts. Within that, a crew of three were submerged to 16,000 feet. And, these were used in the exploration of the Titanic and the IMAX movie Titanic. And, here we see from the Mir-1, we see a view of the Mir-2 examining components of the Titanic. For that cast maraging steel, we had a special invention, along with Ed Sadowsky, where we went through the martensite reaction two times to get a finer martensite, a finer precipitation phase.

But, from that depth of 16,000 feet to 240,000 miles out, maraging steel bolts were used on the moon in Apollo 11, 1969. Apollo 11 landed with a lunar module on a platform, bolted to a platform. But, after exploration, the two astronauts, Armstrong and Aldrin, climbed the ladder into the lunar module, then they had to leave and part away from the platform. The module and platform were joined by four maraging steel bolts. Here, you can see components of those bolts. They were redundantly, explosively sheared. Four bolts had to go off twice at the same time by electrical stimulation. They had to go off at the same time and successfully explode and separate, or the two astronauts would not have been able to return to earth. And, here I have some of those components, souvenirs that I was given by Grumman Aircraft. This is test number 164 of many test samples that were tested to assure the proper separation of the lunar module and the landing platform.

Nyberg:

I don't think there's too many people on planet Earth that can say the material they developed was used and is sitting up on the moon right now. That's amazing, Ray.

Decker:

And, this piece right here is still on the moon; not this one, but a similar piece is still on the moon.

Nyberg:

That is absolutely incredible. That's amazing.

25:21 Maraging Steel's Worldwide Influence and Applications

Nyberg:

So, Ray, that's pretty incredible stuff there. Where else was maraging steel used in, or do we see it today in your career?

Decker:

Well, here's another one, Eric. Mary and I were in Moscow at the Steel Institute, and we ran into the case where Russians used maraging steel for their Olympic epees. The story was that their 1986 gold medal winner was killed in an accident during practice where a steel epee snapped and penetrated his mask. So they moved to maraging steel, tougher, more ductile epees in the Russian Olympic Epees.

Then, another application is in golf clubs, making the face of the golf club, the driver, out of maraging steel to give a trampoline effect, an acceleration of the ball as it leaves the face of the driver. And, here's the bad one. We worked with the national labs to adopt maraging steel for centrifuges for processing uranium. And, that was stolen by AQ Khan from Pakistan, who then became the father of the atom bomb in Pakistan; and, they sold the technology of centrifuges to Iran and North Korea. So, that was a real bad story coming out of the invention. But, moving on to thixomolding, semi-solid injection molding of thixotropic magnesium alloys.

27:07 Thixomolding – Technological Innovation Across 13 countries and the Field of Light Metals

Nyberg:

This was when we met in about 1999, Ray.

Decker:

Yes. This is where we started to work together on committees and work together with work you did at Pacific Northwest. Yes. Basic research was done by Dave Spencer and Mert Flemings at MIT. Then, the applied research by Dow Chemical, Norb Bradley, and Robert Busk, and we picked it up. We did a deal with Dow to start a company to commercialize the technology in 1989. My partners were Dave Dawson and Bob Carnahan. It went much further than we had hoped. It now is 550 machines in 13 countries around the world. Still growing today from that period in 1990. Our partners for Dow Chemical, Spalding, Lindbergh, Comalco from Australia, Amtech from Canada, and Japan Steel Works from Japan.

Nyberg:

In the field of light metals and castings, thixomolding has become a very well-known terminology, and a lot of that resides right there with you, Ray. So, congratulations on that achievement as well.

Decker:

Thank you. This is a principle of the thixomolding, a pictorial of the machine: starting with chipped raw materials, heating in the hopper, then introducing into a rotating, reciprocating screw, where the granules were heated, partially melted and sheared, and then suddenly injected, shot into the mold making a part, a net-shaped part. It used thixotropy; it's like honey: the faster you spread it, the more fluid it becomes. Same thing with metals, semi-solid metals. This is what a small machine looks like. They're now made up to 1300 tons. This is a 220-ton machine. It's a safe, clean environment. It's a portable foundry. Machines have been moved several times from country to country to reach 13 countries.

Applications, the first one was in Japan was Sony, the Walkman, which you're familiar with, then into laptops, cell phones, DLP projectors, digital cameras, etc. And, surprisingly into sporting goods: bicycles, Shimano fishing reels, Oakley sunglasses, K2 snowboards, and Shaggy non-vibrating skis. Then motorcycle fairings with Buell Motorcycles. Then into autos for various applications, including seatbacks and quite a few boxes for gear shifts, etc. And, finally, into the medical field: with toolboxes for the surgeons, lightweight, and now into knee braces where we manufacture magnesium components for the DonJoy ortho nano knee brace, lightweight, and they've sold well over 250,000 of these lightweight knee braces. And, this moved us into the biomedical field.

30:58 nanoMAG – Manufacturing Human Bones from Magnesium Alloys

Decker:

We started up nanoMAG for magnesium alloy body implants in 2012, a startup along with Steve LeBeau. And, effectively, we manufactured human bones from magnesium alloys, fixing bone fractures. Our principles of alloy development, we wanted a bioabsorbable magnesium alloy to fix bones. We micro-alloyed to get the right corrosion rate and the right strength for bone replacement. With body nutrient elements – magnesium, zinc, calcium, manganese, all of which you'll find on the vitamin pill bottle – we picked co-segregating elements, that is, small zinc atoms and large calcium atoms. So, it gets segregation in the alloy. Then, we process for less than 20-nanometer microstructures, viewed at 3 million magnifications in the atom probe in high-definition electron microscopy. Then we designed in <c+a> dislocations on the pyramidal planes of magnesium to gain ductility, avoiding rare earth additions.

My co-inventors were Steve LeBeau, Dan LaCroix, a summer student from Michigan Tech, and Jake Edict. We got the targets from Elizabeth Perepezko of Zimmer Biomet. And, here's the nanostructure at 3 million magnifications. Alpha manganese particles of 8 to 120 nanometers for fine grains, and here are the actual zinc and calcium atoms, small and big co-segregated on planes of the magnesium matrix. The size of the zones is 0.5 by 15 nanometers to strengthen the alloys. Micros done by Professor Allison and Makiheni of the University of Michigan. Examples of implants are for arm fractures or fixing ACL's, for dental vertical augmentation and for mid-phase fracture fixing. And, here's the conversion of the magnesium alloy to bone. This was done in a rabbit femur in 52 weeks. Here, we see part of the original implant, then eating in on the implant is a transition layer, and then eating in on the transition layer is new bone. Here's a calcium map, electron micrograph, showing high calcium in the bone to assure that it is bone. And then, you can see some calcium in the transition layer. So, effectively, these layers are moving in and eating up the implant, making new bone, implant to bone.

Nyberg:

You know, Ray, I broke my leg years ago and had to have a stainless-steel screw put in there. And then, 10, 11 weeks later, another surgery where they had to remove that screw. And, I wish I would have had one of your magnesium screws in there, and I could have been done with it the first time.

Decker:

That's the purpose. You have a screw to replace titanium or stainless steel, where you often have to take the permanent implants out. Our purpose is to dissolve and avoid that possibility.

Nyberg:

Yeah, that's great.

Decker:

You're a good test sample. You should get ready as soon as we can.

Nyberg:

I'm finished with those injuries, I hope.

Decker:

We've had a large NIH-sponsored project in a canine model, with 76 canines, on healing the jawbone. And, here we see that four weeks after the operation, the fracture's partly stabilized. You can see the screws; the plate is in the background. But, after 52 weeks, the bone is entirely healed, better than titanium. A part of the screw has already started to dissolve, to absorb. Now, we broadened this out with partners, always partners, to dental vertical augmentation of the jaw with University of Pittsburgh, Sports Medicine, with MDC, spine restoration, with the University of Michigan, ACL's with MDC, and foot and ankle fixation by MDC. Our partners being Andrew Brown and Professor Charles Sfeir of Pittsburgh, Rob Ball of MDC, Professors Steve Goldstein and Ken Kozloff of the University of Michigan.

There are some possible additional benefits of these that we're still working on, one being antibacterial effects to prevent infections. Then, a possibility of osteoporosis treatment and ear bone restoration. All these need to be thoroughly investigated. All of these need to be passed by FDA before they can be used on humans, but we're pushing toward that. So, here's my recipe for alloy design in application coming from those technical investigations. Have our basic research foundation, apply computer software, go to the lab and confirm and observe the experiments. Look for serendipity by the Princes of Persia. Go to the library, go to the technical societies: TMS, ASM, MRS, for their support. Apply market development from the start, then stir vigorously with your partners.

Nyberg:

That's definitely proven to be a good recipe for success. I'd say you've got one-of-a-kind parts on the moon, and then you've got parts that every one of us holds in our hand in cell phone components. So, that's really amazing, Ray. I really liked the part where you use the computer to design the alloys, but then you always emphasize getting out there in the lab and witnessing, so you can observe those serendipitous moments. That's really important, I think.

38:08 A Message to Future Materials Scientists – The Best Things Are Yet to Come

Nyberg:

Thanks, Ray, for all of that. I know everyone is going to really appreciate that. I think with your experience, and so much that you've seen, I wonder if there's any recommendations you can give to the next generation of material scientists, metallurgists, and, in addition to that, maybe your vision of trends you see materials going into the future.

Decker:

Yes. Glad to comment, Eric. The opportunities for young people are very numerous in the field of engineering and materials engineering. We have some outstanding challenges, like in energy, like in climate change, which could be very exciting to attack and very satisfying when you solve practical solutions to these challenges. Our tools are much better. Our knowledge is much better. So, it's a very exciting prospect for young people these days. And, from where I sit right now, I think the opportunities are greater than they ever have been, and the best things are yet to come: many surprises, much serendipity, and much application of technology to solving the world's problems. So, you've got a great career ahead of you approaching science and technology. That's the message to all people entering the field.

40:08 Materials Science, An Evolving Field – A Future in Additive Manufacturing

Nyberg:

What's your take on additive manufacturing, Ray? That's a huge topic in today's materials world. Where do you see the additive manufacturing and the integrated computational materials engineering, these areas in particular?

Decker:

I've paid considerable attention to that Eric, good question. I'm on the board of QuesTek Innovations, which is a leader in the field. So, I observed their activities now for eight years. It's very exciting, very promising field, very powerful. You can now develop an alloy from basic theory in a matter of a few months, narrow in very quickly on the solution with the power of the computer and the basic models. Additive manufacturing is a particularly challenging field, a very complicated field. But now, there are some sections of that field, which are becoming more promising, more practical, more near-term. One is a nickel-based superalloys for repairing turbine blades. Another is titanium components for aircraft.

And, one that I particularly like is one that QuesTek has developed a simple maraging steel for replacement parts. It's a stainless maraging steel, lower costs where you don't have to heat treat. You don't have to use pressure treatments after forming the part. You can treat and use the alloy as cooled from additive manufacturing as-machined. This is particularly promising for in-field replacement of spare parts like shipboard. If you have a failed part on shipboard thousands of miles from port, if you had an additive manufacturing machine on board, you could make a spare part in copper alloys. If you're in the field with an ordinance field maintenance unit behind the front lines, and you have a failed tank or failed truck or vehicle, you can replace that with a maraging steel stainless part and get that unit back in operation within a couple of days to protect the men in the army. [With emerging fields such as AM and AI, creative research promises to discover the "sweet spot".]

Nyberg:

It just goes to show you that the invention and the materials continue to evolve as time goes on. So, you started in Maraging steel, and they're still working on it today. That's amazing!

Decker:

And, the additive manufacturing is going to be a real winner. We're not sure which fields will be the best yet, but it's an area of very high research and development activity. It could be sure something very significant will come out of it. It's a good field to follow.

Nyberg:

Thank you, Ray.

43:51 University Mentors – Learning Application, Interactions, and Having Fun with Metallurgy

Nyberg:

Ray, could you tell us something about some of the influences that you had and some of your colleagues that you had while you were at the universities?

Decker:

Yes, sir, glad to do that. I had, at Michigan, a very dedicated faculty. It was very much aligned to application of metals and tuned to objectives of application and practical use of what we learned. So, that was certainly a trend of the teaching of my mentor, Dr. Freeman, and other professors on the faculty of metallurgical engineering at Michigan. One other that I should mention is Professor Maurice Sinnott, who led me into joining TMS and ASM as a junior. That turned out to be one of the best pieces of advice I had ever received in Michigan. We had a very good high-temperature alloy test lab at the University of Michigan, which I joined in 1950 with the help of my friend, Jack Rowe, who later received a PhD from Dr. Freeman. He was a very good friend and colleague. He helped me do the best in school and find the best outlets for my energy in school.

Nyberg:

We would say that today as, he kept you out of trouble, Ray.

Decker:

Yeah, kept me out of trouble. I didn't have time for trouble. Another prof was Dick Flinn, who knew the human side of engineering. So, he was a very good leader in teaching us interactions with other engineers, interactions with the societies, and just plain having fun with metallurgy, including a softball team where he was the ace pitcher.

Nyberg:

That's great.

46:41 Memories of Michigan – Dr. Flinn, My Influence to Join Inco

Decker:

And, we had several colleagues in the high-temperature lab that were real contributors to superalloy metallurgy at that time. And, they've gone on to excellent jobs. Dr. Flinn was the big influence of going to Inco. He had worked there in previous days, and so he gave me a very high recommendation to choose Inco amongst the various offers I had upon receiving my PhD. Another professor is Wil Bigelow, who still is a retired professor from the department at Michigan today. He was a pioneer in electronic microscopy, on my thesis committee, and he performed electron microscopy on the samples I had, discovering the effects of boron zirconium. So, many good memories from Michigan and memories of the ability to work my way through school. I came out debt-free, receiving my PhD, which would have been impossible in many universities, then and today. That was a nice way to start the career, not having debt, being able to start out buying a house, etc.

Nyberg:

Thank you. That's great to be able to reflect and remember those that influenced us throughout, throughout our careers.

Decker:

The other thing about Michigan I recall is the honor system. In any exam, we filled out a blue book, and there was a section at the end where you signed a pledge that you had not cheated, nor had you seen anybody else cheat on the exam. And, I do not recall ever seeing anybody else cheat or cheating myself. So, that was ingrained in graduation from the University of Michigan, and I am sure many other schools.

49:08 Admiration for Dale Stein – Enhancing Engineering at Michigan Tech University

Nyberg:

That's great, Ray. Are there any other people or influences that you had during your university days?

Decker:

Yes. I certainly want to mention my good experience at Michigan Tech University. I was recruited there by Dale Stein, a great metallurgist, who was President of Michigan Tech. Dale raised the quality of Michigan Tech very much to the point where a Michigan Tech undergraduate materials engineer is highly sought throughout the state of Michigan and throughout the country. They're noted for practical application, hitting the road where the rubber counts. I had a great experience with Dale, a very fine man and a very influential fella. He was very active in TMS also, and I'm sure he's a fellow of TMS. I have great admiration for his accomplishments at Michigan Tech University.

Dale and I started a bio-science institute at Michigan Tech. It's specialized in faster-growing trees, genetic engineering trees to grow faster for lumber. Also, we did work on changing the color of certain trees to be more attractive as furniture, as woodwork. So. that was the start of some genetic engineering work under the Bio-science Institute at Michigan Tech University.

Nyberg:

Well, that's interesting, Ray. I know some MTU grads, and they definitely know their stuff. So, I can appreciate that.

51:22 Technical Society Experiences – TMS, My Learning Machine

Decker:

Now I'd like to talk, Eric, about my great experience with you and with TMS.

Nyberg:

Please tell us about your experiences with the technical societies that you've been involved with. I know that's been a big part of your career as well.

Decker:

Well, I joined TMS in 1951. Just recently became a Fellow. In the 70s, I was on the Planning Committee. I had been on the Magnesium Committee with Eric for many years. And, there was an honorary symposium for me this year. I won the Magnesium Technology Best Paper Award in 2019. Way back, I won the Robert Mehl Gold Medal for honorary lecture. And now, I continue to learn from TMS publications and symposiums, and, truly, TMS has been my learning machine, from the sparse knowledge of 1950 to our deep knowledge of metallurgy today.

A somewhat different experience in ASM. I joined in 1950, became a fellow in 1970. And, we did some planning, and I was chairman of the Diamond Decade Planning Committee, 1984. That's when we decided to expand from metals to materials and from the US to international. I was chairman of the Name Change Committee. That led to chairman of the Organizing Committee of the World Materials Congress in 1988, where all the materials societies around the world came to join us.

I served as President of ASM from 87 to 88, and that's where we did the transformation of the American Society of Metals to ASM international. Since then, I've been very active in the ASM Materials Education Foundation. First as chairman, but now I'm still active in this purpose of STEM education, science and technology education, exciting young people in our profession, camps for teachers and students. We've had more than 7,000 high school teachers in these camps so far. And, this is a continuing favorite activity of mine in my professional activities.

Summarizing my university appointments: part-time adjunct at Brooklyn Poly night school, New York University, same. Then Vice-President at Michigan Tech University from 1982 to 1986. And now, since 1994, adjunct professor at the University of Michigan and also interacting with universities. We've had joint nanoMAG research projects sponsored by National Science Foundation, National Institute of Health, Department of Energy, involving Michigan, Pittsburgh, Nebraska, Santa Barbara, New Hampshire, North Carolina A&T, Michigan State, MTU, Ohio State, Madison, and with Eric at the Pacific Northwest National Laboratory.

55:00 A 70-year Career Progressing the Advancement of Knowledge and Technology

Decker:

Then other national activities: on the National Materials Advisory Board of the 70s, election to the National Academy of Engineering in 1980, election to the executive board of SHRP, US Strategic Highway Research Program in the 1980s, finally, as chairman of the Research and Technology Coordination Committee of the Federal Highway Administration in the 1990s. The results were published in *Public Roads*, co-authored with Don Kelly, developing long lasting for maintenance highway pavement research needs. A major outcome was "Superpave" long life, rut-free, asphalt highways.

To observe, finally, the trends during the 70-year career, we've seen a great advance of basic knowledge and models, powerful new instruments. In 1958, we saw only 1000x. Now, in today's field, we go up to 3 million magnifications. Now, we have an internet library going from 4 journals in 1958 to 1100 materials journals today—an acceleration of information transfer and ease of access, computerized alloy design. A strong role of the universities, the national lab in generating technology and transferring it to industry. Increased financial support from government agencies, a big benefit of more women in the technology workforce. In my 1952 bachelor's class, engineering, at Michigan, there were three women out of 500 graduates. Today, about 35% of the metallurgy materials department at Michigan are women, and they will be outstanding contributors to society.

Now, we've expanded from a US technology base to a broad-based international technology base, to the benefit of all of us. A final piece of advice, back to the milking of cows, the three-legged career stool: I recommend finding partners, going to the library and technical societies for continual learning, and going to the gym for exercise. And, finally, the most important slide recognizing all the support I've had during these various activities: the Magnesium Committee of TMS, National Science Foundation, National Institute of Health, State of Michigan, the strategic partners: Dow, Lindberg, Spalding, Comalco, Amtech, JSW, Inco's R&D and market development, and the University of Michigan, Michigan State, Pittsburgh, New Hampshire, California, Santa Barbara, North Carolina State A&T, Nebraska, Michigan Tech. With Tracy, Professor Jones, Tori, Professor Pollock, Professor Allison, Makiheni, Professor Marquis, Lindsay, Etienne, Abshishek, Professor Goldstein, Professor Kozloff, Professor Yalisove, Professor Boehlert, Andrew Brown, Professor Sfeir, Professor Tuteja, Professor Knezevic, Professor Beyerlein, Professor Sankar and, of course, Eric Nyberg at Pacific Northwest. And, thank you very much, Michele and Eric, for this opportunity. Thank you very much.

Nyberg:

Well, Ray, it's been an honor to work with you. I’ve learned a lot from you over the years, and it's really unique to find a person who can explain things on different levels to different people. It's really my pleasure and honor to be able to capture your career today. And, I am very proud and happy to be the one to be able to interview you today. And, thank you very much.

Decker:

Thank you.