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ORAL HISTORY PROGRAM

Merton Flemings: A Leader of the Materials Science Movement at MIT

2019

PREFACE

The following oral history is the result of a recorded interview with Merton Flemings conducted by Diran Apelian on April 16, 2019. This interview is part of the American Institute of Mining, Metallurgical, and Petroleum Engineers Oral History Project.

ABSTRACT

Beginning as a hometown tinkerer, young Merton Flemings soon became an engineer after pursuing metallurgy at MIT. From an engineering student to an MIT professor, Flemings' career evolved as he transformed MIT's metallurgy department through his research and focus on the importance of engineering science and industry relations. Flemings set the stage for solidification processes across the field through his research, teachings, and written work. His book, "Solidification Processing", became one of the most impactful texts used in the materials science and engineering field. Flemings became a leader of the materials science movement at MIT by recognizing there must be a change to expand the department beyond just metallurgy. He redefined the metallurgy department's principles and transformed its curriculum to encompass a breadth of all materials. He continued to influence the field through the creation of MIT's renowned Materials Processing Center. Flemings' initiative to create this center showcases how his passion for innovation has impacted the evolution of materials science at MIT.

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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00:09 INTRODUCTION

Apelian:

Today is Tuesday, April 16, 2019. We're having a conversation with Professor Merton Flemings of MIT, who is a luminary in the field of materials science and engineering and one of the founding fathers of the science of solidification. This interview is being conducted by and sponsored by the American Institute of Mining, Metallurgical, and Petroleum Engineers as part of the oral history project. We are here in the home of Professor Flemings and Elizabeth Flemings's house here in Cambridge, Massachusetts. My name is Diran Apelian. I'm a professor at WPI and honored to say one of Professor Flemings's past students and still learning from him. I want to thank you for hosting us and having us in your home, and we are looking forward to the conversation that we're going to have. Thank you.

Flemings:

Thank you for being here.

01:01 FROM A TINKER IN WORCESTER TO AN ENGINEERING STUDENT AT MIT

Apelian:

Professor Flemings, it would be very useful for you to share with us your early years, your childhood, schooling, your interest in engineering.

Flemings:

Well, I led a pretty normal New England childhood, a descendant of farmers and merchants in New England. I grew up in Worcester, Massachusetts, right around the corner from Worcester Polytechnic Institute (Diran's academic home for many years). I had a wonderful physics teacher and a grand but difficult math teacher. I was interested in things . . . making things work . . . from the time I was very young. My father was quite set on Worcester Polytechnic Institute for perfectly normal family financial reasons. I thought WPI was a wonderful school with only one disadvantage, that I lived around the corner from it. When I was admitted to MIT, I took that as a wonderful second choice for my father and first choice for me. And, that was the beginning.

Apelian:

As a young man growing up in Worcester, were you a tinkerer, were you building things, making things? Tell us about those years.

Flemings:

Yes, I was a tinkerer in a sense, with a little workshop down in the cellar and always interested in building things I could use. But, I wouldn't say I was like some of the young people today who kind of do the most amazing things when they're young. I was also interested in the outdoors and spent a lot of time that way as well, especially in the mountains of northern New England.

03:00 WHAT INFLUENCED MY CHOICE OF ENGINEERING AND METALLURGY

Apelian:

Can you share with us some of the influences that took you towards the path of engineering technology science, were they high school teachers who influenced you? How did that come about?

Flemings:

They were certainly the high school teachers, the physics teacher especially. But, beyond that, really at that early age, I was looking for a kind of profession that I felt I could make a difference in. I had a second choice, and that was journalism. I had an uncle who was a journalist, actually happened to have been killed in the Second World War. I thought I was interested in literature, and I thought that would be a wonderful career. But, then I thought with the strong help, I must say, of my grandfather, I felt I could make more of an impact in the field of engineering, and I chose that route.

Apelian:

When you matriculated at MIT to start your university journey, how did you choose metallurgy and materials? So many choices, civil engineering, chemical engineering, so many choices.

Flemings:

MIT, I suppose, like most engineering schools today, admits people broadly in any field. At MIT we were expected then to make up our mind by the beginning of the second term or at least by the middle of the second term of the first year. I dallied a little with thinking about physics but decided the competition there was pretty stiff, and that it was further removed from the hands-on things that interested me. Mechanical engineering was a choice. But, in the end, the decision came down, I think, more than anything else to the fact that I had two mature fraternity brothers, both of whom were in metallurgy, and they told me it was a wonderful place to be. I said, that's good enough for me, chose metallurgy, and have never regretted it.

05:15 THE POST-WORLD WAR II ERA AT MIT – YEARS OF ENORMOUS CHANGE

Apelian:

In those years, when you were at MIT, they were the post-war years. I think you started MIT in 1947. Tell us about that era right after World War II.

Flemings:

They were wonderful years. They were wonderful years. They were the beginning of years of enormous change at MIT. On the student side, my freshman class was about half people like me right out of high school and the other half veterans who were there on the GI Bill. So, it was a most unusual and exciting four years for that reason alone, as well as for many others. Also, MIT in general, and the department of metallurgy in particular, had been major players in the technology of the Second World War, in terms of radar, the atom bomb, and in other areas where new or improved materials were critical to the war efforts. Our Department Head, for example, was the Associate Head of Metallurgy at Los Alamos during the Second World War.

After the war, after all the interaction they'd had with scientists at Los Alamos and the other laboratories, these faculty members had a new vision of what metallurgy could be and where it could go. But, in the meanwhile, the department also comprised old-style metallurgists, many of whom didn't have doctorates but had immense industrial experience, close contacts with industry, and they too had something to offer.

And, there we were as undergraduates, a part of this change that was wonderful for us and certainly helped us to have the courage in later years to continue these kinds of changes in the field as we perceived it and as we practiced it at MIT.

07:50 MIT'S CHARACTERISTIC CURRICULUM – MIXING SCIENCE WITH INDUSTRY EXPERIENCE

Apelian:

You're describing a very special era where you had the best of both worlds. You had a great deal of industrial experience through your mentors, as well as faculty at the cutting edge of science who had a key role to play at Los Alamos. So, you had the best of both worlds. Do you think that continued on at MIT or shifted over time?

Flemings:

Yes, we did have the mix of two great worlds, and it was a characteristic that has continued at MIT during all of the years since then. But, I must say, and sometimes we compare it with a pendulum swinging back and forth, I'm not sure that's a wholly accurate analogy, but if you think about it as a pendulum, it is true that in some years following the beginning of the 1960s, engineering science became increasingly strong. By the way, I was totally supportive of that, helping the department move toward incorporating more science in the curriculum, more engineering science in the curriculum, and the research.

At the same time, by the late 1970s, it seemed to me that we'd maybe gone a little too far, that we'd forgotten how important the hands-on activities are. Some of the faculty had largely lost touch with industry and industry needs. At that time, I and a number of other faculty members felt strongly, it was time to bring back more of the hands-on activity, more of the interactions with industry, and I certainly undertook some actions at that time to help that happen.

10:02 GREATEST INFLUENCERS ON MY EARLY YEARS AT MIT

Apelian:

In your early years at MIT, can you tell us about some of the professors who influenced you?

Flemings:

Well, in my early years at MIT, I would say there were two faculty members that stood out. One was Nick Grant, and, by the way, both of these were strong members of the metallurgy professional societies and professional community. Nick Grant was my undergraduate advisor, a former football player from Carnegie Tech who was interested in a whole lot of things in the world besides metallurgy, but who was a very accomplished and successful metallurgist. Howard Taylor was a man brought in after the war, he'd been there before, but who had practical foundry experience at the Naval Research Laboratory, and early in the '50s built a wonderful foundry laboratory at MIT.

Apelian:

In addition to professors at MIT, I'm certain that there were classmates and peers in your class that also were influential in your early years. Could you talk about that?

Flemings:

Well, I had two sets of classmates that were influential. The veterans that came back opened up a whole new world, maybe a little sooner than was healthy for an 18-year-old, but I think having said that; I think it was very healthy indeed. They brought a perspective both of hard work, and of a little bit of hard playing now and then as well. In the later undergraduate years, and particularly in the graduate years, I had two roommates from our department, David Ragone and Ed Hucke. We studied together as undergraduates, and, as graduate students, we lived together. We did our theses together, and I can remember many, many long nights in the laboratory using equipment that was only available to us in the evening. And, having the companionship, and I might say the competitiveness, of two fellow graduate students, was a very healthy thing for me in maintaining my equilibrium going through those exciting years.

Apelian:

Did you keep up with them after graduation?

Flemings:

I certainly did, and one of them lives very close now in New England, and one in California, and both chose the academic career path. Dave and Ed went directly into academia. I went to industry for two years and never regretted it but was very happy to then join MIT after that time. And, I've been there ever since.

13:28 UNDERGRADUATE SUMMER JOBS AND EXPERIENCE WITH INDUSTRY

Apelian:

While you were at MIT undergraduate and graduate years, did you have any internships with industry, or did you have a lot of contact with the industrial world?

Flemings:

In our undergraduate years, we did take a tour of industry, and we toured industry that doesn't exist today, at least where it was. We had a wonderful tour of the brass industry and several different companies in Connecticut. We visited a jewelry making company, which in fact, I guess, does exist today. We visited a steel mill, which is a totally different operation than it was then. I worked in the metallurgy field one summer. The summer after my junior year, I worked in a heat-treating outfit for the first half where I had an 11-hour night shift tending heat treat furnaces. And then, a job in the second half of the summer came through to work in a laboratory of the Naval Laboratory, down in Rhode Island.

I thought the opportunity to work in metallurgy was one I shouldn’t pass up. Unlike many government laboratories today, this laboratory at the end of the Second World War no longer seemed to have a mission, and didn't know quite what to do with me. So, my first experience in a laboratory outside MIT was a disappointment, and I decided then that I would seek work where I would have hands on experience making things.

Those were the last two summers of my undergraduate years. The first two summers were totally unrelated to the profession but have remained with me as two of the best summers in my life. Following my freshman year and my sophomore year, I was, I guess you'd say, a lumberjack for the first half of the summer, working for the Forest Service in Idaho. For the second half of each summer, the fires came, and our job was fighting fires. Those wonderful summer days remain with me today.

16:15 WORK AT THE AMERICAN BRAKE SHOE COMPANY – WHY I CHOSE INDUSTRY

Apelian:

It's funny; once you graduated from MIT, you had choices to make to go into academia, laboratories, or industry, and you chose industry. How did that come about?

Flemings:

Well, you mentioned my two fellow graduate students, Dave and Ed. We had spent our graduate career competing with each other to see how quickly we could graduate (while still writing a respectable thesis). And, all three of us finished our degrees in a time that is rather shorter than the average these days. And, at the end of that, much as I had found it thrilling in a sense, I thought it was time to leave the university and go and see what the other half of the world is like. And, I went to a foundry laboratory in New Jersey and spent two very good years there.

Apelian:

Tell us about your experience at the foundry laboratory in Mahwah, New Jersey, at the American Brake Shoe Company. What was that like, and what did you do?

Flemings:

Well, a part of my graduate work had a pretty practical objective: to develop ways to make stronger aluminum castings. Textbook metallurgy at the time taught that grain size in cast aluminum is a predominant factor influencing strength and ductility. Work in our foundry laboratory showed, on the other hand, that dendrite arm spacing is a far more important factor. We experimented with ways to do that in the laboratory, to make simple shapes, adding "chills" to sand molds to cause more rapid solidification (to get the fine dendrite arm spacing) while still maintaining the feeding to achieve a sound casting. And, my job at then called American Brake Shoe Company was to take those ideas and make real castings with them and show that these ideas could result in a much better-quality aluminum castings.

I spent two years at American Brake Shoe applying the ideas I had learned in the foundry laboratory at MIT. Control of dendrite arm spacing was the key central one, but, of course, there were other parts of the recipe as well: customers for our "Premium Quality" castings. By the end of my second year, we had a pilot-scale operation. We were producing castings with guaranteed properties well above those then available. The methods and specifications we developed are now in wide industrial usage.

20:17 LEAVING INDUSTRY TO JOIN ACADEMIA AT MIT

Apelian:

You mentioned your two classmates and your close friends at MIT years, Ed Hucke and Dave Ragone, what happened to them? Where did they end up?

Flemings:

Dave went on to become, eventually, the President of Case Western Reserve University, and later a venture capitalist before retirement. Ed Hucke, as I say, became a very successful faculty member and retired a good deal younger than I did to play tennis in California.

Apelian:

Did they have any influence on you for you to leave industry and to return back to MIT and join academia?

Flemings:

Well, I couldn't say, no, maybe a little bit. But, I can tell you, industry was far better than the government laboratory that I had worked in some years earlier. But, I was still aghast when, at five o'clock every day, the workmen all laid down their tools and went home. And, there I was with my day's work, in my view, not done. In other words, the pace that I encountered was less than I wanted, and the intellectual stimulation not as great. And so, toward the end of my second year at the foundry, I used my vacation to go and visit schools and apply for jobs, which is another story of another time. This was now 1950.

It was a time of huge expansion still of the university systems and engineering, in particular, in the United States so that schools were hiring faculty at rates that haven't happened since and certainly is not happening now. So, I made a kind of grand round circle trip in my car visiting universities, starting clockwise at Penn State University, then Iowa, Michigan, Cornell, and finally MIT. Several of the universities indicated strong interest. One of them offered me a position only a few weeks later, that was as Associate Professor in charge of their foundry laboratory.

When I told my thesis mentor, Howard Taylor, that I was ready to go back to the university and was planning to accept the offer I had received, he said, "You know, I am not the Department Head, so I can't talk about a faculty position, but wouldn't you like to come back and be a research staff member?" And, what should I say? With some embarrassment, I said, "Thank you, but no, thank you. I think now I'd like to take a faculty position." And, he said, "Well okay, I'll work on it." And, he worked on it, and pretty soon I was offered a chance to come back to MIT and, of course, took the opportunity.

25:02 EARLY CAREER AMIDST CHANGES TO BROADEN MIT ENGINEERING

Apelian:

Professor Flemings, can you share with us your early years at MIT as an Assistant Professor, and then being promoted to Associate, then full Professor? Tell us about that journey because it was also a time of many, many changes in American cultural life as well and political life. So, tell us about the early years.

Flemings:

Well, I came back to MIT happily, as I've said, and continued my research in the fairly applied aspects of foundry practice, now under the direction of, or at least in association with, the senior Professor Howard Taylor. We worked on gating and risering and fluidity and other basic foundry engineering problems. We tried to treat these subjects quantitatively and did so where we could, but they still were subjects quite narrowly focused on problems of the existing foundry as it stood. I was also wonderfully engaged in teaching broad metallurgy subjects, and all of this was at the time when MIT was now moving more quickly away from focus on specific industries and more broadly onto questions of engineering science.

The aim of the Dean of Engineering, speaking at that time, was that we would work on subjects and work in ways that would be broadly applicable to many industries, not just to one industry specifically. As a result, not too many years after I returned to MIT, it became clear that there was not going to be a place much longer at MIT for the large machine shop that we had, or the metalworking shop, or the enormous electric generators that were in existence in the electrical engineering department, or the quite extensive foundry laboratory.

27:56 MIT'S MOVE TO ENGINEERING SCIENCE

Flemings:

It was also clear that, if I was to stay at MIT and get tenure, if I was to have a full career there, I would need to change my research direction also, which I did with alacrity. I did with excitement. I thought it was the right way to go, and I thought I could do it. Already at this time, the senior foundry Professor, Howard Taylor, was ill and soon passed away, and the burden was then on my shoulders to do or not do what I should do with regard to the foundry. So, in short order, we shut the foundry down, in the sense that we decreased the laboratory staff population from some six non-professional people to one. And, I began to look for new areas of research, that is, areas of research where I could use my expertise and my students' expertise and contribute, I felt, in important ways to the foundry still in the future but also to other areas such as the steel-making industry. My aim was to find areas where we could continue to contribute to industry but in a more general and deeper way. And, from that point on, I sought different kinds of research support, and I used current research support in ways that were acceptable to my sponsors to undertake these new studies, all of which revolved around the study more broadly of solidification, of what went on, of understanding details of the process that were not then well understood, but always with the intention, ultimately, to use these studies to come up with useful ideas, with useful understandings, with understandings of the process that would benefit the industry.

30:46 SETTING THE STAGE FOR SOLIDIFICATION PROCESSES

Apelian:

Your contributions are viewed as being the scientific foundations of liquid to solid transformations and solidification processing. But, the context that you've had with the industry experience certainly set the stage and the motivation to bring in the science into it. While you were at MIT, there were also luminaries at Harvard University like Bruce Chalmers, and others around the country, at Stanford University, Tiller and others. Tell us about the interactions that you've had with those other key people in the field and if they shaped your thinking in any way as well?

Flemings:

I had wonderful interactions with Bruce Chalmers. We had a period over a year or more where our research groups met together at least once a month, maybe more often, I don't remember, and where we shared our thinking. Bill Tiller came at the field from a totally different way than I did. Bill started with the math. I usually started trying to understand physical behavior from experiment and then amplify the understanding by calculation. In later years, Wilfried Kurz was one of many whose work influenced my own.

32:22 UNDERSTANDING THE IMPORTANCE OF ENGINEERING SCIENCE FROM INDUSTRY

Apelian:

Professor Flemings, do you think your industrial experience that you had at American Brake Shoe, and all the work you did with various laboratories, helped you make the transition from foundry technology to engineering science?

Flemings:

My industrial experience was an enormous help in making the transition to a meaningful form of engineering science. For example, it taught me much about dendrites in practice. I understood it from looking in the microscope, and I understood it from the thermocouple measurements, and I developed a practical "feel" for the physics of how metals solidify. I certainly learned how important dendrite arm spacing was and began to understand that textbook explanations of this were, at best, only partially correct. I learned how important porosity and inclusions are. I could see many fundamental problems, many engineering science problems associated with every aspect of this, that would have applications beyond just aluminum casting, and there was something in me that wanted to think more deeply about each one of these problems, more deeply than one could do in industry.

34:01 DEVELOPING A FUNDAMENTAL UNDERSTANDING OF CENTERLINE SEGREGATION

Flemings:

So, returning to MIT, I made it a point to continue to have contact with industry, and I continued to find industrial context over the years, vital in helping determine the directions of my research. To pick a simple example, a few years after my return to MIT, I was consulting with the basic research laboratory of U.S. Steel Company. At that time, U.S. Steel was building their first large slab continuous caster outside of Chicago and finding a problem with centerline segregation; the segregation occurred right at the time that bulging was in the casting.

With each bulge, there was an area of macrosegregation there of centerline increased segregation. Well, I was familiar with hot tearing from my foundry practice, and I knew that, if you pull a semi-solid metal apart, the liquid flows in, and I thought, "That's got to be the answer." I think U.S. Steel was happy with the answer, and it helped them get rid of the bulging. But, more importantly, they then funded me for some years to continue work related to macrosegregation. We proceeded to follow a path to try to understand it. We tried to duplicate the bulging, and the experiment in which we tried to duplicate the bulging showed that bulging might be there, but it wasn't the biggest, it wasn't the most important thing.

To put the idea, to put the discovery, you might say, simply, the classic explanation for centerline segregation is always that the dendrites push the carbon and other impurities toward the center, and that's why they end up there. And, whether you look in the older textbooks or in the steel-making handbooks, you find that explanation. The explanation is dead wrong, and we spent the next few years looking deeply at this problem, understanding it mathematically and developing the foundation that is now widely used in practice in solidification of all kinds of castings and ingots, ferrous and non-ferrous.

38:10 WRITING ONE OF THE MSE FIELD'S MOST IMPACTFUL TEXTS "SOLIDIFICATION PROCESSING"

Apelian:

How did the book Solidification Processing come about?

Flemings:

The book turned out to be more important for the field and, I think, more important for how people view the research that I've done than I expected or thought about. I think the book came about primarily because it was time for me to take a sabbatical, and I used that sabbatical to work on my class notes over the previous some years and wrote the book. And so, I'm happy that it still is widely used, even though out of print.

Apelian:

Professor Flemings, your book has had tremendous impact in the field, but, as one looks at it, it is not structured the way most books are when they start with nucleation theory and go on, but rather you start directly with heat flow. Tell us about how you put that together, which I'm sure mimics or is very similar to the way you taught the course as well. Give us your thoughts that said how you put that together.

Flemings:

Well, that's right. The book is based on a course that I taught, and, in both the course and in the book, I tried to deal first with the general overarching problems in casting and the overall different processes, ranging from single crystal growth through the sand castings and tried, in each chapter of the book following the general introduction, to deal with the heat and mass transfer, not of this process or that process but of all of the processes, tried to see where the similarities are between single crystal growing and foundry practice and where the differences are. And, mainly, I tried to keep the book mathematically simple, not clouding issues but not delving into minute detail, which is necessary in some instances, but not, I think, for a beginning text or even for a text of use to engineers in industry. But, what's important in practice is the basic concepts, underlying equations, not how fancy the equations are. And, that was my aim throughout the book.

40:34 FORMING THE RENOWNED MATERIALS PROCESSING CENTER AT MIT

Apelian:

Professor Flemings, the Materials Processing Center at MIT, is well known, and you are the Founding Director of that Center. What were the events that led to the formation of that Center?

Flemings:

Well, I've mentioned that, by the '60s and then certainly into the '70s, I had the view that engineering science, important as it was, was crowding out some of the other things we should have in our department. And, I also felt that there was insufficient attention paid broadly at MIT and, including in our department, to industrial support and industrial interactions. Both for the stronger industrial interactions and to counterbalance to some extent to engineering science, I thought a new center was called for. I went to the Dean, and, after considerable deliberations, the answer was, if you can fund it, go for it. And, I was fortunate enough to obtain significant long-term funding for the processing center. The main source being NASA.

Flemings:

The main initial source of funding was NASA. NASA’s purpose in funding it was their belief that, before we can learn to process things in space, we better learn to process them better on earth. That funding enabled the initial start, but significant funding then came in the succeeding years from industry. And, the processing center that's remained in existence right up until this time, when it's now finally been joined with the materials science center at MIT, providing to that center a focus on industry and industrial interactions that they haven't had before.

43:03 LEADING AN ACADEMIC MOVEMENT AT MIT – FROM JUST METALLURGY TO MATERIALS SCIENCE

AND ENGINEERING

Apelian:

Professor Flemings, you had a wonderful tenure as Department Head at MIT, where many wonderful things happened. Can you share with us some of the highlights from your perspective?

Flemings:

I'd be happy to, and to do that, I'd like to go back again, back into history. In the late 1950s, in my very early years on the faculty, the faculty was still, at that point, divided into quite, what seems today, unusual discrete components.

There were the two faculty members who dealt only with a specific class of metals (aluminum, steel, copper, etc.), and there were courses that dealt with only with a specific metal. We also had a focus on mineral dressing. We had large jaw cut crushing machines, and I've mentioned that we had large industrial equipment. We didn't think of metallurgy as a cohesive field. We thought of it as an agglomeration of a lot of things, from mining to finishing. John Chipman, the Department Head at that time, convened a committee to reorganize the department and to reorganize the teaching.

And, he said this is not the way to think about a department, and the ultimate diagram or picture that they came up with, at that time, was to think of it, not as an agglomeration of different metals and different aspects, but with all metals at the middle of it. And then, what our core was, was metal, generally, around the hub these different aspects. But, the courses should deal, for example, he was saying even then, not just with aluminum metallurgy or steel metallurgy but with metallurgy, and, of course, things were now coming along that made that easier to think about, including, for example, x-ray crystallography. You do that with all metals not just with one. And so, the teaching then moved very quickly to teaching physical metallurgy or mechanical metallurgy, dealing with all of the materials. Then, as the years went on from that time through the '60s and '70s, we all understood the importance of moving from only metallurgy toward materials. We thought it made sense. As the time went on, and we realized that there were so many jobs for our students out in the materials industry broadly, that a lot of what we had, the understanding we had, was as applicable to polymers and ceramics as it was to metallurgy. In fact, if we were to serve our students, we needed to be moving toward material science and engineering. So, over those next decades, we had made steps along the way.

47:21 DEFINING THE DEPARTMENT'S INTELLECTUAL PRINCIPLES AND REFORMING CURRICULUM

Flemings:

When I became Department Head, we had changed and had already begun to think of ourselves as a materials department, but we were still largely, in fact, mostly a metallurgy department. We had a small group of electronic materials people, a very small polymer program, and a ceramic activity. But, we did not have courses that blanketed these different fields. We didn't have a structural course that dealt with metals and ceramics and polymers. And, we needed a new idea of what our department was, in our teaching and in our research. Gradually, we formulated what we wanted to be, more specifically, what our teaching program should be. Our conclusion, which we spent much time implementing during my tenure, was that our teaching should not be compartmentalized by material class, but the overall academic program should comprise teaching broadly, the structure of materials, the processing of materials, the properties of all materials, and the performance of materials.

Those were the principles that would bring us together, and then we would need to move towards our courses in this direction, our new faculty hires in this direction, and our research, of course, in this direction. And, that was my job then when I took over as Department Head. We knew what we had to do, we knew that it was important to do. We were certainly among the first of the metallurgy departments in this country, or in the world, leading the movement away from just metallurgy to the broader field of materials. And, I might say that, in the beginning, it didn't wholly meet with approval from industry people, especially from the traditional metallurgical industries. But, we felt we had to do it, and, ultimately, we've had the strong support industry for what we did.

50:10 THE INFLUENCE OF MY UNIFIED VISION OF MATERIALS – SHIFTING THE GENDER BALANCE

Apelian:

Professor Flemings, you talk about this unified vision of materials, materials science and engineering and the transformation you made under your leadership as Department Head. How did that reflect in students' interests in the field of materials?

Flemings:

Well, first of all, the interest of the female student population of young women increased remarkably. I think that there was some hesitation on the part of young women to want to enter a department that was associated only with big blast furnaces and foundries but had broader appeal. But, the same is true of men, too. The move was critical to maintain and increase our male student population, too. And, we made the beginning of hiring of women on our faculty, a trend that was continued happily, strongly, after I was Department Head.

51:23 GLOBAL OUTREACH IN THE MSE COMMUNITY

Apelian:

Professor Flemings, your outreach in the community, the materials science engineering community, is certainly not North America-centric. It's global. Could you tell us about your experiences and relationships around the world, not just in North America?

Flemings:

Well, I've greatly enjoyed my contacts with my colleagues throughout the world, and I've had many such collaborations and contacts with faculty members and with industry from both Europe and Asia. I've taken sabbaticals in these different countries. I've had students who've gone on to be distinguished faculty members in both Europe and Asia. My wife is a Japanese scholar, and we had a wonderful year in Japan, where I was a visiting faculty member at the University of Tokyo, and also on a half-time appointment with Nippon Steel, and worked with the researchers in the laboratory there.

The research that we've done happily has found use in an application in many countries of the world, and it's been my honor to visit those countries from time to time and see some of the applications of work that we've done. Before I leave the topic, I should say that one of the responsibilities of a Department Head is to accept and welcome and seek support from alumni and from industry, to aid in not just our research, but in support of faculty and support of students. I did spend a fair amount of time in Japan working with companies, and, you know, grateful that we received a number of faculty endowed chairs from Japan, as well as some from this country.

54:16 FORMING THE SINGAPORE MIT ALLIANCE

Apelian:

Professor Flemings, you're well-recognized all throughout the world and had a global impact in many countries. Tell us about the Singapore MIT Alliance that you hatted and led for many years. How did that come about?

Flemings:

Well, I stepped down from being Department Head when I was 65, after 12 years, and, at that age, it seemed appropriate to pass that mantle on to someone else. And, of course, I was then a little bored and asked the Dean what else he had in mind. And, at that time, a member the Singapore government was anxious that, actually a man who had graduated from MIT, was anxious that he do everything he could to raise the quality of education, engineering education in Singapore and, at first, asked MIT if MIT would start an affiliate college in Singapore. We appropriately, that is MIT appropriately said, that is not something we wanted to do. But, we would establish a committee of faculty members to investigate, well, a committee of faculty members to visit Singapore, to work with Singapore, and study their engineering education and write a report and see if we could build on that in some way. So, I was asked to do that, or invited to do that. And, I formed a committee of comprising faculty from some five different engineering departments, and we worked over a period of six or eight months in and out of Singapore reviewing their education and wrote a report.

The report was greeted, I might say, with mixed emotions on the part of Singapore, because it was respectful of a strong system and bright people but did point out areas where we felt improvements could be made. Growing out of that, then, after extensive negotiations, we established a major collaboration between MIT and Singapore, which has lasted right up to the present time and has gradually evolved into broader activities and collaborations between the two countries.

57:17 INNOVATION, INVENTION, AND THE LEMELSON INITIATIVE

Apelian:

Professor Flemings, as one looks at your work, innovation is really the common thread across all of your patents, publications, and the results that have actually been commercialized and used by industry. Then, after the Singapore Alliance that you led, you took on the Lemelson Initiative at MIT, which is also based on innovation. Tell us about how that all came together and what you accomplished during that era.

Flemings:

Well, you're right, that invention and innovation have always been nearest and dearest to my heart. I've always wanted to go deeply into problems, not for mathematical sophistication, but to find out what else might be down there underneath. It's so easy to find short term solutions to problems, and neglect the pay dirt that lies underneath, for how you might use the ideas there in new and different applications. So, I loved to invent, and I have quite a few patents with my students over the years, 30 plus I believe. And, the opportunity then arose for the engineering school to lead a program supported by the Lemelson Foundation in invention, and, by that time in my career, I was now half time, happily. And, taking on the Lemelson program was something that was appropriate, that didn't require a full-time faculty member, but something that certainly related to my interests. And so, we took over a small program that had been formally handled over in the Sloan school and proceeded to expand it and develop it into a program that involved high school students from all over the country, doing inventive projects. We established a number of prizes, and continued a prize of half a million dollars for the best inventor of the year, and basically put together a program that remains today a strong part of MIT.

1:00:11 AN UNDYING PRIDE IN MY STUDENTS

Apelian:

The Lemelson Prize certainly celebrates invention and innovation, but, on a personal level you have had, Professor Flemings, you've had many, many students over the years, and invention and innovation was also inbred in all of your students. And, I cannot imagine that it has not had a tremendous impact, not only to society at large but to many other generations of students. Tell us a bit about your reflections on your interactions with your students, and where they're at today, and what they've done.

Flemings:

Well, I can tell you this: what I am most proud of in my career is my students and what they have done. And, these are students all over the world. They've become faculty members, deans, college presidents, leaders in industries in their home countries. All of them have made significant engineering accomplishments, and I believe enjoy their work.

Apelian:

Getting emotional. So, Professor Flemings, I can surely tell you as one of your past students that that pride and love and affection is a two-way street. I know at least 20 or 30 of your past students that I'm in touch with who were with you on your 70th-anniversary celebration and who are constantly thinking of you and are grateful to how you have touched our lives. So, I think in a way, you should be gratified to know that the good work that you've done has had a lasting effect on many of people. And, it's really a circle of goodness that keeps continuing on. So, it's circular, certainly circular.

Flemings:

Well, I think, Diran, I think often of those 30 students and many more besides. With many of you I felt, at that time, we were more collaborators than professor and student. Clearly, there was that professor-student relationship, but my view was that we worked in the laboratory together. We tried to understand together what was going on. We were excited when we found what was going on, and where we made an impact, and it's been that kind of relation that I've felt in the years since. And, if anything, the shoe is now on the other foot, where I turn to some of my former students for advice and mentoring at this point.

1:03:21 HONORS - ALBERT EASTON WHITE DISTINGUISHED TEACHER AWARD OF ASM

Apelian:

Professor Flemings, as one looks at your accomplishments, you have so many awards. There's no way I can read them; it's several pages long. Highly recognized, well deserved from the National Academy of Engineering to other academies around the world. Surely there must be one or two of these awards that stand out in your mind. So, how do you feel about all this recognition, and what matters to you? What are the ones that you covet the most?

Flemings:

Well, yes, I've been honored to receive the awards I have on behalf, I might say, both of myself and the students who worked with me to create the things we created. I will also say, though, that, if I were to pick the kind of award, or even the award, and certainly the kind of award that means the most to me, the example I would give is the 2005 Albert Easton White Award of the ASM that recognizes both the significant accomplishments of our research group but also the unusually, as I quote here, but also the unusually long and devoted service in teaching. In the end, that's why we're in the university, for the teaching, and the students, and what they're going to do. And so, that's why I would pick that award. So, there's an example.

Apelian:

Wonderful. You're referring to the Albert Easton White Distinguished Teacher Award of ASM, and that's a wonderful way of bringing that all together. Thank you.

Apelian:

Over the years, you've garnered a lot of wisdom, and I know you're the kind of person who likes to share and to give; generosity is in your DNA. What advice would you give to a young person, 18, 19, 20-year-older, who's getting into the field today?

Flemings:

I believe I would tell that person to find a job, a profession, a life work that is fulfilling where you can make an impact, and then work at it. And, besides that, find a partner to share the life with you and plan to make an impact with him or her on the world you live in, big or small.