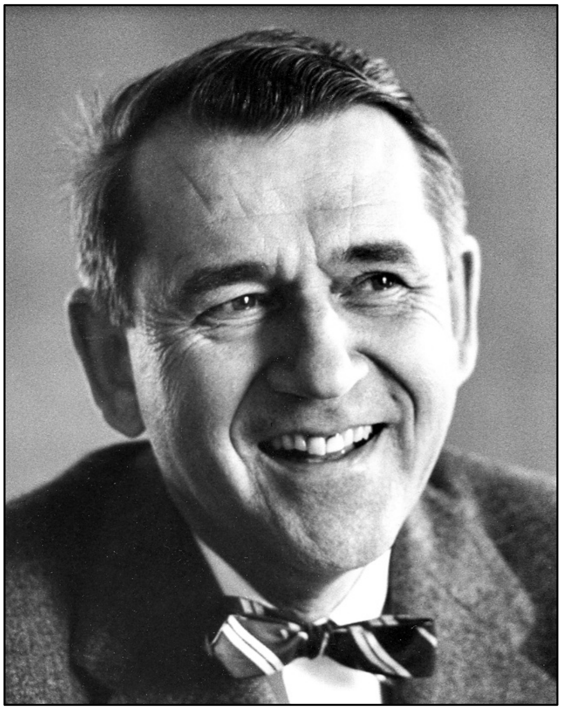

Frederick Lindvall, 1960. Photo by Joe Monroe.

FREDERICK C. LINDVALL
(1903 – 1989)

INTERVIEWED BY
ANN SCHEID

November 17 & 21, and December 8, 1978

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CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

Subject area
Engineering, aeronautics.

Abstract
An interview in three sessions, November and December 1978, with Frederick C. Lindvall, professor of engineering, emeritus, in the Division of Engineering and Applied Science. Dr. Lindvall received his BS from the University of Illinois (1924) and his PhD from Caltech (1928). He joined the Caltech faculty in 1930 as an instructor in electrical engineering and served as chairman of the Division of Engineering and Applied Science from 1945 (when it was known as the Division of Civil and Mechanical Engineering and Aeronautics) to 1969, becoming professor emeritus in 1970.

He recalls his childhood in Moline, Illinois; first two years of college at UC Southern Branch, in Los Angeles; youthful interest in railway operations; junior and senior years at University of Illinois; graduate work at Caltech with Francis Maxstadt, under Royal W. Sorensen; thesis work on vacuum switch. Comments

on professors Smythe, Epstein, Bateman, Zwicky, Tolman, Judy. Origin of Sorensen's high voltage laboratory and collaboration with Southern California Edison. Works for General Electric before joining Caltech faculty, 1930.

Recalls family trip to Europe just before World War I and difficulties getting back to the States. Graduate teaching; recollections of Millikans; campus life in the 1930s; outstanding graduate students.

Works on rockets and torpedoes in World War II. Caltech in wartime. Engineering division chairmanship; curriculum revision in the 1950s, new emphasis on applied science. Government support post-*Sputnik*. Interest in humanities. Work on Freshman Admissions Committee; travels to interview high school prospects.

Trips to Soviet Union, Africa, India, to investigate engineering education. Work at Deere & Company and son's earthquake consulting firm after his retirement.

Administrative information

Access

The interview is unrestricted.

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ORAL HISTORY PROJECT

INTERVIEW WITH FREDERICK C. LINDVALL

BY ANN SCHEID

PASADENA, CALIFORNIA

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CALIFORNIA INSTITUTE OF TECHNOLOGY ARCHIVES

ORAL HISTORY PROJECT

Interview with Frederick C. Lindvall **by Ann Scheid**

Pasadena, California

Session l	**November l7, 1978**
Session 2	**November 2l, 1978**
Session 3	**December 8, 1978**

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SCHEID: Where were you born?

LINDVALL: In Moline, Illinois. My parents had settled there a long time before, and my father had started a—we used to call them drugstores; we'd call it a pharmacy today. In those days, a pharmacist had to do a good deal more in the way of compounding medicines and salves and whatnot than happens today. And so, inadvertently, I learned a fair amount of chemistry from listening to him talk and watching him work in the store. So when I got to high school chemistry, that was a breeze; I'd heard most of the words before. We had living with us, all the time I was growing up, my mother's sister, who was an elementary school teacher. She took a great deal of interest in my education. She would know if I wasn't doing well in school, and would let me know and help me. Also she was much interested in what I might do as a career, ultimately. So she arranged through friends in the community to let me see various professions in action, such as visiting court, where she knew one of the judges; visiting the Rock Island Railroad shops, where she knew the superintendent; visiting the surgery at a local hospital, where one of the doctors let me stand around and watch—I didn't faint. [Laughter] And one way or another, I got a fair idea of what the different professions were up to. My father used to take us to conventions of the American Pharmaceutical Association. At one of those, I met Dr. Dohme, who later founded Sharp & Dohme, a pharmaceutical firm. He asked me what I was going to do when I grew up. I said I thought I wanted to be an engineer.

He said, "What do you want to do that for? You'll probably work for somebody else all your life. Why don't you get into a business such as mine, and you can be your own boss." Well, I didn't take his advice. I wanted engineering, perhaps because I'd always been interested in things—gadgets and whatnot. It was a source of concern to my parents when I would immediately, on receiving a new toy, start taking it apart. In those days, toys were put together more with nuts and bolts and less with rivets and spot-welding and so forth, so it was possible to take things apart and find out how things worked. That, perhaps, was the start of my interest in at least the hardware aspects of engineering.

So I went through high school there in Moline, Illinois. Before I finished high school, my father sold his drugstore; a local bank wanted the corner on which it stood. He was very much attracted to the price they offered, so he sold out. Then the next year, 1914, the whole family went on a trip to Europe. My father and mother thought it would be nice, for sentimental reasons, to spend their twenty-fifth wedding anniversary in Sweden, as near to my father's birthplace as they could, which we did. We were touring around Europe and were stuck in Switzerland when World War I broke out. It took us quite a while before we could get permission to cross France and get over to England, but we finally did, and we finally got passage on a ship back to the States. We made the trip with the portholes blocked with brown paper, and we took a northern route to escape submarines and so on, landed at Boston instead of New York as scheduled. And it was a good thing they did, because the next trip that old ship, the *S.S. Arabic,* was sunk. But I got some impressions of how a country behaves at the start of a war. At that time, the Germans were making their big push toward Paris. We stayed overnight in Dijon; I could hear the big guns firing. That made quite an impression on me.

Well, at any rate, in 1920 my parents decided that they'd lived long enough in Moline, with my father's hay fever every year. So they decided to move to California, and we came to Los Angeles. I enrolled in what was then called the Southern Branch of the University of California, which was located in what was the old normal school on Vermont Avenue in L.A. That school had a program which was the first two years of engineering; it paralleled what Berkeley offered as the first two years in engineering. So that's where I spent those first two years, getting the basic chemistry, physics, math, surveying, and so on. That was interesting, because we had some excellent teachers, who hadn't gone all gung-ho for research, they still had time for students. One character in particular, William Conger Morgan, was head of chemistry. He was a character who loved his jokes, and he had lots of choice expressions, such as referring to some of our early examination papers: "I'm wondering what the animal thought of when he made those tracks." He also said, "I'll give you problems. Sometimes I might have to lead the kitty up backwards, but don't let it fool you." Things like that. I also met a young instructor in physics, Arthur Warner, who was starting to take work for a PhD here at Caltech. Over the years, we maintained a friendship, until his death within this past year.

From the Southern Branch of the University of California, I transferred back to the University of Illinois, because at that time I had made up my mind I wanted to be in the railway business. So I enrolled in what they called railway electrical engineering, which was quite a promising subject at the time. After I finished that course, I received two or three railroad offers. But strangely enough, the man who was head of the department was honest enough to caution those of us who received offers. He said, "Well, it's a tough game, this railroad business. If you live long enough, through the seniority system you might get to be foreman of a roundhouse." That was a bit discouraging. Well, I wrote to the Los Angeles Railway company that ran the yellow cars at the time, to see if there was a chance of going to work for them. I received a rather curt letter back, saying they had no need for anyone with my training.

Well, anyway, the family still wanted to be in Los Angeles, so I came back out here and went down to the railroad car shops—that is, the street-railway car shops—and talked to the superintendent down there, and he gave me a job wiring streetcars. They were buying a whole group of new cars at the time, which came only partly equipped. My job was to put in the electrical part of the equipment. That was good experience. I learned a lot about people—shop men, what their reactions were, and so on. After a few months of that, I saw the chief engineer from the company walking through the shop one day; I had met him in a professional society meeting in Los Angeles I used to go to at nights. And I said, "I think I've learned all I want to know about streetcar wiring. Do you think you have anything closer to engineering that I could move into?" He said he would see. Well, after that moment, the men in the shop took a different view of me; they didn't like me anymore. They thought I was a spy or something. But I received an offer of a position uptown, what they called "inspector." My job was to keep track of the system outside, where the underground cables for the return current from the trolley cars went back to the substations, because they were having trouble at times with excavations coming along and cutting through one of these cables. And then the return current would get on the water pipes and gas pipes and so on and would cause electrolysis problems when it left the pipes to get back into the substation. So I was at that for another six or seven months. And in the summer vacation, up in the high Sierras, which I suppose is a good place for introspection, I decided there was no future in the street railway business.

I had a couple of good friends from these early days at the Southern Branch who came over to Caltech. One of them, Bill [William L.] Holladay, later became president of the Caltech alumni. Lays Griswold was another one. I talked to them, and they thought Caltech was a wonderful place and asked, "What did you want to study there?" I said that about all I could study—I couldn't continue in the railway business—would be electrical engineering. So I came over and talked to Professor [Royal W.] Sorensen [professor of electrical engineering; d. 1965]. He didn't know anything about me, hadn't seen any transcripts or anything, so he was properly noncommittal but suggested I send in my transcripts and so on, which I did. And then he said they would like to have me as a graduate student. I came in the fall of 1925, worked for [Francis W.] Maxstadt [instructor, later assoc. professor in electrical engineering] in the laboratory as a teaching assistant, and kept on there for the next three years, until I got my PhD in 1928. That was an interesting class that year, with people such as—who are still living—Arnold Beckman, [James] Hugh Hamilton, Charlie [Charles F.] Richter. Among those who died who were good friends were Clark Millikan and Morgan Ward in mathematics.

SCHEID: I'd like to go back a little bit. I wanted to ask you a little more about your childhood. Your aunt was your main inspiration, rather than teachers in the schools, is that it, in your early years?

LINDVALL: Yes.

SCHEID: Were you the oldest child? Did you have siblings?

LINDVALL: I had one sister, twelve years older, and she regarded me as a young squirt all the time, naturally. She went to Oberlin College and graduated there; that was a school that had no interest for me.

SCHEID: What was your father's education?

LINDVALL: Self-educated. He came from Sweden. He was, I think, twelve years old when he and his family came over. His father said, "We'll probably never see Sweden again, so we will all now talk English from here on." Which wasn't too much of a problem for my father and his siblings. It was hard on his mother, but they made out.

SCHEID: Why did they decide to emigrate, do you know?

LINDVALL: I think just for greater opportunity. They lived in a backwoods part of Sweden—agricultural. My grandfather had no established profession. He was pretty much a handyman around the place; he could do most anything. In fact, he built the pipe organ in the little church.

SCHEID: So he was like a carpenter?

LINDVALL: Yes, carpenter and general handyman and mechanic.

SCHEID: So he didn't go out and homestead or anything?

LINDVALL: No. Later on, he tried to get into the pipe organ business in the United States and made a bad mistake in bidding on a church organ in St. Louis, lost quite a lot of money in it, and decided that he was through with the organ business.

SCHEID: Did you have much of a technical education in school?

LINDVALL: Well, all we had was the usual algebra and geometry, physics and chemistry. We also had shop work—or manual training, as it used to be called. That had woodshop and it had metalworking, too. I worked a couple of summers in local factories doing machine-shop work.

SCHEID: You mentioned that you wanted to do engineering. When did that idea arise in your mind?

LINDVALL: Well, about the time I had to make a decision as to what school I wanted to go to. By that time, I was pretty well convinced that I didn't want any of these other professions, and engineering still had an appeal.

SCHEID: Did you have someone you knew who was an engineer whom you admired?

LINDVALL: No, I didn't, it was just the general subject matter. Automobiles were just beginning to come along. My father bought his first car in 1913, I think. He also bought an electric automobile for my mother and sister at that time. Why it's taken so long to get back to electric cars I don't know. In those days, kids had a chance to work on cars. The Model-T Fords were just wonderful for youngsters to take apart and repair.

SCHEID: Well, maybe it was also a necessity. There weren't that many people around who repaired them.

LINDVALL: Well, that's right. Garages were few and far between.

SCHEID: Were you ever interested in any of those other fields?

LINDVALL: Well, as I say, watching railroads, yes. And that led me to my BS [1924] program at the University of Illinois. But law and medicine didn't have any appeal. I knew quite a few doctors through my father and his store, but their lives somehow didn't appeal to me.

SCHEID: Engineering at that time was a growing field, wasn't it?

LINDVALL: Well, yes, of course, because the railroads were still expanding, and the automotive business was just beginning, and all the things that went along with the automotive business. For example, there was a smallish company in Moline called Borg & Beck, and they started making clutches for automobiles, which they sold to various makers of cars. And there were a lot of makers of cars in those days; practically every crossroads had a car factory. That business gradually grew and moved out of the community and was the basis for what's now Borg-Warner. And another factory, Moline Tool Company, made the first multiple drilling equipment for boring out cylinder blocks for automobile engines—to bore all four cylinders, or six cylinders, at a time. That kind of thing was developing all over the country and called for engineering activities.

SCHEID: You saw yourself as designing those kinds of things?

LINDVALL: Yes. Well, operations, such as I encountered in railroads, was more to my liking.

SCHEID: Was it always assumed that you would go on to a university?

LINDVALL: Oh, yes. My sister had graduated from Oberlin, and it was just assumed that I would graduate from college some place.

SCHEID: There weren't any financial problems?

LINDVALL: No, fortunately. Also, it was a lot cheaper to go to school in those days.

SCHEID: That's right. When you decided to go into railroad engineering, what did you know about the prospects?

LINDVALL: Very little. I saw the big railroad shops and the operations of trains and whatnot. With my family I had done a fair amount of traveling. But I didn't really know anything about the railroad business. I think what I really would have been more interested in is if I'd gotten into the railroad equipment business rather than thinking about the operation or management of railroads.

SCHEID: Working for a company that supplied them, perhaps.

LINDVALL: Supplied rolling stock—that is, the locomotives, or passenger and freight cars, brake equipment, that sort of thing.

SCHEID: But there weren't any opportunities in that field?

LINDVALL: Well, I just didn't think about it. And those companies weren't recruiting. In fact, it took quite a while before railroads appreciated that there was anything to be gained by taking on people who'd had more education than they could offer in their own shops.

SCHEID: How did this program start at the University of Illinois, then—this program of railroad engineering? Was it one of the rare programs of the country?

LINDVALL: It was rare. Illinois and Purdue, I think, were the two outstanding ones in railroad engineering at the time. And they did a certain amount of research or investigation for the railroads—brake testing, locomotive testing, and so on. The University of Illinois had a test car that could be coupled in behind a locomotive and all the characteristics of the locomotive were determined—the tractive effort, the drawbar pull, fuel consumption, all that sort of thing.

SCHEID: But they were training people who weren't being hired by the railroads.

LINDVALL: Not in any quantity, no.

SCHEID: But they were being financed by the railroads it sounds like.

LINDVALL: These investigations? Yes, really through associations—the Association of American Railroads, or trade associations that were making the equipment they wanted tests run on.

SCHEID: I didn't realize you had gone to UCLA, or to the ancestor of UCLA. Did you live at home, then, when you were going there?

LINDVALL: Yes. I rode the streetcar to the campus.

SCHEID: Where did you live in L.A.?

LINDVALL: On North Burlington Avenue—the area south of Temple and just a little bit north of Westlake Park, which is now called MacArthur Park.

SCHEID: You would have been able to go to Berkeley after that, but you chose, because of the railroad business, to go to Illinois?

LINDVALL: That's right.

SCHEID: Did you have any particularly influential teachers at Illinois? You mentioned some at UCLA.

LINDVALL: Well, in retrospect, I would say that perhaps the most outstanding teacher I had at Illinois was not in either the railway or the electrical engineering department. He was a mechanical engineer, Professor [George Alfred] Goodenough, and he was a specialist in thermodynamics. He was a very broad-gauged man. He had a tremendous interest in English literature. He used to be asked, more or less regularly, by the English Department to teach a course in English, in which they expected him to do a great deal of reading aloud to the students. And this he did with very good effect. Maybe he was the one who helped me establish and maintain an interest in the humanities—well, he more or less reinforced it. I had a rude awakening when I first went to the Southern Branch of the University of California. They had what they called then, and may still have, I don't know, what was called the Subject A examination.

SCHEID: Yes, they still have it.

LINDVALL: Which I flunked, after having gotten A's in English in high school. So I was put into one of the classes we used to refer to as "Bonehead English." Fortunately, I had a very good teacher who got us really interested in literature. And I went on and took more of that kind of thing than I needed to. When I was at Illinois, I wanted to take some more. I was a junior then, and no humanities whatsoever was required of the engineers. Well, I did register for a course in 19th century English poets. I showed up at the class and turned in my registration card. The instructor shuffled them and said, "Here's a blue card." All the rest of them were white. "Blue card, that's engineering isn't it? Well, aren't you in the wrong course?" I said, "I don't think so. May I stay?" "Well, I guess so. It's unusual, though, for any engineer to come over here and take a course." So I did and enjoyed it, and I took a couple more humanities courses there. So I was somewhat of a maverick in that respect.

SCHEID: In the early twenties, university life must have been quite different from what it is today.

LINDVALL: Yes, most of the students lived in fraternities or rooming houses. Entering as a junior, I was not particularly interesting to fraternities, so I lived with some fellows I knew from Moline, in a rooming house. It was very satisfactory.

SCHEID: They didn't have dormitories as they do now?

LINDVALL: No. Well, they had a couple of dorms, which were rather old. One of my friends said he decided to move out after a rat ran across his bed one night. [Laughter]

SCHEID: Were there many women at the university at that time?

LINDVALL: Oh yes. It had been co-ed for a long time. But not in engineering.

SCHEID: When you came to Los Angeles with your family, what were your impressions? What was your life like, compared to what it had been in Moline, Illinois?

LINDVALL: Well, for one thing, I didn't have to help my father shovel snow. And of course we had a car and enjoyed driving around the countryside, although the Sunday afternoon traffic jams were really horrendous. Very few intersections had any type of traffic control. One notorious corner was Sunset Boulevard and Western Avenue, which at that time had a couple of movie studios right near by—one of them was right on the corner. Once in a while there'd be a police officer directing traffic, but normally no, and there were no signals. So it would back up for two or three blocks and you'd inch your way through, and with some certain amount of bluffing and whatnot, you'd finally get through. One of the most interesting times was when, at that corner, the old comedian Ben Turpin, who had crossed eyes, got out in the middle of the street to direct traffic. He'd be looking one way and motioning another, and that only added to the confusion. [Laughter]

SCHEID: You mentioned going up into the Sierras. Did you start to go out into the countryside like that when you came out here, or had you always done that?

LINDVALL: No, I'd never done much of that. But I met some young men who liked to do that, so we would go backpacking in the Sierras. Then the family made a drive in the early days into Yosemite. We did it the hard way—up over Wawona Road and down into the valley.

SCHEID: You mentioned that you came to Caltech because you had a teacher at UCLA who had studied there.

LINDVALL: Art Warner. And then two friends who later graduated from Caltech. They talked it up with great enthusiasm.

SCHEID: Did they graduate in engineering, too?

LINDVALL: Yes.

SCHEID: Was the public aware of Caltech very much at that time?

LINDVALL: Not very much, no. We heard about it while we were finishing over at the Southern Branch, because you've had two years of engineering, and where do you get the rest of it? And Caltech was mentioned. But as I say, I had this urge to follow the railway course.

SCHEID: What other schools would have been alternatives at that time?

LINDVALL: Well, Berkeley, of course. And most any of the state universities had engineering, but I hadn't thought about them. USC had engineering, but it was not very strong at that time and not highly recommended. The natural place to have gone would have been Berkeley.

Begin Tape l, Side 2

SCHEID: We were talking about Caltech. We didn't go into much detail about your studies here. What were the courses you took that you particularly enjoyed, that made a big impression on you.

LINDVALL: Well, at that time, people who were starting graduate study in electrical engineering were encouraged by Professor Sorensen to get all the physics and math that they could. He had the philosophy that you shouldn't establish a great many highly specialized electrical engineering courses. So I was in the same physics classes, and advanced math classes, and so on, as people who were taking physics. In fact, at the time I got my PhD [1928], the requirements for physics and engineering were such that my degree could have been labeled either one. But I chose the electrical engineering label. I had some very interesting people as teachers. Dr. [William Ralph] Smythe was, as we used to say, a fellow who separated the men from the boys. [Laughter]

SCHEID: How did he do that?

LINDVALL: Well, his course in electricity and magnetism was a very demanding course, with problems that taxed one's ingenuity and math ability and so forth. It was very good. Then I had lectures in thermodynamics from Dr. Paul Epstein. He gave beautiful polished lectures, which I enjoyed very much. But I was very grateful, along with all the rest of the class, when just before final examination day, Dr. Epstein posted a notice that he had concluded that the material of the course did not lend itself to an examination. [Laughter] Also, Dr. Harry Bateman, an English-trained mathematician, offered a course in advanced vector analysis, which I took. It caused me a good deal of difficulty, because it turned out to be pretty much a transformation-of-coordinates type of course. In other words, Dr. Bateman would give an hour lecture on whatever he happened to be working on at the time, and then he would usually say, "Well, all right, as an exercise, put this into vector analysis form." But it made us work, and I learned a good deal from it. Then I had a very interesting course from Fritz Zwicky, who taught what was really sort of an introduction to thermodynamics of a broader sense than I had encountered as an engineering student. Engineers at that time were concerned more or less with the thermodynamic properties of steam and refrigeration vapors. Zwicky broadened it out to include a lot of the basic things that are in physical chemistry and an overall energy approach to problems. So that was a very helpful experience.

And then I took a course in atomic physics from Dr. Richard Tolman. We were using a new book at the time, which was in German—*Atomic Structure and Spectral Lines*—and we had to sweat it through in the German language as we studied it. Dr. Tolman was very frank and earnest. Some bright guy would ask a question, and Tolman would say, "Don't rush me on that; that's in tomorrow's lesson." But that course was very stimulating, because Tolman himself was a very stimulating person. I also took from him an Introduction to Relativity course, which involved a lot of his personal philosophy about science.

SCHEID: It sounds as though the education at Caltech was very theoretical.

LINDVALL: Oh, it was. On the engineering side, we studied practical matters of transmission-line design, high-voltage transmission of power. At that time, the mathematics for doing that was only in the development stage, so we had to do a lot of our calculations, you might say, the hard way, because convenient tables of functions and so on simply didn't exist at the time.

SCHEID: You mentioned that Smythe taught by using problems. The others that you mentioned seem to have taught theory.

LINDVALL: Well, Zwicky gave us a lot of problems to do. But Epstein was lecturing, giving us the broad picture of thermodynamics.

SCHEID: What had been your experience in your courses before? Was this problem-oriented approach the usual approach in the field?

LINDVALL: Yes. Well, the mathematical basis for engineering hadn't been as developed in the early twenties as it has been since.

When I was graduate student at Caltech, I lived in a bachelor shack with [G.] Harvey Cameron. At that time, he had just gotten his PhD and he was [Robert Andrews] Millikan's first assistant in cosmic rays when cosmic rays were not a respectable subject of investigation—they hadn't established themselves. [I also lived] with Hal [Hallam E.] Mendenhall, who got his degree the year before I did and later went on to Bell Labs. Mendenhall owes his life to Professor Sorensen, literally, because in working with what we called the vacuum switch in the high-voltage laboratory, Mendenhall reached up to make an electrical connection and got hold of the high-voltage power service coming into the laboratory. Professor Sorensen was there and used artificial resuscitation and got him breathing again by the time the ambulance came. His feet were horribly burned, and he spent months afterward hospitalized with skin grafts and one thing or another, but they never did quite take. But he's made a career, with crutches and canes, since, and it never got his spirit down. And then there was Arthur Warner, who was my first physics instructor, at SBUC. The four of us lived in a bachelor shack, up there in Chester Court, which has disappeared. It was there I first learned to do a little elementary cooking. I've kept on with it and enjoyed it ever since.

Later on, Cameron and I were living alone together in another house, and then he went off to accept a teaching position in physics at Hamilton College, in Clinton, New York, where he stayed for the rest of his life. Well, one of the things that I missed and Mendenhall missed was something of a humanistic/social-science nature in graduate work here at Caltech. So we spoke to Professor [Clinton] Judy, who was then chairman of the Humanities Division, and asked if it would be possible to have some kind of a seminar or something of that sort, rather than just sitting in on any undergraduate class we wanted to. So he started a little informal seminar. We used to meet at his house, which was a lovely place for meetings. It was one that he'd built to house his books—he had a tremendous personal library.

SCHEID: Where was his house?

LINDVALL: It was on Woodstock Road, a little dead-end street down in San Marino. Among those who used to go to that seminar were Charlie Richter; Clark Millikan; Fritz Zwicky; Graham Laing, who was an economics professor; and one or two of the English instructors from time to time.

SCHEID: Roger Stanton, perhaps?

LINDVALL: Yes, he would come once in a while. We used to meet about once a week, and each of us in turn would present a paper on some non-technical subject. And that was very good.

SCHEID: What kinds of papers were presented?

LINDVALL: Well, Zwicky, for instance, gave a review of a then new book, *The Decline of the West* by Oswald Spengler [1922], which none of us understood very well, and I don't think he did either, but it stimulated a lot of discussion. Clark Millikan gave a paper on

James Branch Cabell. In the discussion of that, Graham Laing came through with a number of his shady jokes. I might interpolate here and say that we all urged Graham Laing to record or to write down his limericks; he had a vast store of them. We would ask him, “Well, give us the limerick of so-and-so.” And he would say, “Do you want the French or the English version?” And he said, “Well, why write these down, because no one would ever publish them.” But if he’d done so, and we’d kept the manuscript, it could have been published today. He was a very stimulating fellow. In those days the Humanities Division was almost completely composed of more of the “Mr. Chips” type. Research was all right, if somebody wanted to do some research and write a paper, but it was not, shall we say, pushed. So in that sense, Caltech humanities has changed considerably. And I can understand why; they don’t want to appear to be just a service department.

SCHEID: Do you remember any papers that you presented?

LINDVALL: Well, I gave a paper on a Professor Stuart Sherman, who was a professor of English at Illinois and quite a literary critic. He’d written a number of books of literary criticism.

SCHEID: Do you remember anything that Charles Richter did?

LINDVALL: He gave a talk on Dante’s *Inferno*. And be confessed at that time that he was studying Italian so that he could read it in the original. [Laughter]

SCHEID: You mentioned before that you had a course with Tolman and the text was in German. You knew German, then?

LINDVALL: Well, German was one of the languages we had to learn and pass an examination in; fortunately, it was just a reading examination.

SCHEID: German and French probably?

LINDVALL: Yes. Well, of course, I got into research for my PhD thesis[1], and I continued work on the vacuum switch, which was an idea of Professor Sorensen's. It was well known that a high vacuum was a good insulator, but could it be used as a medium in which electric current could be interrupted? There were about as many people who argued that it could as that it couldn't. Those who said it couldn't said, "Well, an arc would form, and it would never go out. The metallic ions from the electrodes would maintain the arc." And there were those who said, "Well, with alternating current, the current has to go through zero twice in each cycle. And at that time, if the metallic ions got out of the way, there would be a good vacuum again, so the arc would not re-strike." And indeed, that's the way it worked. We were able to use the high-voltage laboratory as a source of power to do switching with small switches. We built a larger switch, which was a single-pole switch, which we took out to one of the Southern California Edison Company's substations, and we demonstrated it there. It was a pretty impressive demonstration, because in those days the circuit breakers were oil-filled, and they would, from time to time, blow up, starting fires and otherwise being messy. So there was a great deal of interest in anything that could replace oil circuit breakers. So then, with the cooperation of the Edison Company, we built a three-phase switch, and that was really too far ahead of its time, because not enough was known about high-vacuum technique and how to handle it, or how to get clean metals for the system. So it was never very successful. It worked if we kept the pumps going vigorously and didn't allow any leakage to occur, and that kind of thing. But like many of Professor Sorensen's ideas, it was way ahead of its time. It wasn't until nearly thirty years later that one of the early Caltech students, James Cobine, at General Electric Company, brought it to commercial use. By that time, vacuum techniques and clean metals and a better understanding of metal arcs had been achieved, so it was possible to make a commercially acceptable switch.

SCHEID: You mentioned Professor Sorensen and his other ideas? What were some of his other ideas?

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[1] "Contact behavior and gas phenomena in a vacuum switch" (1928)

LINDVALL: First of all, he had the idea for the high-voltage testing laboratory. He got together with the Edison Company; they were pioneering in high-voltage transmission at the time—real national pioneering. He offered to design transformers if Edison would build [Caltech] a lab. He had done transformer design when he was at General Electric, before he came to Caltech [Royal W. Sorensen came to what was then called Throop Polytechnic Institute from General Electric in 1910—ed.]. And he designed these high-voltage transformers and designed the interconnection, so that you could get a million volts out with enough current to be realistic. The transformers were built by Westinghouse. General Electric didn't trust his design, although he was one of their old alums, you might say. Westinghouse built them, but wouldn't guarantee what they would do when they were interconnected. But after they were interconnected and working successfully, the company came around and put the "W" nameplate on them.

So that was a pioneer effort. And in that laboratory, Professor Sorensen and graduate students worked on some of the problems of high-voltage transmission. One of his concepts was that, sooner or later, the whole Pacific Coast would be tied together in one big high-voltage transmission system. I remember when that paper was presented at a technical meeting, it was almost laughed out of the meeting. But it wasn't very many years later until Edison and Pacific Gas & Electric were interchanging power, and then it was extended to the Pacific Northwest and down to San Diego.

The Edison company had a small research crew that would use the high-voltage lab about half the time and studied some of the practical problems of insulators—the insulator strings that supported the transmission wires. One of these problems was the nature of flashovers. That's what the laboratory would do, build up the voltage until the insulator string would flashover, and then the Edison people would design guard rings and so forth, so that the flash would not cascade over the porcelain insulators and crack them from the heat. They worked out methods of washing these insulators with a high-pressure water jet and found out that this could be done without shutting the power down. And they studied corona discharge from the wires and protuberances, things of that sort—a lot of little housekeeping details that were necessary before they could go up in voltage to the so-called 230,000-volt line, which they built from Big Creek down. It was built as 150,000, and then they raised the voltage to 230,000. And all the other transmission lines have been built in that range or higher.

SCHEID: How long had Southern California Edison been associated with Caltech in this cooperative effort, do you know?

LINDVALL: The high-voltage laboratory was finished, I think, in 1924. It was a going operation at the time I came, in 1925.

SCHEID: And had Sorensen just come then, or was he here earlier?

LINDVALL: No, he came, I think, back in 1910.

SCHEID: Oh, he was here before [R. A.] Millikan then.

LINDVALL: Yes. Sorensen was cagey enough to see that if he hitched electrical engineering to physics, rather than leaving it tied to civil and mechanical engineering, he'd have a better chance of doing graduate programs, and indeed that's the way it worked out.

SCHEID: In the cooperation with Edison, Edison provided the money for the lab?

LINDVALL: They built the laboratory with their money, with the arrangement that they would have half-time use of it. For a while, they used it about half-time, and then their use gradually tapered off as the power industry developed more and more of the high-voltage knowhow. So there was less and less need for it. Then shortly after Caltech's lab was working, General Electric was instrumental in getting a lab built at Stanford, where General Electric transformers could be used instead of Westinghouse. [Laughter]

SCHEID: So the Edison employees worked in your lab with the Caltech students and professors?

LINDVALL: Well, most of the time the Edison people worked by themselves, but the students frequently helped them.

SCHEID: When you were at Caltech at that time, were you paying your own tuition?

LINDVALL: Well, as a teaching assistant, I had a remission of tuition. And at that time, when I first was a teaching assistant, tuition was $90 a year.

SCHEID: But then you had to pay for your own living expenses.

LINDVALL: Well, I had money that I'd saved up in that year that I worked for the street railways, and then I got a small stipend. I don't remember how much it was.

SCHEID: Besides this high-voltage transmission, was Sorensen involved in any other major projects?

LINDVALL: He did a lot of consulting work on high-voltage transmission. He helped quite a bit with the Los Angeles Bureau of Power & Light and their line to Boulder Dam, and with the Metropolitan Water District. He was very helpful to the Metropolitan Water District in sort of an overview of the electrical equipment that went into their pumping stations.

SCHEID: Were there other professors in electrical engineering that were doing different kinds of work?

LINDVALL: Well, there was Francis Maxstadt, whom I mentioned earlier. He taught a course in electric traction. Later on, after I came back to teach here, I took over that course, until student interest dwindled to practically zero. Then there was Professor [George] Forster, who taught some physics and he taught some electrical engineering. He later moved up to the FCC, where he was much more in his element, you might say, than around here. Then there was Stuart Mackeown, who came here as a National

Research Fellow. He did some teaching. I think he taught the first course in electronics here in electrical engineering and sort of grew up with the business.

SCHEID: I was going to ask you whether you enjoyed teaching. You were getting some teaching experience at that time. Did you find that enjoyable?

LINDVALL: Yes. Of course, I naturally didn't know really enough about the psychology of students to always handle the class properly, but most of the time I did. I remember one day the class was sort of unruly, and one of the fellows who was the football team captain came to my rescue by saying, "Pipe down, you guys! I want to hear what he has to say."

SCHEID: Did you have small classes?

LINDVALL: Oh, ten, twelve, that sort of thing.

SCHEID: Did you also teach lab courses?

LINDVALL: Yes. Electrical machinery laboratory, which gradually phased out as electronics came in.

SCHEID: But what were you teaching as the regular course?

LINDVALL: Power transmission and electrical machine design. Well, electrical machine design came after I was full-time on the teaching faculty. I could incorporate some of my General Electric experience in that. But mostly, as a teaching assistant, I had to work on those subjects that I could handle from my undergraduate experience.

SCHEID: I wanted to ask you also: You were living in Pasadena, and you told me a little bit about life on Chester Court, but what about the larger scene in Pasadena? Did you participate in anything in Pasadena at that time?

LINDVALL: Well, I didn't very much, except I was a devotee of the Pasadena Playhouse. I used to go there for practically every play they had. And there were even a few Caltech faculty who used to participate in small parts there. One year, they put on a play written by E. T. Bell, the mathematician, which was based on science fiction. And I think Professor Zwicky worked on some of the sound and lighting effects to enhance the science-fiction aspect.

SCHEID: That was when it was in its old building, right?

LINDVALL: The one they're trying to rebuild. Gilmor Brown was the head man. It was to a considerable extent an amateur affair. It gradually took on the aspect of being a theater school, and it became less and less of a place for young fellows or young women who wanted to get a little experience on the stage but didn't have any ideas of making a career of it.

SCHEID: Do you know people who participated? Do you remember some of the names?

LINDVALL: Oh, heck, I've forgotten. Right after talking pictures started to come in, a few of the old-time silent-picture people came over to get training in speaking and took roles for which they'd have to learn their parts, which they hadn't had to do in the silent pictures. But I have a weak memory for things like that.

SCHEID: I meant people at Caltech who took part. You mentioned Bell and Zwicky, but were other people around the campus involved in it?

LINDVALL: I don't remember any—at least I wouldn't want to mention any, because I'm not sure.

SCHEID: I've seen photographs of a couple of the Millikan boys in plays at the Playhouse. But I don't know anything more about it than that.

LINDVALL: That may be.

Well, let's see. I finally got through with all my degree requirements, and got the PhD in 1928—as I say, with some colleagues who turned out to be pretty illustrious people. At that time, we held commencement on the east façade of the Gates building [Gates Chemical Laboratory]. As you know, there are stairs coming up and a platform with stairs going down. At that time, Richard Tolman was dean of graduate studies, and he loved to announce each PhD candidate: "And he is the author of a thesis entitled"—and he would reel off the whole technical phrase. And if it was in German, he would love it even more. [Laughter]

SCHEID: Did people write their theses in German?

LINDVALL: A couple of them did. Particularly, we had two or three students who were Norwegians or Hollanders, for whom that was an easier language.

SCHEID: So there were students coming from that far away at that time?

LINDVALL: Yes.

SCHEID: Caltech had that kind of a reputation?

LINDVALL: Well, it got that reputation fairly early. Millikan, early on, induced Dr. Epstein to come—he was in Germany, and he came over here. And we had a succession of important visitors from Europe, people such as Bohr, Einstein, Lorentz. Lorentz was a wonderful man. He gave beautiful lectures, and he would finish the lecture and turn to us with a little smile and say, "That is the result, if I have made no mistake." He was here a couple of times, I think. People of that sort would go back and talk about this new institution. And of course [Arthur Amos] Noyes, in chemistry, was well known in this country and in Europe.

SCHEID: You mentioned Bohr. Did you go to lectures of his?

LINDVALL: Yes. He was very difficult to understand. Even for a Dane, his English was difficult.

SCHEID: It was not the material so much as the language?

LINDVALL: Well, in those days, atomic physics was a little more straightforward and less mathematical than it is today. Modern quantum mechanics was just beginning to come in.

SCHEID: The book that you were using, the German book, do you remember who that was by?

LINDVALL: [Arnold] Sommerfeld [*Atombau und Spektrallinien*, 1921].

SCHEID: Oh, it was Sommerfeld. He came here, too, didn't he? Did you hear him?

LINDVALL: Only in the seminars. In those days, the principal seminar, which we all attended—at least the engineers and the physics people did, and the astronomers—was the so-called physics seminar. Dr. [R. A.] Millikan used to go around to the lab, and he'd see one of the graduate students and say, "Well, here's a new paper in your field. Report on it at the seminar." And then, of course, the faculty would take turns and the visitors would participate. Sir James Jeans came. He and Millikan had lots of arguments about cosmic rays. For a little levity, I can remember one seminar where Millikan was theorizing about the origin of cosmic rays after listening to some of Jean's cosmology. Zwicky was in the row in front of me, and Zwicky started rocking back and forth in his seat, muttering, "Jesus Christ, he's crazy." [Laughter] I don't know how many people in the hall heard it. In those days, cosmic rays were not fully established as a tool for nuclear physics research.

Well, now where do we go? Oh yes, I graduated, and Professor Sorensen thought it would be highly desirable for me to have so-called practical engineering experience, whether I wanted teaching as a career or not. Based on his own experience, he thought that was good—to have some practical engineering in the background. And indeed, I must say that while we used to be a little impatient at times—we'd say, "Well, today Sorensen did some more reminiscing"—we learned a great deal of engineering vicariously that way. We didn't realize it at the time, but it had a lot of merit. Well, at any rate, I went to the General Electric Company, into their general engineering department. It was a small department that handled oddball problems with a certain amount of original investigation. I spent a period of about three months in their test course and in their advanced course in engineering, some of which was fairly easy for me, having had the work here. But those were good tough engineering problems, more comprehensive than anything that had been offered here. Then I had various assignments working with various engineers in the company on machine design, and over in the research laboratory, where I learned a good deal from Dr. [Willis R.] Whitney, who was then the research director for General Electric. He had a wonderful manner of operation. He used to say that it wasn't his business to direct research but to make opportunities for people who had ideas in his laboratory. He sat more in a permissive capacity than as a director. And his method of working was to be out of his office most of the time, sitting around in the other people's laboratories, talking about their problems, and so on. Very broad-gauged individual. So that research lab experience was interesting to me. And then Professor Sorensen asked me if I'd be interested in coming back to Caltech—this was, I guess, the summer of 1930. And I said I would, even though it meant a cut in pay.

SCHEID: Did you jump at the chance? I mean, you wanted to come back?

LINDVALL: Well, we had just been married when we went to Schenectady, to GE, and we were both anxious to get back to California. We didn't love the Schenectady winters. So I won't say I jumped at the chance, but I was glad of the opportunity.

SCHEID: Was your wife a native Californian?

LINDVALL: No, from Michigan. So we were glad to come back here. I was an instructor, and then over the years got promoted.

SCHEID: When you got your PhD, did you consider seriously going into the academic area?

LINDVALL: Not at that time. I agreed with Sorensen that some engineering experience in an engineering company would be helpful to me if I ever wanted to teach. But I thought it was a good idea to go back into teaching again.

SCHEID: You liked it?

LINDVALL: Yes, I did.

SCHEID: Right before that was the stock market crash. Did that affect the situation in any way?

LINDVALL: Well, after I left General Electric Company, engineers were in deep trouble. While General Electric had a very enlightened, almost paternalistic, policy of retaining their engineers, the only way they could do it was to reduce the work week and reduce the pay accordingly, rather than have heavy layoffs. Westinghouse Company, on the other hand, had massive layoffs. They lost some of their finest engineers, and they never were quite up to GE's engineering after that. Some schools benefitted by having some of their top engineers get into academic work.

SCHEID: Maybe we'd better stop for today.

FREDERICK C. LINDVALL

SESSION 2

November 21, 1978

Begin Tape 2, Side 1

SCHEID: Well, these are just little points, but I wanted to clarify a couple of things. Where did your grandparents settle when they came to this country?

LINDVALL: In the little town of Orion, Illinois, which is not far from the Moline-Rock Island Quad Cities area.

SCHEID: What about your mother's family; you didn't mention anything about them.

LINDVALL: Well, both her parents were born in Sweden. They met in this country and were married here.

SCHEID: Were they part of a church group or something? How did they meet?

LINDVALL: Well, I don't know. They just happened to be in the same town, I guess.

SCHEID: I see. Then you mentioned that when you were in Europe in 1914, you saw how a country behaves at the start of a war. I wondered if you could elaborate on that a little bit.

LINDVALL: Well, of course everything was disrupted. We got permission to cross France, but we had to take our chances with any train that had space. The trains, of course, were all busy hauling troops. So a train would come into a station and we would learn whether there were any seats left. If so, we would go as far as we could on that one, and then get off and try for another one. So we finally got to Paris, where all the taxis were being run up to the front as a way of transporting troops. I don't know what they expected to do—scare the Germans with the taxis or what—but at any rate, that meant that transportation around Paris was very difficult. We had to go to some headquarters to get permission to stay overnight in Paris and again to leave in the morning, which we did on a train to get to the Channel and crossed to England. The French were busily digging rows of trenches outside Paris, expecting the Germans to get much closer than they ever did.

SCHEID: Had you been in Germany at all, prior to the war's outbreak?

LINDVALL: Yes.

SCHEID: Did you sense anything there?

LINDVALL: Well, there were some Americans who were a little closer to things at the embassy, who felt that there was trouble coming, that war was likely to break out that summer. The exact alignment—who was going to be fighting whom—was not quite clear. But one thing was evident: The Germans were recalling all of their people who were of military age who were vacationing in Italy or Switzerland or someplace else. So the trains were full of fellows coming back to Germany to be ready for mobilization.

SCHEID: When you got to England, what was that like?

LINDVALL: Well, that was relatively quiet. There hadn't been any bombings from zeppelins or anything of that sort, in the early stages of the war. Of course transportation to the United States was very difficult to come by. But we met a woman who every summer would take a few ladies on a tour of Europe. She was the wife of a minister in the Boston area. She was glad to join forces with us, because at least there was one man in the group then. She knew a shipping agent—at a little hole-in-the-wall place—who managed to wangle us passage on a ship. We were warned that we might not be able to get bunks and so on; we might have to sleep on deck chairs, things of that sort.

SCHEID: Was that true?

LINDVALL: No, we got bunks all right.

SCHEID: And the U-boats were already all over?

LINDVALL: Oh, yes. So they were very careful.

SCHEID: You mentioned that when you were at the Southern Branch of the University of California, you took surveying. Was that part of the engineering course at that time?

LINDVALL: Oh, at that time all engineers took surveying, yes.

SCHEID: That was just a standard part of the curriculum?

LINDVALL: Yes, and quite a bit of mechanical drawing.

SCHEID: Was the course much more vocational than it is now?

LINDVALL: Well, one could do a credible job of surveying as a result of having had that experience. But it wasn't intended as a training course for surveyors, but rather so that all engineers would understand land surveying and the principles underlying it.

SCHEID: Then I was going to ask about your time at the University of Illinois. In this period, do you recall what the general social background was of the students at the university at that time? Was it a mixture?

LINDVALL: It was a mixture, the sort of thing you get in any state university.

SCHEID: So people who didn't have a lot of money were also able to attend?

LINDVALL: That's right.

SCHEID: Because the tuition was low, or because they were working?

LINDVALL: Well, both. There were always fellows, you know, who were waiting tables in the sorority houses or in restaurants in town.

SCHEID: Robert Millikan got his Nobel Prize in 1923, and that was around the time you were deciding to come to Caltech. Did that make a big splash, that prize?

LINDVALL: No, it didn't create much of a ripple in the Middle West. I'm sure the *Chicago Tribune* had a story about it, but it didn't make an impression on me. I'm sure it made a big impression locally.

SCHEID: You mentioned Tolman's course on relativity and his personal philosophy of science. Do you recall that?

LINDVALL: Well, no real details. But he had his own way of phrasing things. Well, I remember one. He said, "Entropy is the degree of rundown-ness of the universe."

SCHEID: Then you also mentioned a few people that were in your class in 1928—among them, Clark Millikan. Did you know him well?

LINDVALL: He was taking mostly mathematics, and he wasn't in the engineering courses to any extent. But we were in some physics courses together and also a math course or two. Clark was a very intense person; he would work long hours at his studies and thesis preparation and so on. That was, of course, before we had any aeronautics at all.

SCHEID: Do you think he was overwhelmed by his father's reputation?

LINDVALL: Well, I think he was not overwhelmed by it. There's at least one story, that while he was still at Yale, he was reading something in the press about his father talking about science and religion. The story is that Clark wrote to his father and said, "Please stick to science." [Laughter]

SCHEID: The Millikan family was quite religious, I understand, weren't they?

LINDVALL: Reasonably so, yes.

SCHEID: Did you know them well? Did you know Mrs. Millikan at all?

LINDVALL: She had tea parties for graduate students, and then later on for faculty. She would bring the undergraduate students in too, on successive Sunday afternoons. She would have a Miss Durkes, who essentially ran the registrar's office, come, because she would know practically all the students by sight and by name, and she would perform introductions.

SCHEID: What transpired at these parties?

LINDVALL: Oh, you just stand around. There was a comedian in those days who used to laugh about tea parties and say, "Giggle, gabble, gobble, and git."

SCHEID: Were the students made to feel at ease at these things?

LINDVALL: Not particularly, no. They came out of a sense of duty. And she did them as a sense of duty.

SCHEID: So it really didn't help things that much, as far as the student life here was concerned.

LINDVALL: Oh, I think it was a help, all right. At least some of the students got the feeling that somebody cared.

SCHEID: Then I wanted to ask you a little bit about Sorensen. Do you know how he happened to come to Caltech? You mentioned he was at GE before.

LINDVALL: I don't know just how the connection was made, but President [James] Scherer of Throop Polytechnic Institute had been given Sorensen's name as someone who might possibly be interested in coming out here to start some work in electrical engineering. The idea appealed to Sorensen, so he came I think it was in 1910.

SCHEID: How did he run his high-voltage lab? He had the Edison people and the students, and how did he portion out the responsibilities?

LINDVALL: Well, he would do some work at the laboratory, and he would always have some graduate students who were studying various phenomena there. And then of course the Edison people had their time in the laboratory, in which they did what they wanted to do, with or without student participation.

SCHEID: Did he work right along with the students?

LINDVALL: Oh, yes.

SCHEID: Were you close to him personally at all?

LINDVALL: Reasonably so, yes. That is, after I came back here and was teaching full-time.

SCHEID: You said that Edison eventually left the lab.

LINDVALL: It was no longer needed to answer questions in high-voltage engineering. Those either had been answered or there were then other laboratories of the major equipment manufacturers to produce design data and recommendations.

SCHEID: And there weren't any other questions that they could have explored that would have been beneficial to their own business?

LINDVALL: I think not.

SCHEID: Then you mentioned the productions at the [Pasadena] Playhouse. I wonder if you remember any specifically that made a big impression on you.

LINDVALL: Sorry, my memory's too bad on that.

SCHEID: What kind of repertoire did they have?

LINDVALL: Oh, they did a variety of things—some Shakespeare; they did, I think, several of O'Neill's plays; they tried to do some contemporary playwrights, and things that didn't call for too much professionalism, because it was, after all, a teaching operation.

SCHEID: Then I wanted to ask, what were the specific problems that you worked on at GE?

LINDVALL: One was a rather thorough study of a starting motor for automobiles—specifically, we made a very careful study of one for the Ford car. We found that we could indeed improve it, get more starting capability out of it than as it was then built. But when GE priced it out and made a proposition to the Ford people, the Ford people said, "Well, you're way off base on the price. We can't afford that luxury."

SCHEID: Do you know if that type of motor was ever used later or not?

LINDVALL: No, there have always been minor refinements, little improvements, and in particular, cutting pennies out of the cost of all those automotive things.

SCHEID: Were there other problems that would give an idea of what people were working on at that time?

LINDVALL: Well, I worked with an older engineer who had ideas for liquid cooling of alternators—that is, big alternating-current generators. We worked out a design which had oil-filled cable instead of the usual windings, and oil was to be circulated through the cable to remove the heat from the wire windings. It never got beyond the conceptual design stage, because at that time the company was also promoting the idea of cooling generators with hydrogen, which had some incidental advantages as well as being a good cooling medium. They had a lot of work to do to quell the doubts that people had in mind, because hydrogen was considered dangerous. You remembered your high school chemistry class, where hydrogen and oxygen exploded.

SCHEID: But that was more successful?

LINDVALL: Well, it has been done now, but it was one of those things that was way ahead of its time. Then I worked in another design section, which made rather specialized alternating-current motors that had adjustable speed motors for alternating current.

SCHEID: Well, then you came back to Caltech [1930], and maybe you'd like to talk about that.

LINDVALL: Yes. Well, I started teaching some of the established undergraduate courses. After a year or so, I was encouraged to start a graduate course, which was called Engineering Problems, because while I was at GE in the advanced course in engineering, I was impressed with the educational value of comprehensive problems. In other words, there we would take a week to work a problem, and that was the general concept of this particular course that I started here. Also, it was not limited to any one particular discipline. It was not all electrical or all mechanical but generally a mishmash that forced the students to dust off some of the things they thought they'd left behind. It was well received by the students, although they hated the hard work involved. Many of the problems would have been a lot easier for them if they'd had the little calculators that are available today, because there was a certain amount of drudgery calculation involved in order to arrive at a numerical and definite answer.

SCHEID: How did you set up these problems?

LINDVALL: Well, I dreamed them up, or I'd read a paper on some situation out of which I could create a problem.

SCHEID: And you had to go through the drudgery yourself, as well.

LINDVALL: Yes. Right.

SCHEID: Did you get some good innovative solutions from students?

LINDVALL: Sometimes a student would approach a problem in quite a different way from what had been done before, and that was always refreshing. Si [Simon] Ramo came up with a most novel solution to a problem in vibration of a generator system—a light plant in a small town. And he wrote it up in the manner of a *Saturday Evening Pos*t series called "Alexander Botts," the tractor salesman. He had little pictures he'd cut out of magazines and whatnot to illustrate this thing. It was a very, very ingenious thing he produced.

SCHEID: The solution was just as ingenious as the presentation?

LINDVALL: Well, the solution was absolutely correct, because, after all, the physical facts couldn't be denied.

SCHEID: What kind of students did you get at this time at Caltech?

LINDVALL: Well, in those days—the middle thirties—we had some awfully fine students who were afraid of the Depression job situation, and if they could possibly wangle a chance to go on and do graduate work, they wanted to do it that way. Well, for instance, in one of the most outstanding classes—those who got doctorates in 1936—just to name a few people, there was Dr. [William A.] Fowler, who's on the faculty here, Dean Wooldridge, Si Ramo, Bill [William H.] Pickering, John Pierce. They all stimulated one another. It was a real pleasure to work with students like that.

SCHEID: Were they undergraduates here, too, or not?

LINDVALL: For the most part they weren't. Pierce was an undergraduate here. Ramo came from the University of Utah. Fowler was from Ohio State, I think.

SCHEID: How were they recruited to Caltech? Were they given instructorships, as you had been?

LINDVALL: Some of them were, yes, otherwise they couldn't have come.

SCHEID: That brings me to the money situation at the time. It wasn't very good for Caltech either, was it?

LINDVALL: Well, of course everything was very cheap in those days. My annual salary of $2,500 went along pretty well. You could buy lots of food and stuff for that. So we had no complaints. Granted, the college did have to cut corners here and there and hold back on hiring people and so on. At one faculty meeting, Dr. Millikan made a plea that it would be nice if the faculty were to pass a resolution recommending to the trustees that their salaries be reduced by 10 percent. Well, Dr. Epstein, with his logical mind, said, "We do not vote to increase our salaries, why should we vote to decrease them." [Laughter] However, we did have a cut, nevertheless.

SCHEID: Was there a shortage of students at that time, or was there more of an increase?

LINDVALL: There was an increase in graduate students. The undergraduates were holding very well. Of course, their tuition costs were much lower then, and it was more of a commuting college than it is now. Students could get there with their cars or motor bikes, or if they came from Los Angeles, on the Pacific Electric Railway, which ran up Lake Avenue.

SCHEID: So the geographical range from which you drew students was not as wide as it is now?

LINDVALL: No. There were three or four principal high schools in Los Angeles that supplied many of the students—Manual Arts High School was one, Los Angeles High School was another, and Hollywood High.

SCHEID: Was the caliber of the undergraduates very high?

LINDVALL: It was high. Caltech used its own entrance examination at that time. There were always high school teachers who were really dedicated science people, and they liked to send their best students over here.

SCHEID: I see. What were the job prospects for these students when they got out?

LINDVALL: Not very good. Toward the end of the thirties, things began to improve. But many of them had to go to work at much lower-skilled jobs than they were trained for. There were a lot of public works that made it easier for those who were in civil engineering to find jobs. The Metropolitan Water District built the aqueduct, and so on, at that time. There were a lot of college students who worked almost at common labor [wages] on that, until things improved.

SCHEID: There was a lot of government aid going into all sorts of projects at that time; but was it coming to education?

LINDVALL: No, not particularly, no. I don't remember any government money coming here for educational programs. Later on, when we got into the war, there were war training programs.

SCHEID: Well, there was a pretty outstanding faculty here at that time around here, too.

LINDVALL: Yes, it was small but good.

SCHEID: Do you recall any of your colleagues who were particularly outstanding?

LINDVALL: Well, of course [Linus] Pauling was an outstanding teacher in chemistry. And Jesse DuMond in some physics courses. Zwicky, and of course Smythe.

SCHEID: Did you know any of these people personally? Did you have much contact with them?

LINDVALL: Not very much. Graduate students, you know, tend to stick with their peers, and faculty stick with their peers and age groups, and so on. Although there was a good deal of partying going on in which faculty would invite students. During the winter of ’32-’33, we built a house up in Altadena, and we built in a very convenient outdoor barbecue. I wish we had the money for all the steaks that went over that barbecue up to the time we sold the house. We had lots of student and faculty parties up there.

SCHEID: Did you invite mostly people from electrical engineering?

LINDVALL: No, we pretty well mixed up. For instance, we have an old snapshot of Linus Pauling sitting and working hard at a little puzzle that he couldn’t quite figure out. Morgan Ward, in mathematics—his wife and my wife were very good friends. And people from the electrical engineering faculty and from chemistry—the [Ernest H.] Swifts. We weren’t parochial in the people we liked around Caltech. Quite a few from humanities, too, we’d have from time to time.

SCHEID: Were Dr. Judy’s seminars still going on in this period, or when did they stop?

LINDVALL: They quit about that time, in the early thirties.

SCHEID: Was there anything like that to replace them?

LINDVALL: No. There was some additional humanities work going on, such as business administration, the kind of thing Horace Gilbert taught, based on his Harvard Business School experience. Then there was a greater offering of courses in the humanities, in history and in English literature particularly. Some graduate students would take them. Then there was always the language instruction, because, after all, you did have to get over your language hurdles for the PhD.

SCHEID: What sort of work were you concentrating on in this period? What was your special interest?

LINDVALL: Well, I was exploring atmospheric glow discharges. I got the idea from reading that somebody had discovered that a glow discharge had microphonic properties. I thought, well, if it's microphonic, maybe it will work as an anemometer for wind-tunnel purposes. So I worked away at that for two or three years. Then I had a couple of graduate students who came along and worked on various aspects of it, different modifications and so on. So I kept that going. And I got involved in some railroad equipment business through some consulting connections—railroad refrigerator-car improvements and passenger-car improvements. The passenger-car business was ahead of its time, and we got three cars into regular passenger service just about the time Pearl Harbor hit. So there was no more passenger-car business until the war was over. But I was able to spend my consulting time doing that kind of railroad-car design and refrigerator-car equipment design.

SCHEID: So that was going back to what you'd originally been interested in?

LINDVALL: Yes, right.

SCHEID: Were you consulting during this period?

LINDVALL: Well, it was off and on. And of course, when you're just getting started as a faculty man, nobody's beating at your door for your services. It takes a while and help from the older people, who would say, "Well, now, we've got a new man on the faculty, and he could do this for you very nicely." That's how one gets started. And they had the same general concept of consulting being a desirable thing for an engineer, because of the real-world contacts and experience that that brought.

SCHEID: Was Caltech getting money from industry in this period to any appreciable extent?

LINDVALL: Not to any appreciable extent, no. Indirectly, yes. For example, the Metropolitan Water District built a hydrodynamics laboratory to test models of the pumps the Water District needed for the aqueduct line. The net result was that there were much better pump designs than the manufacturers had first proposed. They were much more efficient, and consequently the pumping costs to the aqueduct system were substantially reduced. Later on, they did some pump work for the Grand Coulee [Dam] project, too. So the various manufacturers of pumps were in and out of that laboratory all the time. So while they weren't directly supporting it, indirectly they were.

SCHEID: But was there any kind of gift of facilities by industry?

LINDVALL: Not to amount to anything, no.

SCHEID: Did they give money for students, scholarships and things like that?

LINDVALL: To a very limited extent, yes.

Things went along that way. I had graduate students whose theses I supervised and so on. One of my stars was Rube [Ruben F.] Mettler, who's head of TRW now. My first graduate student was named Gibson Pleasants. We worked together trying to understand cathode ray oscillographs to be used for high-voltage and lightning studies. At that time there were no sealed-off cathode-ray systems. We built various forms of cathode-ray things. I know now they were very crude, but we were learning the principles. Then Pleasants took a year off. He had some kind of traveling fellowship, so he spent it in Germany at a Berlin laboratory where such work was going on. He came back, then, and finished his thesis here [1933]. Then a couple of other students worked on various problems of cathode-ray oscillography. By that time, sealed tubes were beginning to appear on the market, so that ceased to be a fruitful field of study.

SCHEID: Were the Germans far ahead at that time in this area?

LINDVALL: Not a great deal, no. They were somewhat ahead on vacuum pumps and that sort of thing. A lot of the early vacuum pumps that were used in this country were imported.

SCHEID: Did you have other outstanding students whom you remember, either graduate or undergraduate? You mentioned the class of '36, but I just wondered if there were any others that you particularly noticed?

LINDVALL: Well, Arthur Harrison was one. He had his career afterward as professor at the University of Washington in electrical engineering. And Charlie [Charles C.] Lash, who went into geophysics and was with one of the oil companies in Oklahoma through his career.

Begin Tape 2, Side 2

LINDVALL: Well, shortly before Pearl Harbor, I got involved with Dr. [Charles C.] Lauritsen's group. Dr. Lauritsen was much impressed with what rockets might do. He had a chance to learn something of the English experience with rockets, and he got a project started on rockets, in 1940. It was all very hush-hush. I was asked if I could help on this, so I started devoting part of my time to it. And then when Pearl Harbor hit, I went full-time on it. My particular responsibility was rocket launchers. And at that time we had them for land use, ships and aircraft. Well, later on, Carl Anderson, who was also working on the project, took over the aircraft-type launchers, and I continued with the shipboard launchers, particularly those for landing craft, and some for land vehicles and for amphibious vehicles. Those were hardworking days. We would get up real early in the morning, drive out to Goldstone Lake and do our test firing out there, and then drive home again and get home after dark.

Then the Navy came to Dr. Lauritsen and said, "We're having torpedo trouble. The Mark 13 aircraft torpedo is not performing as it should, and could you people form a group to work on this problem?" So I was asked to form a torpedo group, which I did, and I dropped out of the rocket business at that time. And we had a group of engineers to study the Mark 13 torpedo. The problem with it was that it was dropped from aircraft, but they had such limitations on the speed at which it could be dropped, and the altitude from which it could be dropped, that the torpedo planes were virtually sitting ducks for anti-aircraft fire from the ships they were attacking. Also, the torpedoes wouldn't run properly after they got into the water. They would suffer internal damage and would breach out of the water and run in a crazy path, this kind of thing. So we built a launching facility up behind Morris Dam—the reservoir there was City of Pasadena property—to simulate water entry. It was a long tube down the hillside, and we blew torpedoes out with compressed air. They would enter the water at whatever speed we wanted, depending on the amount of air pressure we put behind them. And we would study the underwater trajectory and examine the works afterward to see what internal damage there was, and also we developed instruments to determine the kind of accelerations that were occurring in different parts of the torpedo at water entry. Also, we explored various head shapes, to see if anything better for water entry was possible. It turned out that that head shape was pretty fair, the one that was on there. But we discovered, in the process of making launchings with actual and dummy torpedoes, that the tail structure exerted quite an influence in controlling the entry. And the more tail structure we had on there while we were experimenting, the better it behaved. So we came up with the idea of a ring, a so-called shroud ring, that went on the tail of the torpedo.

By that time, another group here at Caltech was working in the water tunnel and they found a good profile for this ringtail. Then we would machine these out, put them on torpedoes, and stabilize the water entry. And certain improvements inside in the way of the mounting of the equipment—gyros and so on—kept things running, as the term goes, “hot, straight, and normal.” We conducted tests at sea. We had one particular carrier that furnished its planes for testing and we loaded them with these modified torpedoes, and the torpedo planes would fire them at their own ship—of course there was no explosive in them. They were set to run deep, so that if they ran properly they would run under the ship. That so impressed the skipper that he said he wanted all the modified ringtail torpedoes that he could get his hands on, and he was going to take them out to Pearl Harbor, which he did. He demonstrated those torpedoes to Admiral Nimitz, and Nimitz sent off a dispatch to the Bureau of Ordnance, ordering them to modify some thousand Mark 13 torpedoes. The Bureau of Ordnance hadn't heard much about this, so they were quite upset about it. But that's the way we were able to work here at Caltech, directly with the fleet and not through all the cumbersome Washington machinery. So Caltech undertook to have a lot of these ringtails built and installed on torpedoes that went into service, until the Navy could get into their own production on them. But that helped out, and we felt we had really accomplished something there.

SCHEID: How long did it take to do that?

LINDVALL: Well, we were at it a couple of years. They were beginning to do useful work. And the limitations on height of drop and speed of attack were removed. They would enter the water properly and run properly. Then, I've forgotten the exact time, but I was asked to divide my engineering group and assist the Manhattan Project people. After all, the folks up at Los Alamos were kind of lonesome when it came to procurement of things. They didn't have hardware stores handy and things like that. So I split my group and we added some more engineering people to it and took over part of the manufacturing facilities we had acquired for rocket work out here on East Foothill. And we did procurement work for the Manhattan Project. The principal mission was to develop a backup fusing system for the A-bombs. Our version of it didn't have to be used, because the Los Alamos version actually worked.

SCHEID: But nobody knew until—

LINDVALL: That's right. They had to be sure.

SCHEID: So, actually Caltech was involved in manufacturing at this time.

LINDVALL: Oh, yes, we modified several hundred torpedoes before the Navy got its production going. And Caltech had quite a rocket-manufacturing business—made well over a million rockets that went into service.

SCHEID: And this was all done by machinists on the campus here, or were machinists hired by the institute?

LINDVALL: No, it was job shops all over the place; wherever we could get any machine time, we would contract for parts. The Caltech people, principally our chemical engineers Bruce Sage and Will [William N.] Lacey, set up the powder-extrusion facility in Eaton Canyon, to make these powder grains for the rockets. That was a big operation.

SCHEID: And you were getting contracts then from the government?

LINDVALL: Yes, we worked under the National Defense Research Committee—NDRC. It was later on called OSRD, the Office of Scientific Research and Development. At that time, Dr. Tolman was one of the principal people in that operation in Washington, as well as Vannevar Bush.

SCHEID: What was happening to the regular activities of the institute at this time?

LINDVALL: Oh, they were going along. They had special war training programs, in which people taught things which were perhaps a little elementary—drafting, elementary electronics, and things of that sort—and we would get people wherever we could, people who were teaching in high schools and junior colleges. They would make themselves available for this kind of teaching. So there was quite a bit of wartime training done that way, to help build up skills in people who didn't have them but otherwise could be useful in industry and the war effort.

SCHEID: So the training became less academic at this point.

LINDVALL: Yes. There were, of course, a few of our regular students. But then the Navy V-12 program was set up here, and a whole group of students transferred down from Stanford to Caltech, so that there was a sudden increase in the student body at that time. Various people taught in this Navy program.

SCHEID: What did the V-12 program entail?

LINDVALL: Well, it was mostly engineering, with some work that was relevant to Navy things—some on ordnance, some on navigation principles, things of that sort.

SCHEID: Were these people being trained to go directly into the military?

LINDVALL: Yes, to be commissioned.

SCHEID: How did this affect your teaching?

LINDVALL: Well, I was doing none. I was working on rockets and torpedoes all this time.

SCHEID: Well, who was teaching the students?

LINDVALL: Professor Sorensen kept on teaching. So did Maxstadt and [Robert] Daugherty, and a number of these people who, for one reason or another, didn't want to or didn't fit into what was going on in the Caltech contracts. So they kept on teaching and doing double duty, almost, as teachers.

SCHEID: Did the student body stay at a similar level at that time?

LINDVALL: Well, it fell off. I mean, if you look back at the war years, you'll see fewer than you see before. [Reading from the Caltech Bulletin] There's a list of engineering students—civilian students—getting a bachelor's degree. Then Navy V-12 students, science civilian students and Navy V-12 students in science. So with the V-12 program in here, the student body, I think, averaged out pretty much the same.

SCHEID: But were these V-12 students of the caliber of the normal Caltech student?

LINDVALL: Pretty much. I couldn't say as well, because I didn't do any teaching of them.

SCHEID: Did you do quite a bit of traveling in this period?

LINDVALL: Oh, yes, to make installations of rocket launchers on support boats that were going to take part in the African invasion.

SCHEID: I see. Where did you go for that?

LINDVALL: Norfolk, Virginia. There we conducted some test firings, or demonstration firings, with these special rockets—barrage rockets, we called them. They were quite inaccurate as far as trying to hit a target, but for barrage purposes, bombarding a beach prior to landing, they were quite effective.

SCHEID: How were they launched?

LINDVALL: Out of a thing that looked very much like a packing crate. Each one had its own set of rails, and they were launched with a firing switch that sequenced them.

SCHEID: They were on ships behind those that were going to be landing?

LINDVALL: These were landing-craft types. They were running a little ahead of the larger landing craft.

SCHEID: You mentioned going out on a carrier for your torpedo testing.

LINDVALL: Well, actually we were in a Navy blimp, looking down to watch these torpedoes running.

SCHEID: That was here off the coast of Southern California?

LINDVALL: Yes, that's right. Oh, there were lots of trips to Washington. And then when I got on the Manhattan Project, there were some trips to Los Alamos to talk about things we were doing here.

SCHEID: Did you meet [Enrico] Fermi and [Edward] Teller?

LINDVALL: Not those people, no. Robert Oppenheimer was in charge at Los Alamos. Of course I met him, and the two Lauritsens were there, and several other physicists from different places.

SCHEID: Bob [Robert L.] Walker—wasn't he working there?

LINDVALL: He was there. So was Bob [Robert F.] Bacher, and some others from the East, various places.

SCHEID: Were you at Los Alamos when the tests were made?

LINDVALL: No. But one day—this was while I was on the Manhattan Project—I got a call from an old Caltech man who had been a Naval Reserve officer and was back in uniform, and he was with Navy procurement in Los Angeles. He called me and said, "Do you know a Dr. [Victor Hugo] Benioff in the Seismological Laboratory?" "Oh, yes, I know Benioff." "Well, I have a secret dispatch to deliver to him, and would you mind coming along and identifying him to me?" So he drove up in his Navy car and he had sidearms. He made me describe Benioff to him before we got there. Fortunately, this was one of the times Benioff did have a moustache.

SCHEID: He kept shaving it off?

LINDVALL: On and off. So he delivered the message and got a signature for it. Actually what the message was, was for Benioff to watch at the time of the Trinity shot, to see if there was a recordable bump on the record. And there was.

SCHEID: That's as close as you got to the actual blast?

LINDVALL: Yes. And also, one of the things we were asked to do at Caltech—and we built these from scratch—was replicas of the A-bomb that were just simply TNT bombs, which would be dropped. They would be decoys, you might say, and the real one would come right down along with them, if we wanted to play it that way. So we manufactured quite a bunch of those. They turned out to be pretty potent TNT bombs in their own right.

SCHEID: They looked just like the atomic one?

LINDVALL: Yes. If the people on the ground could see these things coming, they would recognize the shape.

SCHEID: Robert Millikan was still head of Caltech in this period. Was he really running things?

LINDVALL: He began to sort of lose touch with things, because the business office was so filled up with contracts. After all, we were handling millions of dollars' worth of procurement contracts, and scads of people were on the payroll who never were Caltech folks before, that sort of thing. So right after the war, a couple of business types who had come in on the rocket procurement moved over into the business office at Caltech and began to make more order out of things. Originally, Millikan and Ned [Edward C.] Barrett, the secretary, ran things pretty much out of their pockets. There weren't good records or good systematic dealings with the faculty and so on. Once in a while, I might get a letter saying that my salary had been increased, but a couple of times I discovered that I'd got an increase because the deposits they were making for me at the bank were bigger than they had been. But I had never been notified. [Laughter] Then, shortly after the war was over, Dr. Millikan asked me if I would become chairman of the Division of Civil and Mechanical Engineering and Aeronautics.

SCHEID: Was Millikan running off to Washington during this period, too?

LINDVALL: Not very much, no.

SCHEID: You did get a salary increase, then?

LINDVALL: Over the years, yes.

SCHEID: But it took a long time? I've heard stories of people not getting an increase for ten years.

LINDVALL: I don't remember what the sequence was, but I never worried about it very much. I figured if I was doing all right I'd be taken care of. But in the early days, I would never know, really, from one year to the next, whether I'd have a job. I wouldn't get a letter reappointing me. So I would ask Professor Sorensen, and he'd say, "Oh, you've got nothing to worry about."

SCHEID: I see. But when did you finally get tenure, or know that you were going to be here for good?

LINDVALL: It was toward the end of the war. Or just about the time—I don't remember when I was promoted to full professor [1942.—ed.].

SCHEID: You said there wasn't any government aid, to your knowledge, to the institute in the thirties, and then of course the forties changed everything.

LINDVALL: Well, in the thirties some Navy man thought the Navy ought to be doing some kind of research and development and had the idea of farming it out to colleges. He talked it up to Millikan, and he mentioned it to me and to Clark Millikan, and Clark and I became Naval Reserve officers at that time. Then, at least as far as I was concerned, they sent me a list of things that were of interest to the Navy, and there were two or three of them that I thought we could work on. I went to Millikan with these suggestions, and he said, "Who's going to pay for it?" I said, "Well, they seem to expect us to buy whatever equipment we need and buy the supplies."

"Nonsense, we can't afford that. If the Navy won't pay for it, we don't do it." And we didn't. [Laughter]

SCHEID: And they weren't intending to give you any money?

LINDVALL: No, not at that time.

SCHEID: Do you know what year that was, when that all happened?

LINDVALL: Oh, it must have been about 1937, 1938, along in there. Because I was still commissioned on reserve when Pearl Harbor came along, and I thought surely I'd be called up, and I was. I was to go somewhere—I've forgotten where—to teach diesel engineering. And I said to Dr. Millikan, "Well, I've been teaching that here." "Oh," he said, "that's ridiculous. They shouldn't have you do that." So he wrote a letter to somebody, and I never heard anymore from the Navy after that. [Laughter]

Well, as far as the engineering division was concerned, my major responsibility was to build up graduate work in civil and mechanical engineering, which had not had the kind of development that electrical had had, nor had it gone the way aeronautics had under [Theodore] von Kármán. Von Kármán was then director of Guggenheim Aeronautical Laboratory, and he certainly didn't need me for a boss. It ran practically as a little division by itself.

SCHEID: Although it was technically in the engineering division?

LINDVALL: Yes. I had to see to it that they got their salaries come budget time—things of that kind. So there was a building up of mechanical and civil. And of course, in the meantime, electrical was growing, particularly in the applied-science direction. It became fairly clear to me that if engineering were to survive at Caltech and be any better than second-rate, it would have to be pretty close to science. So I tried, rightly or wrongly, to steer things in the direction of applied science and tended to appoint people who were interested in going in that direction. The research was of that nature, rather than nuts-and-bolts kind of engineering.

SCHEID: In the case of mechanical engineering, what were some examples of this kind of direction?

LINDVALL: Well, at that time, mechanical engineering had, as part of it, some metallurgy, and Professor [Pol] Duwez came down from JPL [Jet Propulsion Laboratory] to do some good work in metallurgy. Up to that time, it had been pretty much state-of-the-art metallurgy. Duwez began to do research in new fields and did very well. The fluid mechanics became more theoretical, as it should have, and, in its concept, came closer to aeronautics than it had been before. And thermodynamics was upgraded. Those are just some examples. Research in hydrodynamics went on in the water tunnels and the facilities left over from war activities of that Caltech group.

SCHEID: You mentioned von Kármán. Did you know him well? He was a colorful character.

LINDVALL: I knew him reasonably well. As I say, I didn't have anything to teach him. But he was always very kind and helpful to me when I would go to him for advice and discussions.

SCHEID: He wasn't involved in either the Lauritsen or the Manhattan Project?

LINDVALL: No. He started this thing called JATO—Jet Assisted Take-Off—and that grew out of some rocket work that he and Frank Malina started up in the Arroyo when there was nothing much up there. And that quickly grew into what became JPL. In the meantime, Aerojet had started the manufacturing end of the JATO rocket units. Clark Millikan devoted himself to that kind of thing; so did von Kármán, as well as others.

SCHEID: No companies grew out of your war projects?

LINDVALL: Well, some that became principal manufacturers of rocket components became very successful manufacturing companies and developed their own contracts for rockets, contracting directly with the Navy. But there were no industries of the kind that came out of the Radiation Lab at MIT, for example.

SCHEID: You mentioned Pol Duwez coming from JPL. Did you attempt to make use of JPL for your students, as a training place?

LINDVALL: Well, yes. Students could go up there under certain conditions and use the facilities, and for a while Duwez was back and forth. Then—I've forgotten just when it happened—but Harry Guggenheim wanted to establish what became known as the Jet Propulsion Center, which was a campus teaching activity. He gave money to get it going, and we made use of facilities up at JPL for laboratory experiences for the students and some thesis work. That was always difficult, because only U.S. citizens could go there at that time, and we had Frenchmen and Canadians who couldn't go up there and do experiments, so we gave that up as a lab facility.

SCHEID: Is that still a problem?

LINDVALL: Well, I don't know whether they use it now or not. Professor [W. Duncan] Rannie is, of course, the Goddard Professor of Jet Propulsion, but I think he did his research on campus—axial-flow compressors and turbine equipment as part of jet-propulsion systems. I think they've pretty well confined their student research to the campus.

SCHEID: I asked because that was one of [Marvin L. "Murph"] Goldberger's [Caltech president 1978-1987] points at his inauguration address—that he wanted to increase collaboration with JPL.

LINDVALL: Yes, that's right. Well, it's not as bad now as it used to be, because, you see, for a long time it was operated under an Army contract and they had Army security people there. I know there was one big flap when a fellow completed his PhD thesis and a security officer up at the lab said, "Oh no, you can't publish that." We finally wrestled it around so that they accepted it. After NASA took it over [1958], they still had security, more for property-protection reasons than for military security—although some NASA information is also military information, so they have to keep things straight in that sense.

SCHEID: I know you were on the Academic Freedom and Tenure Committee.

LINDVALL: Well, fortunately the faculty established an academic freedom committee, and so did the trustees—a parallel one, of trustee members—in advance of any problem. So that when a problem did occur, we had the machinery all ready to go, and we met with the trustee people and the problem evaporated.

SCHEID: What was the machinery?

LINDVALL: Well, simply that separately and together we would have discussions about the case, whatever it was, and conduct whatever hearings seemed appropriate, to assure that the faculty person got a fair hearing.

SCHEID: What was the case?

LINDVALL: I don't want to say.

SCHEID: Was this person retained on the faculty?

LINDVALL: Yes.

SCHEID: Were there several cases, or just one?

LINDVALL: That was the only one I was involved in. We had rotating terms, so nobody served all the time on it.

SCHEID: Were the trustees generally supportive of the faculty?

LINDVALL: Yes, once they learned the facts.

SCHEID: So it was an internal thing at Caltech. There was never any investigation by the FBI?

LINDVALL: No.

SCHEID: Was the committee in consensus, generally, on this?

LINDVALL: Yes.

SCHEID: And was the case known outside the Caltech community at all?

LINDVALL: No, not to my knowledge.

SCHEID: How did the case come up? Did someone say something?

LINDVALL: Political activity.

SCHEID: I see. This person had become known, generally, to a lot of people.

LINDVALL: Yes, to the dislike of some of the trustees.

SCHEID: I think we're practically at the end of the tape. So rather than start on something else here, why don't we carry over to the next time, and then I'll probably ask you a few more questions about what we talked about today.

FREDERICK C. LINDVALL

SESSION 3

December 8, 1978

Begin Tape 3, Side 1

SCHEID: You were president of the American Society for Engineering Education?

LINDVALL: Yes.

SCHEID: When was that?

LINDVALL: I think I can pin it down—1957-58.

SCHEID: So you were quite involved in devising the engineering curriculum. When did you become interested in that?

LINDVALL: You mean on the campus?

SCHEID: Yes.

LINDVALL: Well, it was a gradual transition, as some subjects ceased to be of interest or relevance. We were gradually shifting our emphasis here from the more nuts-and-bolts engineering to the applied-science kind of engineering, with more emphasis on the theoretical and fundamental background of engineering. So one course after another was introduced that carried on this shift.

SCHEID: Could you be more specific about the kinds of courses that were dropped?

LINDVALL: Well, for example, it was traditional over many years for engineers to have surveying. That was dropped. Mechanical drawing was also considered a necessary thing, but we gradually phased it out and made it optional for students. Engineering design as such, which was really machine design, no longer seemed to have a place here, so it was gradually phased out except as an elective subject, and a few students would take it.

SCHEID: You mentioned that when you came to Caltech, you took many physics courses and basic science courses. So was there a big change between the twenties when you were a student and the later years?

LINDVALL: What I was just talking about was undergraduates. And I came into graduate work here. So over the years, undergraduate work absorbed more and more of what had been in graduate work fifteen or twenty years earlier. So the general level of mathematics competence had to be built up in the undergraduate work. Another aspect of the undergraduate program, which eventually disappeared, was so-called shop work. Many engineering schools hung on to it much longer than Caltech did. But while it’s good to know about manufacturing methods and how to run a lathe, build a machine, know a little something about foundry, there isn’t room in the curriculum for it.

SCHEID: Did these changes come about because of changes in the demands of industry, in the kinds of people they wanted, or what was the impetus behind these changes?

LINDVALL: Well, it was really our thought as to the way engineering education was going—that industry would less and less demand the how-to-do-it kind of engineer and would look more for the fellow who could attack a problem he hadn’t seen before.

SCHEID: Did the caliber of students change?

LINDVALL: The level of the entering students was improving all along, particularly in mathematics. In our admissions, we switched to college boards, and over the years the mathematical competence of the incoming students was up and up, just about the top of the scoring on the college boards. Many of them were able to start in advanced placement in mathematics. In the engineering curriculum, we introduced some so-called applied mathematics, which would carry on from the usual calculus and differential equations into applications of these subjects and also some new elements, like Bessel functions.

SCHEID: Were the engineering students thrown together a lot with the science students?

LINDVALL: That's pretty much the case in the first two years.

SCHEID: The level of Caltech students was going up. Why was this? Was it that they were drawing from a larger group of people over the years and began drawing nationally rather than just locally?

LINDVALL: Yes, that's right. It ceased to be a California college. Our admissions procedures broadened out. We were sending folks out to interview students at high schools, and we began to draw from certain large schools in the East and the West Coast, and some from the Midwest.

SCHEID: And when did this change take place?

LINDVALL: It was gradual, in the fifties and sixties.

SCHEID: After the war, then.

LINDVALL: After the war there was a considerable impetus, yes. Then of course, after *Sputnik*, which was in 1957, there was a big push to go into science and engineering. So we had many more applicants, and we were able to choose a higher cut.

SCHEID: There was also a great expansion in funding, wasn't there, in this period?

LINDVALL: Well, not so much for educational purposes as for research, which was supposed to strengthen the whole institute by improving the faculty. That had more impact on graduate study than it did on undergraduate.

SCHEID: What were the benefits of this research to the undergraduates?

LINDVALL: Well, the fundamental argument was always that the professor who was doing research was keeping current and up-to-date and always had new information with which to challenge his students. He could come in from his laboratory, and sometimes he would forget what he was supposed to be talking about and talk about his research. That was the main effect, I would say. And the students were well aware that the faculty people were doing research.

SCHEID: Were the undergraduates involved in research at all?

LINDVALL: To a limited extent. Not so much in engineering as in chemistry and biology. There, because of simpler apparatus and a wider variety of subjects to look into, it was easier for an undergraduate to do something significant. Much of the engineering research involved investigations with substantial pieces of equipment. Often the equipment wasn't ready or wasn't working, and so a student wouldn't get much for a while.

SCHEID: So you think the research being carried out by the faculty had a positive effect on the education of the students?

LINDVALL: Well, I *have* to say so. It's the party line. [Laughter]

SCHEID: I see. But you maybe have some reservations about that?

LINDVALL: Well, some of the students had reservations: "He's never in his office. I want to see him. He's always in his lab. He doesn't want to talk in his lab about my problems, because all his grade records are in his office." You know, that kind of thing. Any way you cut it, there's always going to be some disappointments.

SCHEID: But students kept coming to Caltech. I noticed that there was a sharp decline in enrollment in engineering in the late fifties and sixties, in that period, wasn't there? I don't know if that still holds true or not.

LINDVALL: Well, let's see. It increased after *Sputnik*, which brought it into the sixties. In the latter part of the sixties, it sort of leveled off. I've forgotten just when it was that there were some rather drastic cutbacks in funding for aerospace activities. Many quite senior engineers were laid off. There was bad publicity on that account, so some engineering student interest fell off. It's back up again now, apparently.

SCHEID: Do you feel the students react to this kind of publicity?

LINDVALL: Well, they react to what they read and what they hear from their peers, and to a certain extent what they hear from their counselors. There've been a couple of times in the past when counselors got bad advice. Some well-meaning people posted estimates of the engineering employment requirements in the next few years, showing them going down. They were hardly published before they started going up. But the counselors got in some bad words about engineering at that time.

SCHEID: What about the relative attractiveness of engineering versus science?

LINDVALL: Well, right now engineering is the big thing.

SCHEID: Because of the job possibilities, you feel?

LINDVALL: Well, that certainly has an effect. And also some aspects of physics, high-energy physics and so on, aren't hiring as many folks as they once did. The money for research isn't there, and some of our students here who might have been in physics feel that there are more job opportunities if they're called engineers. Because they've been aware that in the past some of the recruiters who came here didn't really care whether a fellow had had electrical engineering or physics. The mix of courses was substantially the same, and what the option was was less important.

SCHEID: What about the role of humanities in education at Caltech?

LINDVALL: Well, I've always believed in it, and I believe it's been a good thing. It's always been taken somewhat reluctantly by the students. In fact, over the years, in talking with alumni, it seems that there's always been a delayed reaction. Many alumni are *very* grateful for the fact that they had this exposure to non-technical material, whereas many of their colleagues who went through other engineering schools had nothing of this kind, except English comp or something pedestrian like that.

SCHEID: What do you think is special about Caltech's approach to engineering in the curriculum?

LINDVALL: Well, two things: One is the humanities content, which was established in the curriculum a long time ago, and Caltech was outstanding among engineering schools for the high percentage of non-technical material. The other is the engineering-science approach—that is, more emphasis on the fundamentals of engineering rather than on the how-to-do-it engineering.

SCHEID: What about the graduate curriculum? Is it more necessary to have a doctorate than it used to be, in engineering?

LINDVALL: The big resurgence in research that came after the war opened up many opportunities, and the PhD degree became a very good union card. Originally, about the time I got my doctorate in engineering, industry was indifferent toward it. They didn't see that it had much relevance to what they were doing. Over the years, that attitude has changed; and now there are many corporations that come around here recruiting PhDs. It slowly caught on, because the companies found that a fellow with a PhD had learned how to undertake a new problem and could do things that were not routine.

SCHEID: Some of these PhDs become faculty members. Is it difficult to recruit them into being faculty members when they have these attractive offers?

LINDVALL: Sometimes.

SCHEID: Is that a basic problem in engineering, as opposed to maybe physics, where industry is not so attractive?

LINDVALL: I would think so, yes. Here, I think that a great many of the fellows who take PhD degrees do have teaching as a target—if not immediately, at least later on.

SCHEID: Why would you say that?

LINDVALL: I think it's a matter of their basic interests, and what they've seen of the Caltech faculty, the way it operates and the research it does, and so on.

SCHEID: So would it be the attractiveness of greater freedom in research subjects?

LINDVALL: Well, that's certainly an attraction.

SCHEID: Did you ever have trouble, as head of the engineering division [1945-1969], recruiting faculty to Caltech?

LINDVALL: No, no. Always there was the problem of, "Is this the right man?" And, in general, we have tried not to recruit a man for a specific teaching responsibility but to find a good man in a general area, and then let him work out his own set of courses of instruction and his own research program. In other words, we've always wanted to look for outstanding people first, because they turn out to be quite flexible.

SCHEID: What were your basic responsibilities as division head? What did you see as your role?

LINDVALL: Well, to encourage people who came in with good ideas or a line of research that seemed promising. To act more, you might say, in a permissive and encouraging way rather than trying to direct everything. Of course, there were always the routine things—we had to do budgets, equipment, and allocation of funds among various faculty groups.

SCHEID: Did you have a board that you consulted, or did you make most of the decisions yourself?

LINDVALL: Well, there were a few key faculty people whose judgment I trusted, of whom I would ask questions. We didn't usually get together and meet formally on things. And we didn't have very many meetings of the division as a whole. And when we did, to talk about some curriculum or policy matter, we never voted. We would also get the senior members of the division together for consideration of promotions and new appointments. But we never took votes. I would listen to the discussions and make up a consensus.

SCHEID: Is that typical, do you think, of the divisions here?

LINDVALL: Some were much more formal. And the more formality you get, the more chance there is for divisiveness.

SCHEID: Did you continue to teach during the years you had all these other responsibilities?

LINDVALL: Well, I did for a while. The main course I was teaching was this course in graduate problems, which I think we mentioned earlier. Then I had a young assistant professor who came in and helped me with that course, and it was quite clear, after a couple of years of this, that he could do an excellent job on his own, so this was fine.

SCHEID: So you didn't really teach very much then, later on?

LINDVALL: Later on, no, as I got more involved in general institute administrative things.

SCHEID: You mentioned something about sending people around for interviewing incoming students. You were also on the Freshman Admissions Committee. What were some of the concerns of that committee?

LINDVALL: First of all, merely going to the high schools had a good effect. The science teachers and the math teachers knew somebody from Caltech was coming, and that kept the name “Caltech” alive in the schools. In talking with the various teachers of math and science, you learned a great deal more about the applicants than would ever appear on paper. And we’d get positive and negative reactions. I’ve had teachers say, “Yes, he got good grades, but he’s just a greasy grind. He’ll never do anything else but have his nose in the books. He’s not well-rounded at all, and you can probably find a better student.” Then on the other hand, we found out things that explained why an otherwise excellent record might be poor in some respects. That is, the last part of the college board exam might have been way below the standards of the earlier part. And it might turn out that there was a big family problem, such as the student’s illness. Or in one case, a boy’s father had just died and he was shaken up about that, so he did poorly on the exam, and his teachers made a big plea for him: “Just forget that.”

SCHEID: Did you go around yourself and interview?

LINDVALL: Yes, I did it for several years in the Los Angeles area and once took the West Coast.

SCHEID: Did the committee choose who was going to go out and interview?

LINDVALL: Well, when faculty committees were appointed once a year, there was an attempt to get representation from the various divisions on the Freshman Admissions Committee and get some rotation on it. Nobody wanted it indefinitely. So there was always some rotation and shifting of people, and also the assignments would vary. Some professors might have a teaching schedule that particular term that they felt required that they not be away for any protracted period. Somebody else could rearrange the work so that they could be gone two or three weeks and make an East Coast or Midwest interview trip. So it was juggled around from year to year.

SCHEID: When did this begin, this going out and interviewing?

LINDVALL: I can't date it, but it's fairly early in the game. If you're going into the history of the registrar's office, it was about the time Professor [Philip S.] Fogg was asked to take over the registrar's office and the chairmanship of the Admissions Committee [1935].

SCHEID: Why did you decide to do this? It's a big effort for a small school to go out and interview.

LINDVALL: It was a big effort, but we felt that the institute was making a big investment in each student, because the tuition by no means paid his costs here. So we thought we ought to do as good a job of picking the students as possible. Just to have an entrance examination, and a rank list based on that one exam, we thought was not good enough. There were other qualities—of potential leadership, general ability, personality, that kind of thing—that should be cranked into the overall evaluation.

SCHEID: Did you invite students to come here at all?

LINDVALL: Usually it was better to go to the school, because then you could talk to the teachers and get the real scoop, as the saying goes.

SCHEID: So that was an important part of the interview, talking to the teachers rather than the student involved?

LINDVALL: That's right, yes. Sometimes a high school would invite the interviewer to give a little talk to students about what Caltech is, what we're trying to do. That was not done often in recent years, because other schools resented the fact that we were getting a break. They wanted it too.

SCHEID: Do you think this policy attracted more students to Caltech?

LINDVALL: Yes, I think so, because the juniors would know that the seniors were going to be interviewed, and so on. There was always a little delicacy involved. We had to interview more than we would expect to take from that school, so that it wasn't obvious when the students came in for interviews that only the selected ones were being interviewed. If the high school record and the college board scores—or in the early days, our own Caltech exam—showed that the student was not very good and it wasn't really worthwhile to interview him, you didn't want to make that fact known when you went there.

SCHEID: Do you think the interview system changed the character of the freshman class in important ways?

LINDVALL: I think it improved the general quality of the students. We would get fewer—well, "greasy grinds" is the term. We weren't out to recruit for football or basketball or track, but we did get more all-around fellows. We had a chance to look more into what they did, extracurricular activities in high school, as an indication of what they might be expected to do in college and later life. Were their interests broad at all, or were they strictly narrow.

SCHEID: Do you think that those kinds of students had trouble adjusting to Caltech?

LINDVALL: Some of them have always had trouble. Some of them got through high school quite easily and had a rude awakening here.

SCHEID: Did this decrease the dropout rate?

LINDVALL: Yes, maybe a little. But the Admissions Office could tell you more about this than I can remember. At least we thought the interviews were worth the trouble.

SCHEID: You said there was a marked change in the level of preparation of freshmen over the years, in just the purely academic sense. Were there other important changes in the freshman class over the years? I'm thinking of way back, from the twenties up to the sixties.

LINDVALL: Well, in the twenties, we went pretty much on the Caltech exam and on the high school grades. There were some letters of recommendation submitted by teachers, but they were always flowery or guarded. Unless you knew the person writing, you didn't know just what it meant. We took the students unseen, and some of them had fine personalities and some of them had rather mediocre ones. We weren't looking for candidates for the Rotary Club, but nevertheless we started to look for qualities other than just scholastic ones: Did the fellow have any hobbies, for example, like building model airplanes or some other form of tinkering.

SCHEID: You took a trip to the Soviet Union, I believe, and looked at their engineering education system. When was that trip actually?

LINDVALL: 1958.[2]

SCHEID: Oh, right after *Sputnik*.

LINDVALL: Yes. In fact, as we were finishing up our visit, we had a session with the minister of higher education. And I asked him, "Where is the curriculum that trains people to produce *Sputniks*?" He shrugged his shoulders and said, "People like that just emerge."

SCHEID: You didn't find that their curricula were that different or their method of selection was that different?

LINDVALL: Well, at that time, they had their engineering broken into about 160 named curricula in engineering—as specialized as, for example, diesel engineering for stationary power plants, diesel engineering for locomotives. There was railway engineering, railway civil engineering, railway mechanical, railway electrical. There was power

[2] In November 1958, Lindvall headed a mission of eight American engineering professors to the Soviet Union on a one-month tour of various Soviet engineering schools--recounted in a February 1959 *E&S* article: http://calteches.library.caltech.edu/191/1/lindvall.pdf.

engineering. Oh, the whole gamut of things. The best students would try to get into the options that were the most glamorous—that is, communications and electronics. Only the very best students could be selected for those. So there was a kind of built-in screening process, and the students who knew they weren't really tops would opt for one of the less rigorous disciplines or options. So they tended to sort themselves out. And each year the overall planning would specify that they needed to have so many new places in the curriculum in nonferrous metallurgy, for example. So, the word gets around that there will be some openings in nonferrous metallurgy, and somebody who might have wanted to be in the steel business would decide, "Well, maybe I can get into nonferrous and shift later on," or something of that sort. So the schools we went to, which we had selected ourselves, we thought would be good, bad, and indifferent, and we found them that way. The farther from Moscow or Leningrad we went, the lower the general quality. The top professors wanted to be where the action was—namely, Leningrad, Moscow, and Kiev.

SCHEID: Were there significant differences in students' preparation before they got to the university?

LINDVALL: They had been pushed along a little more in mathematics than some of our engineering schools required. A foreign language was something that had been encouraged. Of course, some of them automatically got two languages—their native national language, which was, let's say, Lithuanian, but they also had to have Russian for the college. They had more training in drafting, shop work, and things of that sort. And they usually had to have at least one year of practical work in agriculture or in factories before they could go into college, even. Also, the engineers had a design project, a design thesis. They would work part of the year in an industry, and then at the college they would work on completion of the project they were on in industry—a design or whatever it was. And then they would have to defend that design before a committee of faculty and outside engineers. So in that sense they had a little more rigorous training in current state-of-the-art engineering than our students were getting. Also, their curricula were essentially five years long rather than our typical four-year program. They had a great deal more correspondence work, carefully programmed, and it was possible for students in the correspondence work at various stages in their development to shift into regular academic programs. The correspondence work might cover certain elementary things, such as basic physics, chemistry, mathematics. And when a student had passed suitable examinations, he would be admissible to one of the colleges in a particular option.

SCHEID: It sounds as though their approach was very technical and vocational.

LINDVALL: It was highly technical, and it was tied into the overall planning. Just as I say, they said, "In five years, we will need so many more metallurgists and so many more chemists," and so on. We found when we were there that they hadn't guessed properly in some of their chemistry. They were way behind in polymer chemistry and in plastics. So they were making some changes and shifting some of their students from one form of chemistry to polymer chemistry or plastics.

SCHEID: What was the group that you went over with?

LINDVALL: It was when I had just retired as president of the American Society for Engineering Education, and I selected some people who were keenly interested in engineering education to form this group of about eight, who went on this so-called State Department exchange mission. And the National Science Foundation funded it.

SCHEID: Did you see other things of the country when you were there?

LINDVALL: Well, just in traveling, yes. But things were a lot tighter then. There were certain areas into which we could not go, just as there were areas in the U.S. where Soviet citizens could not go, for no reason at all except they were just playing diplomatic tit-for-tat.

SCHEID: You mentioned the centers of education, but did you get out into other areas?

LINDVALL: Yes, we got out. The farthest we were from Moscow was about 2,200 miles, to a place called Frunze [today called Bishkek], which is the capital of the Kyrgyz Republic, right on the edge of Outer Mongolia. It was rather primitive, although they were very proud of what had happened there since the Revolution. Instead of being a crossroads of camel routes, it was now growing, with industrial and business activities. They were building a new engineering school there, so it was on its way.

Begin Tape 3, Side 2

LINDVALL: We stopped in Kuybyshev to visit an engineering school there.

SCHEID: These engineering schools were supposed to serve their area, then?

LINDVALL: Generally that was true, but also industry sought people across the Soviet Union. I might point out that the engineering in the Soviet Union was at that time, and I think still is, taught in engineering schools and not in the so-called universities. There were three or four engineering schools in Moscow, but not at the University of Moscow, which had science and certain fundamental subjects—mathematics and so on—but not engineering. There was an engineering school for electrotechnics, and an engineering school for power and one for telecommunications.

SCHEID: So the students were separated into these narrow fields early and didn't have contact with other fields?

LINDVALL: Well, the students made those choices feeling that they'd pick the one they had the best chance of getting into.

SCHEID: And the curriculum didn't have the breadth we have at Caltech?

LINDVALL: No. I understand that since we were there, there have been some curricula developed which are quite broad and would be comparable to what we have at, say, Caltech, MIT, Harvey Mudd, and some of the other schools.

SCHEID: Is there anything else you particularly noticed there or found interesting? Maybe off the subject of engineering, but things that impressed you?

LINDVALL: One thing was quite evident: All the engineering schools had excellent libraries of foreign books and current magazines, from the U.S. and the U.K. particularly. English was taught quite generally to engineering students.

SCHEID: Students here don't feel they have to learn Russian. Is that a reasonable assumption?

LINDVALL: Well, let's say it might be true today, but a few years from now—the literature of importance that's coming out in Russian is increasing. Unless one wishes to depend entirely on translations, one might want to learn it. Because, after all, English is well on its way to becoming a lingua franca in science and in technology.

SCHEID: But that may change, as you say.

LINDVALL: Yes. One of the things on our trip in the Soviet Union—we were there a month—we discovered immediately that if we asked to see a particular professor, we would be told, "Well, he's not at the school you're going to go to. He will be in the Academy of Science laboratory." "Well, can we go there and visit him?" "This will be very difficult; we have to get permission." And so the young man from the Ministry of Education would start telephoning up the line, and then they'd telephone him back down the line: "No, he is not in town." Or, "It would be too difficult to go there. It's all the way across Moscow, it would waste your afternoon." That kind of thing.

SCHEID: How did you know whom to ask for—specific professors? Did you know them?

LINDVALL: Oh, a number of us had identified particular people whose names were well known in the literature, and we would ask to see them. Or we would find in their own catalogues, which described the curricula, the name of a man who was in charge of a particular curriculum and we would want to see him.

SCHEID: Was there anyone in your group who knew Russian?

LINDVALL: Yes, Leon Trilling, who was one of our Caltech PhDs [aeronautics, 1948] and had grown up in Poland and had learned Russian as a young man. He was very helpful, because the rest of us were dependent on the interpreters. We'd sit around a table and talk, and if the interpretation was coming out the way Leon thought it should, he would sit quietly. On the other hand, if there was a misunderstanding or misinterpretation, he would begin to fidget and burst in. But, in general, we found that it was better to play down the fact that we had a fluent Russian speaker in our group.

On February 6 and 7, 1959, Lindvall hosted 5 prominent Soviet engineering professors, together with accompanying U.S. State Department members—part of a 3-week tour of American engineering schools.

SCHEID: You were also involved in Caltech's committees on cooperation with industry and patents.

LINDVALL: Oh, those were some standing committees here, yes. In the early days of the Patents Committee, we had some real problems, because there were some interesting propositions made to us by industry which would have tied us up in terms of secrecy on patents. The people who would be working on that would not be able, even in lunch-table conversation, to talk about what they were doing—almost as bad as having secret military work going on. So we established a policy that we would not take work that required any inhibition of what's normally called academic freedom of discussion. We wanted our students who'd worked on this research to be able to present it in seminars, write it up in their theses, and so on. Also, we had to work out policy. We never had a patent policy before we had a Patents Committee. Was there any way in which a discovery of some sort could be assigned to the sponsor of the work? At first it seemed awfully difficult, and we were very stiff-necked about it, but over the years I believe that has relaxed somewhat. At that time, our biologists were very strong in the belief that since many of their discoveries were health-related, they really didn't want anybody to make a profit from them, which was a little difficult to reconcile with the fact that the biologists would happily accept research grants from pharmaceutical houses.

SCHEID: Do the patents ever accrue to Caltech as an institution rather than to a private individual?

LINDVALL: Yes. Under government contracts, the government has the option of first refusal. If the government agency decides it doesn't want to prosecute a patent application on a particular discovery, the institute is free to do so if it wishes. And in some instances that has been done. Originally, there were patents on a vacuum switch of Professor Sorensen's, which were assigned to the institute with certain rights pertaining to General Electric Company, which sponsored some of the work. There was one orthodontist here in town who made a lot of inventions on his own—things that were useful in orthodontics, a little tiny spot welder and various braces and things of that sort. He turned over those patents to Caltech with no strings, and a company was organized on the outside to make these things and sell them to dentists. And, indeed, royalties were collected over quite a few years on these orthodontics-type patents. The vacuum-switch patents just lay dormant until the state of the art in vacuum technology and materials developed to the point where the vacuum switch could be a commercial product. By that time, the basic patents had expired.

SCHEID: But an individual professor never has the right to a patent?

LINDVALL: He assigns it to the institute, and if royalties accrue over the years in excess of the institute's total costs of the development itself and the prosecution of the patent, then a fraction of the royalties from then on will go to the individual inventor. That's, I believe, the way things stand. You can check that.

SCHEID: With regard to cooperation with industry, as you mentioned, you were concerned with preserving academic freedom. Were there any other concerns in that area?

LINDVALL: Well, we tried to encourage industry to suggest lines of investigation that would have some value to industry, preferably in a broad rather than a specific sense, that could be the basis for investigations at the institute. And we tried in all ways to improve relations with industry on recruitment—getting industry to send its representatives over here, encouraging seminar talks, encouraging student society talks with industrial representatives, all of those things—recognizing the fact that at least most of our engineering graduates work for industry. And, after all, we were always passing the hat to industry for funds for general purposes, such as the Industrial Associates program.

SCHEID: That's run on the same basis as the regular Caltech Associates?[3]

LINDVALL: Industrial Associates pay a fee. What it is today, I don't know. They receive certain benefits, in the form of reports, invitations to attend special seminars that are put on from time to time. There's someone on campus—it's probably still called the

[3] The Caltech Associates, formed in 1926, is a financial support group for the Institute.

Industrial Associates Office [Industrial Relations Center—ed.]—who arranges for these lectures and seminars, which involve not only Caltech people but people brought in from outside for a particular subject area. And industries send their representatives if they wish to.

SCHEID: Were you personally involved in fund-raising very much?

LINDVALL: No.

SCHEID: Not even to the extent of giving lectures and so on?

LINDVALL: Oh yes, we all did that sort of thing, and we all participated in helping industrial representatives get acquainted with the campus, touring the campus and so on. I used to be pretty good as a guide.

SCHEID: Well, a lot of them now are alumni of Caltech.

LINDVALL: Yes, this changes the emphasis.

SCHEID: You made a couple of other trips, particularly one to Africa [1971], which I read a little bit about, and it sounded very interesting. I wasn't quite sure what your emphasis was there.

LINDVALL: Well, I went along to see what the engineering education situation was in the countries we visited, and to try to assess to what extent that kind of education, and the research that was going on, was helpful in their economic development. Of course, we spent a lot of time in South Africa, where they were taking care of themselves quite nicely. But in some of the other countries, some of the research and the type of teaching that was going on was too much patterned on the old British colonial schemes. And to a certain extent, that was true in the medical schools we visited. Many of the engineering students were being taught an advanced type of engineering that was not immediately useful in their countries. Most of the developing countries needed a lot more of the how-to-do-it kind of engineering. They needed roads, they needed railways, they needed drainage systems, they needed safe water supplies—and all of these things that are just the infrastructure in our country, which we think nothing about, really. Over there, the universities felt they were a little above that sort of thing: "We're not trade schools." And they were teaching engineering with the object of having their students pass the professional engineering society examinations, which were set by people in London.

SCHEID: I see. What countries did you visit?

LINDVALL: Ghana, Nigeria, Kenya, Uganda, of course South Africa, Rhodesia—that was about it.

SCHEID: Did they have the trade schools, too, on the side?

LINDVALL: Yes, they had some vocational-type schools.

SCHEID: That were attempting to deal with these basic problems?

LINDVALL: Yes. In Kenya at that time, there was a quite good training school, operated by the Department of Telecommunications, to train people for telephone, telegraph, and radio systems—in other words, to service them and to service the signals of the railways, and so on. The man who showed me around there said, "One of our big problems is that our students are grabbed up by private industry to service radio equipment and computer equipment, and we don't get them into the government, for which they've been trained."

SCHEID: You get applications at Caltech from students from underdeveloped countries. Do you think about that question very much when you consider the application? I guess you probably just consider it on its merits.

LINDVALL: We try to consider it on its merits, and if we have any line on the sources of letters of recommendation, if they're from somebody we've had experience with and have some confidence in, we can pay attention. But there are some of these letters of application and recommendation which you are sure are written by some professional scribe somewhere. [Laughter]

SCHEID: When you were there, you were with a group of people from Caltech who were in different fields. Did you emerge with some kind of consensus of recommendations about what should be done?

LINDVALL: Well, we had Professor [Edwin S. "Ned"] Munger, who was really our leader. He's a political geographer. And Horace Gilbert, in business economics; Robert Oliver, who was more general economics; Thayer Scudder, who is a student of African culture and anthropology. I went along looking at engineering and as much of industry as I had an opportunity to visit, and industrial-type labs and research labs that were sponsored by governments in the developing countries. For example, I found in two or three countries efforts being made to use waste materials to get by-products. I believe it was the waste material from the cashew nut that was capable of producing a fair amount of alcohol, which was adequate for industrial purposes, and they were trying to make that economical. Also extraction of oils of various kinds from vegetable products. Then there was a considerable amount of research and development of agricultural products, not really involving engineering as much as plant physiology. There was a limited amount of agricultural machinery development, but it was very difficult to have people accept the concept of making do with what they had, rather than hoping for money to buy equipment.

SCHEID: Did you see any attempts to develop the mining industries?

LINDVALL: Well, of course, in Ghana, bauxite was very important, and the big hydroelectric development there was a joint venture with a couple of the big aluminum companies from the U.S. and Canada, to take the bauxite and make aluminum pig out of it with hydroelectric power. That was one example. And everywhere, there was great desire on the part of the people in government, particularly those of a dictator nature, to have a steel mill. That was a big symbol. Often that kind of thing took priority over the real infrastructure that was needed to support the economy.

SCHEID: Did you write up a report of this trip?

LINDVALL: I believe there was some report written. I couldn't put my hands on it. Perhaps Professor Munger and others in humanities put something together that I don't remember. We all talked about it and gave seminars on it, afterward.

SCHEID: But your feeling was that they were not, either in education or in research, addressing the problems that they really faced.

LINDVALL: No.

SCHEID: They were too influenced by what was going on outside.

LINDVALL: Yes.

SCHEID: Have you ever been back?

LINDVALL: Well, a couple of the countries—Nigeria and Ghana, I mentioned—that was on another trip, with Harrison Brown and his then committee on African affairs of the National Academy of Sciences. I was the engineering type on that group, along with MDs and geographers and archaeologists and so on. That was later. I can't remember the exact date.

SCHEID: And what was the purpose of that trip, the same kind of thing?

LINDVALL: To meet with counterparts in the countries where we went, to see what, if anything, the National Academy of Sciences could do to encourage their governments to set up research that would be beneficial in the development process. There, again, I felt that most of our discussions were on too high and too abstract a level. What they needed to be talking about was roads and sanitation, good water, things of that sort.

SCHEID: You also traveled to India at some point, I think?

LINDVALL: Caltech was one of a consortium of eight other engineering schools that got together and established, and for a time helped staff, an engineering institute of technology at Kanpur, in India. This was a program of the Indian government to have several institutes of technology. USAID [United States Agency for International Development] was backing it financially. Caltech had two or three people who were over there for a period of time helping build labs, organize courses, teach courses. Then after the school had been in operation about five years, the consortium thought that several people who had not been part of the Kanpur operation should go there and see, "How does it look? Have we made any progress in five years?" I was asked to go on that mission. So we went to Kanpur and spent a week or ten days there with some others in engineering, and we wrote up our report afterward.

SCHEID: What did you try to evaluate?

LINDVALL: Well, whether they were doing a good job. Had they been able to recruit and hold good faculty people or were they still too dependent on faculty from the States, and too dependent on the U.S. for equipment and supplies? Were they beginning to stand on their own and maintain proper objectives? We felt that Kanpur was capable of doing a somewhat better job than they were, but they were held down by the minister of education, who didn't want Kanpur to be better than any of the other institutes of technology. So they had problems; they couldn't get out of line with the others on salaries or equipment appropriations, broad scope of work, things of that sort. Also, what were they doing to develop worthwhile relationships with industry? Where did their graduates go to work? Did industry come and employ them? Did industry sponsor any kind of research activities or specialized education? To a considerable extent, industry and the universities were miles apart, and we saw signs that they were gradually coming together. Many of the engineering graduates went to work for the railways, which is good; it's good for the railways to have good people. But the motivation was not all that it should be, because working for the railways provided the greatest amount of job security.

SCHEID: Did you feel that their education was indeed directed toward their problems?

LINDVALL: To a considerable extent. Efforts were being made, at least at Kanpur, to make the work relevant to industrial needs. There again, there was always the problem: Is it today's problems that they need help on in industry, or is it the problems that they will be facing four and five years from now which the students should be addressing themselves to?

SCHEID: So you feel there was a conflict in objectives between giving them basic courses and practical courses.

LINDVALL: That's right. In general, all Indian students shied away from the practical. That was not the gentleman's line.

SCHEID: Well, probably the really good students would have gone to England then, I suppose. Was that also a problem, attracting the best students?

LINDVALL: Oh, many of them did. But those English sources of funds were drying up, and of course, England no longer had the objective that they once had of training high-level civil servants.

SCHEID: You mentioned going to Argentina as well, for a meeting.

LINDVALL: Oh yes, that was a Pan-American Congress on Engineering Education. It was really for various schools to present papers describing their own objectives and curricula, and then general discussions of engineering education and what the needs of particular countries were.

SCHEID: So you became pretty familiar with Latin American problems at that conference?

LINDVALL: On engineering education, yes. Of course, they had a strong European background at those schools. The work would therefore tend to be somewhat theoretical. They were gradually getting away from that and coming more nearly into line with the

U.S. type of engineering education. Again, we were trying to advise them in a polite way, “Don’t get too efficient on this in your education, because you’ve got a lot of hard work of the state-of-the-art nature to do.”

SCHEID: Did you feel that there were certain engineering schools there that were pretty outstanding, then?

LINDVALL: Yes, although many of them were quite old-fashioned, and the professors had a terrible time. The pay was so little that they spent most of their time scrounging around for consulting activities and were seldom at the school. They’d come and give a lecture and disappear. So there was no real cadre of professors at a particular institution who were trying to build it up and improve the situation. In a place like Argentina, they should have been in much better shape, but they’d gone through the Peron period of terrific inflation, and industry was sort of gun-shy of the government, and things of that kind.

SCHEID: I think I’ve run out of questions. Have you got anything you think we’ve missed or that we should talk about?

LINDVALL: No. Except that at the time I reached the age of administrative retirement here as division chairman, I was offered an opportunity to go to Deere & Company and establish a position of vice president of engineering at the corporate level, which is something they had never had. I tried to do that in the three years I was there [1969-1972]—make recommendations that would generally improve the engineering situation, and particularly the interchange of engineering ideas among the different factories. They were pretty parochial in the factories. They did all their engineering themselves.

SCHEID: So you had a lot of duplication of effort?

LINDVALL: Even keeping secrets from other factories of Deere & Company.

SCHEID: I see. Is this a pretty common kind of position to have now in a company—to have someone directing the whole engineering effort?

LINDVALL: Well, it's not so much directing as coordinating it—avoiding duplication of effort and seeing to it that if there's some fundamental area that's helpful to one or more of the factories, that this work gets done someplace. Now, at Deere & Company, they have a central engineering laboratory, which does not design general new products or tell the factories what to do, but they solve problems that the factories have in materials or methods or design details—fracture mechanics, better methods of planting seeds, things of that kind. They're quite well along in agronomy and the machinery that goes along with good agriculture.

SCHEID: Do they have a set percentage of their profit that goes back into this kind of thing?

LINDVALL: Well, over the years they have maintained rather steadily a substantial fraction of sales that went into engineering and product development. That percentage ran around 3 to 4 percent, which was quite high for an industry of that type—higher than the automotive industry by quite a bit.

SCHEID: You just saw that as a temporary position there?

LINDVALL: Oh yes. The chairman there, Mr. [William A.] Hewitt—who's a Caltech trustee—said, "Fred, you're at an age when you would be retiring from Deere & Company when you're coming on board here, so the young fellows will not regard you as a threat." And that, in a sense, was helpful because they would cooperate with me, knowing that I was not in the internal corporate politics.

SCHEID: That was kind of full circle, going back to Moline, after all those years. Was that a peculiar experience?

LINDVALL: Well, in a way it was, but there were very few of the adults that I knew at that time who were still living, or high school associates. There were a few around, but they scattered all over.

SCHEID: It certainly probably didn't look the same as when you lived there.

LINDVALL: Well, the main thing about the town that didn't look the same was the fact that all the beautiful elm trees that used to be there had died off from Dutch elm disease. And the city had not replanted with anything to take their place, so there was a lot of barren area in the town.

SCHEID: When you came back here, then, you founded another company.

LINDVALL: Oh, my son started this business of earthquake sciences and engineering. I'm nominally the president, but since I don't pretend to be a structural engineer or a geologist or a seismologist, about all I can do is to talk generally along business lines with them, and to provide a shoulder on which people can cry, as I always did during the time I was division chairman here.

SCHEID: You say they're primarily concerned with earthquake consulting?

LINDVALL: Yes, consulting on sites to give a client the so-called design earthquake—what they feel is a reasonable expectation of ground motion. Then the client can have his designers or somebody else check out the building design, whether the building exists or not, or the dam exists or is about to be built—whether this will meet the postulated design earthquake. LRA [Lindvall, Richter & Associates] advises on foundation matters and the possibility of soil liquefaction in the event of severe shaking—what this will do to the foundations of a structure or a site.

SCHEID: Do you go beyond the building code that's required? Do you attempt to give more information?

LINDVALL: Well, we attempt to give information that will let the structural designers do their job properly, and we will perform dynamic analyses of structures if requested.

SCHEID: You mentioned dams as well.

LINDVALL: Well, for example, we analyzed the Big Tujunga Dam for the Los Angeles Flood Control District. And we've looked at other dams for the Department of Water and Power, Metropolitan Water District—intake towers, that sort of thing.