Frederick C. Lindvall

—How It Was

Frederick C. Lindvall, professor of engineering emeritus, was interviewed by Ann Underleak Scheid for the Oral History Program of the Caltech Archives. E&S has made a shortened version of the original transcript and presents here Part One (of two parts).

Frederick Lindvall: I was born in Moline, Illinois, where my father had a drugstore. In those days a pharmacist had to do a good deal more in the way of compounding medicines and salves than happens today, and I learned a fair amount of chemistry from listening to my father talk and watching him work in the store. So when I got to high school chemistry, it was a breeze; I'd heard most of the words before.

All the time I was growing up, we had living with us my mother's sister, who was an elementary school teacher, and she took a great deal of interest in my education. She would know if I wasn't doing well in school and would 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 professionals in action — such as visiting a court where she knew one of the judges, visiting the Rock Island Railroad shops where she knew the superintendent, and visiting the surgery at a local hospital where one of the doctors let me stand around and watch. 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 and Dohme, a pharmaceutical firm. He asked me what I was going to do when I grew up, and I said I thought I wanted to be an engineer. His answer to that was, "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, where you can be your own boss?" I didn't take his advice. I wanted engineering, perhaps because I'd always been interested in gadgets and what not. It was a source of concern to my parents when I would, on receiving a new toy, immediately start taking it apart. In those days, toys were put together with nuts and bolts rather than rivets and spot welding, so it was possible to take them apart and find out how things worked.

I went through high school in Moline, and before I finished, my father sold his drugstore. 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 25th wedding anniversary in Sweden as near my father's birthplace as they could, which they did. We were touring around Europe and were stuck in Switzerland when World War I broke out. It took us quite a while to get permission to cross France and get over to England, but we finally made it. At that time the Germans were making their big push toward Paris. I remember we stayed overnight in Dijon, and I could hear the big guns firing. It made quite an impression on me. 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 landed at Boston instead of New York as scheduled.

In 1920 my parents decided that they'd lived long enough in Moline, considering my father's hay fever every year. So they came to Los Angeles, and 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. The school offered the first two years of engineering, and I spent that time getting the basic chemistry, physics, math, surveying, and so on.

From there I transferred to the University of Illinois because I had made up my mind that I wanted to be in the railway business. So I enrolled in what they called railway electrical engineering, which was a promising subject at the time. After I finished the course, I received two or three railroad offers, but the man who was head of the department was honest enough to caution me. He said, "This railroad business is a tough game. If you live long enough, through the seniority system, you might get to be foreman of a roundhouse." That was a bit discouraging, so I wrote out to the Los Angeles Railway Company, which ran the yellow cars in L.A. 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.

I came back out here anyway and went down to the railroad car shops — that is, the street railway car shops — and talked to the superintendent, and he gave me a job wiring streetcars. They were buying a whole group of new cars at the time, and they 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 — what the reactions of shop men were, for example. After a few months of that, I saw the chief engineer walking through the shop one day, and I said to him, "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?" From that moment, the men in the shop didn't like me any more. They thought I was a spy. 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 power from

the trolley cars went back to the substations. They were having trouble with excavation machinery coming along and cutting through these cables. I stayed with that job another six or seven months, but in my summer vacation up in the high Sierra, 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 my early days at SBUC who thought Caltech was a wonderful place. One of them, Bill Holladay, later became president of the Caltech Alumni Association. Loys Griswold was another. So I came over here and talked to Professor Royal Sorensen about studying electrical engineering. He didn't know anything about me, so he was properly noncommittal, but after I sent in my transcripts, he said they would like to have me as a graduate student. I came in the fall of 1925 and worked for Professor Francis Maxstadt in the laboratory as a teaching assistant for the next three years, till I got my PhD in 1928. There was an interesting class that year — Arnold Beckman, Hugh Hamilton, and Charlie Richter. Clark Millikan and Morgan Ward were also here and were my good friends.

Ann Scheid: Was the public aware of Caltech at that time?

FL: Not very much. We heard about it at the time we were finishing over at the Southern Branch, because when you've had two years of engineering you look around for where you can get the rest of it. And Caltech was mentioned.

AS: What were the courses you took at Caltech that you particularly enjoyed?

FL: 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 and advanced math classes as people who were taking physics. In fact, at the time I got my PhD, the requirements for physics and engineering were such that my degree could have been labeled either one, and I chose the electrical engineering label.

I had some very interesting people as teachers. Dr. Smythe was a fellow who separated the men from the boys with the demands of his course in electricity and magnetism. I had lectures in thermodynamics from Paul Epstein — beautiful polished lectures that I enjoyed very much. But I was grateful, along with all the rest of the class, when just before final examination day, he posted a notice that he had concluded that the material in the course did not lend itself to an examination. 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, "As an exercise, put this into vector analysis form." It made us work, but I learned a good deal from it.

I had an 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 to include a lot of the basic things that are in physical chemistry and an overall energy approach to problems.

I also took a course in atomic physics from Richard Tolman. We were using a new book at the time — on atomic structure and spectral lines — and we had to sweat it through in the German language. Dr. Tolman was so frank and earnest that when some bright guy would ask a question, Tolman would say, "Don't rush me on that; that's in tomorrow's lesson." Tolman himself was a very stimulating person, and I also took from him an introduction to relativity course that involved a lot of his personal philosophy about science.

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

FL: Oh, it was. On the engineering side, we studied very practical matters of transmission-line design, high-voltage transmission of power. At that time, the mathematics for doing that was in the development stage, so we had to do a lot of our calculations the hard way. Convenient tables of functions simply didn't exist then.

During the years I was a graduate student here at Caltech. I lived in a bachelor shack with three friends — Harvey Cameron, Hallam (Dick) Mendenhall, and Arthur Warner. Cameron had just gotten his PhD, and he was Robert Millikan's first assistant in cosmic rays when cosmic rays were hardly an intellectually respectable subject of investigation. Dick Mendenhall got his degree a year before I did, and he later went on to Bell Labs. He 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. His feet were terribly burned. Professor Sorensen used artificial resuscitation to get him breathing again by the time the ambulance came. He spent months afterward in the hospital, having skin grafts for his burns, but they never did heal properly. But he's made a career on 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 the Chester Courts, which has since disappeared. It was there I first learned to do a little elementary cooking, and I've kept on with it and enjoyed it ever since.

One of the things Mendenhall and I missed was something of a humanistic-social science nature in the graduate work here at Caltech. So we spoke to Professor Judy, who was then chairman of the humanities division, and asked if it would be possible to have some kind of graduate seminar rather than just being welcome to sit in on an undergraduate class. So he started an informal seminar that used to meet at his house, which was a lovely place for meetings. He'd built the house around his books; he had a tremendous personal library. Among those who used to go to that seminar were Charlie Richter, Clark Millikan, Fritz Zwicky, and Graham Laing, who was an economics professor. We met once a week, and each of us in turn would present a paper on some nontechnical subject.

AS: What kinds of papers were presented?

FL: Well, Zwicky, for instance, gave a review of a then new book, *Decline of the West* by Oswald Spengler. None of us understood it 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, and in a discussion of that Graham Laing came through with a number of his shady jokes. We all urged Laing to record or write down his limericks; he had a vast store of them in both

French and English. But he never did. I gave a paper on Professor Stewart Sherman, a professor at Illinois who had written a number of books of literary criticism. Charlie Richter gave a talk on Dante's *Inferno*. He confessed that he was studying Italian at that time, so he could read it in the original.

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

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

A lot of my work was 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 argued that it couldn't. Those who said it couldn't said, "An arc would form, and it would never go out. The metallic ions from the electrodes would keep coming out and maintain the arc." On the other side there were those who said, "With an alternating current, the current has to go through zero twice in each cycle. And at that point, 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, but we built a larger single-pole switch that we took out to one of the Edison Company's substations and demonstrated. 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 good deal of interest in anything that could replace them. With the cooperation of the Southern California Edison Company, we built a three-phase switch that — like many of Professor Sorensen's ideas — was really too far ahead of its time. 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, though it worked if we kept the pumps going vigorously and didn't allow any leakage to occur.

It wasn't until nearly 30 years later that one of the early Caltech students, James

Royal Sorensen with the 1923 model of his vacuum switch.

Cobine, at General Electric Company, brought the vacuum switch into use. By that time, vacuum techniques and clean metals and a better understanding of metallic arcs had been achieved, so it was possible to make a commercially acceptable switch. Incidentally, Sorensen's original vacuum switch is on display at the Smithsonian Institution in Washington.

AS: What were some of Professor Sorensen's other ideas?

FL: First of all, he had the idea of a high-voltage testing laboratory. He got together with the Edison Company, which was really pioneering nationally in high-voltage transmission, and offered to design transformers if Edison would build a lab. He had done transformer design at General Electric before he came to Caltech. Anyway, at Caltech he designed these high-voltage transformers and the cascade interconnection so that you could get a million volts out with enough current to be realistic. General Electric was unsure of his design, although you might say he was one of their old alums, so Westinghouse built the transformers, though they wouldn't guarantee what they would do when interconnected. But after they were working successfully, Westinghouse put the "W" nameplate on them, as I remember the story.

In the high-voltage lab, Professor Sorensen and his graduate students also 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 that Edison and Pacific Gas & Electric were interchanging power, and then the large-scale power transmission grid was extended to the Pacific Northwest and down to San Diego.

Edison had a small research crew that used the lab about half of the time, and they 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. The laboratory crew would build up the voltage until the insulator strings would flash over, and then the Edison people would design guard rings and the like, so that the flash would not cascade over the porcelain insulators and crack them from the heat. They worked out a method of washing these insulators with a high-pressure water jet and found out that it could be done without shutting the power down. They did a lot of other little housekeeping details that were necessary before they could go up to 230,000 volts on the line that was built from Big Creek.

AS: How long had Edison been associated with Caltech in this cooperative effort?

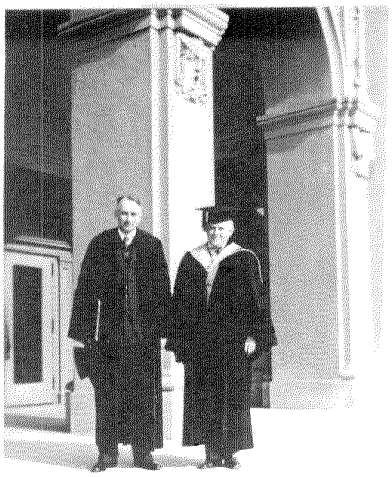
FL: That laboratory was finished, I think, in 1924. It was a going operation at the time I came in 1925. Sorensen had come to Caltech back in 1910. He was cagey enough to see with Millikan's arrival that if he hitched electrical engineering to physics, rather than leaving it tied to civil and mechanical engineering, he'd have a better chance of building graduate programs, which he foresaw as a necessity for the future of the engineering profession. And indeed that's the way it worked out.

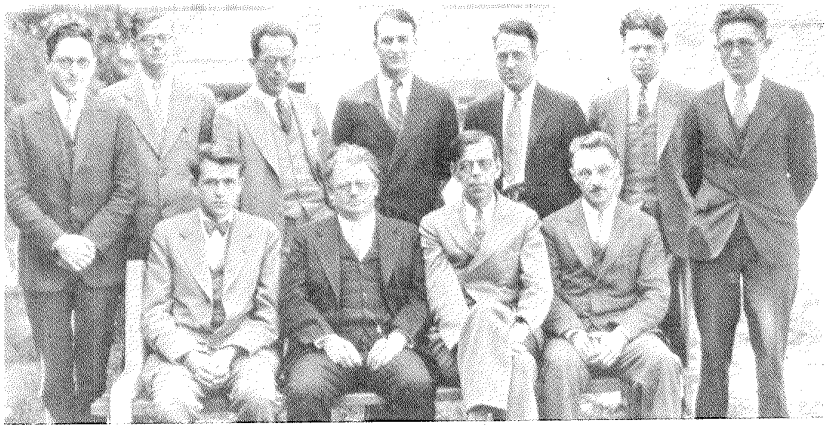
AS: Did Edison provide the money for the lab?

FL: 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 of the time, and then their use gradually tapered off as the power industry developed more and more of the high-voltage know-how. So they had less and less need for it.

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

FL: He helped quite a bit with the Department of Water and Power in Los Angeles and their line to Boulder, and he consulted with the Metropolitan Water District. He gave them a sort of overview of the electrical equipment that went into their pumping stations.





At the left, Richard Tolman and Robert Millikan dressed for the 1935 commencement. Above, the faculty in electrical engineering in 1932. In the front row, left to right, are Frederick Lindvall, Royal Sorensen, Stuart Mackeown, and Francis Maxstadt.

AS: Were there other people in electrical engineering who were doing different kinds of work?

FL: Well, there was Professor Maxstadt. He taught a course in electrical traction; and later on after I came back here to teach, I took over that course until student interest dwindled to zero. Maxstadt was good at electrical machinery.

AS: Did you enjoy teaching?

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

AS: What about the larger scene in Pasadena. Did you participate in anything in Pasadena at that time?

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

Well, I finally got through with all my degree requirements and got the PhD in 1928. At that time we held commencement on the east side of Gates Laboratory. 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. If it was in German, he loved it even more.

AS: Did people write their theses in German?

FL: A couple of them did. We had two or three European students for whom that was an easier language than English.

AS: So Caltech had the kind of reputation by then that brought students from that far away?

FL: Yes. It got that reputation fairly early Millikan induced Paul Epstein to come from Germany. And we had a succession of important visitors from Europe, people like Bohr, Einstein, and Lorentz. Lorentz was a wonderful man, who gave beautiful lectures. 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, Noyes in chemistry was well known in this country and in Europe. Sommerfeld was here, and I heard him in seminars.

In those days the principal seminar, which we all attended, was the so-called physics seminar. Dr. Millikan used to go around to the various labs, and he'd see one of the graduate students and say, "Here's a new paper in your field. Report on it at the seminar." Of course, the faculty would take turns, and the visitors would participate. Sir James Jeans came, and he and Millikan had lots of arguments about cosmic rays. I remember one seminar where Millikan was theorizing about the origin of cosmic rays after listening to some of Jeans's cosmology. Zwicky was in the row in front of me, and he started rocking back and forth in his seat and muttering, "Jesus Christ, he's crazy."

Well, finally I graduated, and Professor Sorensen thought it would be highly desirable for me to have practical engineering experience, whether I wanted a teaching career eventually or not. Based on his own experience, he thought it was good to have some practical engineering in the background. So I went to the General Electric Company, into their general engineering department, which was a small department that handled oddball problems plus a certain amount of original investigation. I spent about three months in their test course and more time in their advanced course in engineering, some of which was fairly easy for me after having been here. But they also gave me some good tough engineering problems, more comprehensive than anything that had been offered here. Then I had various assignments working with different engineers in the company on machine design, and over in the research laboratory where I learned a good deal from Dr. Whitney, who was then the research director for G.E.

In the summer of 1930, Dr. Sorensen asked me if I would be interested in coming back to California, and I said I would even though it meant a cut in pay. In those days $500 was a lot of money. I won't say I jumped at the chance to come back, but I had just been married when I went to G.E., and my wife, Janet, and I didn't love the winters in Schenectady. Also our parents lived in California, so we were glad of the opportunity to return.

AS: What did you do when you came back to Caltech?

FL: I started teaching some of the established undergraduate courses. After a year or so, I was encouraged to start a graduate course that was called Engineering Problems. I got the idea while I was at G.E. in the advanced course in engineering. I was impressed with the educational value of comprehensive problems — taking a week to work a problem — and that was the

general concept of the course that I started. Also the problems were not limited to any one discipline — not all electrical or mechanical engineering — but a mishmash that forced the students to dust off some of the things they thought they had left behind. It was well received by the students, though they hated the hard work that was 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.

AS: You had to go through the drudgery yourself, as well?

FL: Yes. And sometimes a student would approach a problem in a quite different way from what had been done before, and that was always refreshing. Si Ramo came in with a most novel solution to a problem in vibration of a generator system — a light plant in an imaginary small town. He wrote it up in the manner of a story from a *Saturday Evening Post* series called "Alexander Botts, the Tractor Salesman." He had little pictures he had cut out of magazines to illustrate this thing. It was a very, very ingenious thing.

AS: Was the solution as ingenious as the presentation?

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

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

FL: Well, in those days — the middle thirties — we had some awfully fine students who were naturally 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. For instance, in one of the most outstanding classes — those who got their doctorates in 1936 in physics or electrical engineering — there's William Fowler, Dean Wooldridge, Simon Ramo, Bill Pickering, and John Pierce, just to name a few. They all stimulated each other. It was a real pleasure to work with students like that.

AS: How were they recruited to Caltech? Were they given assistantships too, as you had been?

FL: Some of them were; otherwise they couldn't have come. Of course, everything was very cheap in those days. My annual salary was $2500, and you could buy lots of food for that in the thirties, 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 suggested that it would be very nice if the faculty were to pass a resolution recommending to the trustees that their salaries be reduced by 10 percent. Dr. Epstein, with his very logical mind, said, "We do not vote to increase our salaries; why should we vote to decrease them?" Nevertheless, we did have a cut.

AS: Was there a shortage of students at that time or an increase?

FL: There was an increase in graduate students, and the number of undergraduates stayed about the same. Of course, their tuition costs were much lower then, and it was more of a commuting college than it is now. Students could get here with their cars or motorbikes, or if they came from Los Angeles, there was the Pacific Electric Railway, which ran up Lake Avenue.

AS: What were the job prospects for the students when they got out?

FL: Not very good. Toward the end of the thirties things began to improve, but many of them had to work for a time at much lower skilled jobs than they were trained for. There were a lot of things of a public works nature that made it easier for those who were in civil engineering to find jobs. The Metropolitan Water District built the aqueduct at that time, for instance. There was a lot of government aid going into all sorts of projects, but 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.

AS: What kind of work were you concentrating on in this period?

FL: I was exploring atmospheric glow discharges. I had the idea, from something I had read, that somebody had discovered that a glow discharge had microphonic properties, and I thought if it's microphonic, maybe it will work as an anemometer for wind tunnel purposes. I worked away at that for two or three years. Then I had a couple of graduate students who worked on different modifications of it; so I kept that going. I also got involved in some railroad equipment business through some consulting connections — railroad refrigerator 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 was hit. So there was no more passenger car business until after the war was over.

AS: Were you consulting all during this period?

FL: Off and on. Of course, when you're just getting started as a faculty man, nobody's beating on the door for your services. It takes a while and help from older people who are willing to say, "Well, we've got a new man on the faculty who could do this for you very nicely," and that kind of thing. That's how you get started.

AS: Was Caltech getting any money from industry in this period?

FL: Not to any appreciable extent. Indirectly, yes. For example, the Metropolitan Water District built a hydrodynamics laboratory at Caltech to test models of pumps that the district needed for the aqueduct. The net result was that there were much better pump designs than the manufacturers had first proposed. They were more efficient, and consequently the pumping costs to the aqueduct system were substantially reduced. Later on the laboratory 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. They supported it indirectly.

Things went along that way. I had graduate students whose theses I supervised. One of my stars was Rube Mettler, who's head of TRW now. My first graduate student was named Gibson Pleasants, now deceased. 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, and I know now they were very crude, but we were learning the principles. A couple of other students also worked on various problems of cathode ray oscillography, and eventually sealed tubes were beginning to appear on the market, so that ceased to be a fruitful field of study. We were not smart enough to see in our experiments with magnetic focusing the genesis of the electron microscope. □