SEM History

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A.V. De Forest Hans Meier & Prof. Ruge

The MIT Connection

When I was a newcomer to SESA meetings in the early 1950s there was a strong MIT flavor in the Society. By then, Bill Murray and Hans Meier were already past presidents, but Bill was still the Secretary-Treasurer, and Chuck Mahlmann was the editor of the Proceedings. Then there were always the venerable Ferdi Stern and Greer Ellis. The senior MIT faculty then included: Professors A.V. DeForrest (Ferdi and Greer's mentor), Arthur Ruge, J.P. Den Hartog, and Harold Edgerton. I remember seeing some from the latter group at a few SESA meetings, but was not fortunate enough to become well acquainted with them. Other SESA regulars with an MIT connection included: Fred Bailey, A.J. Durelli, Emmett Day, Harry Majors, Everett Reed, Pete Stein, and Jerry Catz.

Clearly, MIT was a hotbed for experimental stress analysis during the gestation period and in the infancy of the SESA. When I saw the name of R. Plunkett from MIT listed as an attendee of the *Eastern Photoelastic Conference,* June 1941, I quickly called Robert and asked him to write about MIT in those years. He kindly agreed and we thank him for the article, which follows.

- C. E. Taylor, SEM Historian

Experimental Stress Analysis at MIT in the 30's and 40's
by Robert Plunkett
Retired Professor of Mechanics, University of Minnesota

I arrived as a freshman at MIT in the fall of 1935 and was fortunate enough to work for J.B. (Bud) Wilbur on the Government funded NYA program. He had recently received the first Ph.D. in Civil Engineering and went on to become Department Chairman and Chief Engineer of the Route 128 ring road project around Boston. In the next few years he and Charles Norris started the structures laboratory and Hans Meier (President

SESA 1950-51) worked in it as a graduate student. They used the Beggs Deformeter equipment on plastic structural bents to study load sharing in large indeterminate structures. Huggenburger Tensometers were used for measuring strains and dial gages and interferometers were used to measure small deflections.

Arthur Ruge had a laboratory down in the Basement of Building 1 where he had built a shake table that used a photocell driven feedback system to follow a cardboard cam to simulate an earthquake. On it he had mounted a model of a water tower. He was frustrated in his attempts to measure the response of the system until he started using unbonded wire strain gages. He spent a lot of time improving these gages and the associated instrumentation, got sidetracked and never went back to the shake table work! I became interested in his work and he helped me do a senior thesis on bonded stain gages with multiple taps for measuring strain fields. It didn't work out too well but I learned a lot about instrumentation. The available electronic DC amplifiers were not very linear, were noisy and drifted. As a result we used high sensitivity light beam galvanometers with battery driven Wheatstone bridges. We modified the galvanometers by removing the original torsion suspensions and replacing them with new ones made from the 0.001 inch wire we used for the strain gages. When the light beam fiduciary mark was focused on a meter stick 20 feet away we could measure to a tenth of a microvolt. Unfortunately, the equipment was very sensitive to magnetic fields; every time an electric street car went by on Massachusetts Avenue, three stories down and a hundred feet away, the light beam swung through 90°. As a result I took most of my data from midnight Sunday to 4 am Monday when the cars didn't run.

As a result of a difference of opinion between a very senior Structures Professor and myself, Dr. Wilbur suggested that I had better change my major when I went to graduate school. For some reason, it didn't occur to me to change universities. In any case I enrolled as a graduate student in Mechanical Engineering and, again with the help of Dr. Wilbur, got an appointment as a Research Assistant in Electrical Engineering with Vanevar Bush and Sam Caldwell, working on the electromechnical differential analyzer. In ME I got to know Bill Murray and his Photoelasticity Laboratory better, but was not really connected with the experimental mechanics work. I learned a lot about relays, servo-feedback and electric motors on the EE project, but the most interesting part was working with Harold Edgerton to construct a special high-speed flash lamp that we used in an electro-optical system to measure total shaft rotation up to 10000 revolutions with an accuracy of 0.01 rotation at 5000 rpm. It was on this project that I learned, the hard way, that transformers don't work very well on DC voltages!

After two years as an EE RA, I was offered an instructorship in ME with a pay raise to $120 per month. That was the fall of 1941. When December 7, 1941 came along, I was called to active duty as a Reserve Officer and was overseas most of the time until the fall of 1945. Things had changed a lot during the war and there were many additions to the faculty. SESA, later SEM, had been founded at the 13th Eastern Photoelasticity Conference and was being directed by Bill Murray. My advisor, J.P. Den Hartog, had been in the Navy and moved from Harvard to MIT. E.G. Orowan was working in Materials. A.V. DeForest had a very lively group in Experimental Stress Analysis. He

had previously developed his scratch gage for fatigue measurements, was working with Greer Ellis on Stresscoat and with Ferdi Stern on Magnaflux. About that time he gave a special course on experimental methods for Lou Coffin, Ken Bodner and myself. We would gather in his laboratory one afternoon a week and A.V. would tell us about an idea he had had that we might play with that session, very informal! The graduate enrollment was not very large at that time. He was also busy with Art Ruge establishing Ruge-DeForest and setting up to manufacture bonded wire strain gages. It must have been about that time that I met Peter Stein who was very active in adapting the electronic instruments developed during the war for experimental mechanics applications.

I am impressed with the great improvement in instrumentation in the past 50 years. For strain gages, we used batteries and galvanometers. Next came balancing circuits that eliminated the linearity problem. Then came AC amplifiers using a 2000 Hz carrier. We used a pen recorder with a maximum frequency response of 50 Hz. Now there are stable DC amplifiers with frequency response to over 100 kHz, a to d converters and digital recording on floppy disks. But it all started with Ruge's unbonded gages, Bill Murray's photoelasticity laboratory, A.V.'s students, Ellis' and Stern's Magnaflux and Stresscoat. By the time I finished at MIT in 1948, the revolution in strain measurements was well under way. The development of unbonded strain gage accelerometers was just getting started and piezoelectric devices were a couple of years off.