



Ed Simmons and Peter K. Stein at the 61st Shock & Vibration Symposium, October 1990, Pasadena CA, where Ed was a featured and honored guest. Ed was wearing the Renaissance uniform which he often wore in his later years. Yes he was a genius and he was different! Photo by P. Stein

Edward E. Simmons, Jr.
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The Unintentional Brilliant Inventor Who Marched to His Own Drummer - Always

THE INVENTION OF THE BONDED RESISTANCE WIRE STRAIN GAGE

by Peter K. Stein

Foreward: Ed Simmons recently died at the age of 93. He was never a member of SESA/SEM, but as an inventor of the wire resistance strain gage he had an enormous influence on the Society. Shortly after Simmons' death Pete Stein wrote an article which highlighted Ed Simmons' fascinating life, but also begins with a glimpse of early strain gage history. Pete Stein is President of Stein Engineering Services, Inc., Phoenix Arizona. He is a Fellow in SEM, recipient of many SEM awards, and a frequent contributor to Experimental Techniques. The following is excerpted from Pete's article.

—C. E. Taylor, SEM Historian

In the Summer of 1936 an interesting team was assembled in the Guggenheim Aeronautical Building at California Institute of Technology, Pasadena, California, under Dr. Theodore von Karman who encouraged a number of orphan projects to operate under his wing when they could find no other home.

DR. DONALD S. CLARK (1906-1976) was a metallurgist doing research on impact properties of materials. His sponsors were: the cream of the crop of American industry at the time: Allis Chalmers Manufacturing Co., Caterpillar Tractor Co., General Petroleum Corp. of America, Hughes Tool Co., Lane-Wells Co., National Supply Co., Arnold Pfau, A. O. Smith Corp., Union Oil of California and M.W. White - all of whom received regular Progress Reports and had to give their permission before the research results could be published. The recipients of these Progress Reports were all metallurgists. The list is cited because no one who read those Progress Reports realized the significance of the invention which permitted the data presented in them, to be gathered.

DR. GOTTFRIED DAETWYLER (1906-1976) received his doctorate in Aerodynamics from the Federal Technical University in Switzerland in 1936 and came to Cal Tech to work under von Karman. His family owned a wire manufacturing company in Switzerland and he had worked there for a few months trying to solve some wire production problems. At Cal Tech he found the wind-tunnel busy with confidential work and, as an alien, he was denied access to it. Since Don Clark's project had found a home in von Karman's building, Daetwyler soon met Clark and discussed his family company's metallurgical problems with him. Daetwyler was fascinated by the Impact Project and as Research Fellow in Aeronautics began to work with Clark.

EDWARD E. SIMMONS, JR. (1911-2004), with his 1936 Cal Tech Master's degree in Electrical Engineering, had a \$0.50/hour job maintaining the EE Lab and taking care of the Physics Stock Room. He also conceived, designed and built special instrumentation for the Pump Project (for the big aqueduct), another one of von Karman's assemblage of projects which could find no other home. He had a reputation of being a near-genius when it came to solving practical instrumentation problems. He worked only at night because the Pump Lab had to operate nights - the Wind Tunnel used all the available power for its day-time higher-priority operation. Simmons also worked on instrumentation problems for the Impact Project.

On September 16, 1936, Daetwyler, after many failures trying to use the newly developed bonded liquid carbon Aquadag™ solution as a strain sensitive device, discussed the problem of dynamic force measurement during impact with Simmons, and Simmons casually suggested bonding a fine, insulated wire to the surface of a prismatic bar to act as a force-measuring transducer.

The bonded resistance strain gage was born and was used successfully until June 1938 when the research results were presented to the world at the ASTM Meeting in Atlantic City, June 27 - July 1.

Dr. Donald S. Clark and Dr. Gottfried Daetwyler, Stress-Strain Relations Under Impact Loading. Proc. ASTM Symposium on Impact Testing, Atlantic City, NJ, June 1938. ASTM, Philadelphia, PA, printed & copyright Jan. 1939, note the date! There was a 2-1/3 year hiatus between the invention and the publication, during which time no one realized what had been invented!

The audience included Dr. Louis Tuckerman of the National Bureau of Standards and inventor of the Tuckerman optical strain gage. The conference proceedings were not printed until January 1939, and during those 2-1/3 years



Ed Simmons and Peter K. Stein at the Southern California Section meeting of SEM, February 15, 1989

(Sept. 1936 – Jan. 1939) no one realized that an invaluable strain measurement transducer had been invented, one for which another part of the world had been waiting for decades.

Clark, the metallurgist, Daetwyler the aero-dynamicist, and Simmons, the electrical engineer, had no clue as to the intrinsic value of the invention and its application as dynamic load cell. In fact, Simmons thought the invention too simple to bother patenting.

The circuit which Simmons used for his 500 ohm gage was a constant current one with a 140 v battery and 900 ohm series resistor making it a 64% efficient circuit versus the 50% efficient Wheatstone bridge, even today a very good solution. He used a 0.5 ohm resistor in series with his gage for calibration purposes. The resistor could be switched into and out of the circuit. Approximately 14 ft of No. 40 Constantan wire was laid longitudinally on the four successive

faces of the prismatic dynamometer bar in zig-zag fashion and coated with glyptal as a binder. His circuit sensitivity was 64 microvolts/microstrain! That's 64 mv/1000 microstrain! He used the single sweep open-shutter technique to photograph the trace on his RCA TM-168A oscilloscope. Simmons was truly a very good EE.

(See a later section about how the Ruge team was stymied by the lack of a good EE!)

The strain gages which Simmons made were of insulated wire, mounted on a paper carrier bonded *wire side down!* The Ruge gages (see below) were made of uninsulated wire mounted *carrier side down*. This enables us to trace the origins of the gages as they spread like wildfire up and down the West Coast in the aircraft industry.

PROF. ARTHUR C. RUGE (1905 - 2000), at the Massachusetts Institute of Technology, Cambridge, Massachusetts, was engaged in research on the earthquake survivability of water towers in 1937, under a grant from Factory Mutual Insurance Company. He and his assistant / doctoral candidate had built a water tower model to be vibrated from the records of a 1920s Long Beach, California earthquake and they wanted to measure the dynamic strains on the tower. No strain gage they tried would work. They were at the end of their rope.

J. HANS MEIER (1913 -), with his Dipl.-ing. degree from the Federal Technical University in Switzerland, had arrived at M.I.T. in 1937, obtained his Master's Degree under Dr. William M. Murray (founder of the Society for Experimental Stress Analysis, today's Society for Experimental Mechanics) and became Prof. Ruge's assistant, working on the theoretical and experimental aspects of the water tower project.

FRANK F. HINES (1913- 2001) joined Prof. Ruge at first to help maintain the failure-prone hydraulic earthquake simulation equipment, since, as a recent transfer student he couldn't find the right courses to take at M.I.T. that semester. His manual dexterity was legendary. In fact he had won a 4-year college scholarship as the first prize in the 1931 Fisher Body Competition, building a hand-crafted model of Napoleon's Wedding Coach.

On SUNDAY, APRIL 3, 1938, Prof. Ruge had a "Eureka" experience, in which he saw the solution to the strain measurement problem: a fine wire, insulated from the test specimen by thin paper, and bonded to the specimen. He tried the idea, it worked remarkably well. Meier altered the aim of his doctoral dissertation from the water tank to the development, evaluation and improvement of the bonded resistance strain gage. His doctoral dissertation still stands as the most exhaustive and predictive study on the bonded wire resistance strain gage. Hines used them on his bachelor's thesis to measure torque, and remained in Prof's lab making and further improving and developing the gages. Both Prof Ruge and Hines remained in that field the rest of their lives.

Ruge and Meier received their doctorates in June 1939. Hines could not receive his Bachelor's Degree personally. It came by mail. He was too busy making strain gages.

THE LACK OF INTERDISCIPLINARY TECHNOLOGY TRANSFER

Simmons, the EE, had no problem in devising an ingenious circuit and instrumentation to measure the tiny voltages under high-speed transient conditions, which emerged from the impact load cell at Cal Tech, but none of his team members realized the significance of the invention. One of the reasons the M.I.T. team abandoned the dynamic-water-tower excitation project as the main focus of their work was that they could not construct, nor find anyone to build, an amplifier which would reproduce the tiny dynamic (3 Hz) voltages from their setup, for measurement. Prof. Ruge did hire an EE Master's candidate for that project, but he was not successful (over 2 years after Simmons!!!). The Civil Engineers, Prof. Ruge and Meier, were stymied by the electrical aspects of the project. The Cal Tech team, Metallurgist Clark, Aerodynamicist Daetwyler and Electrical Engineer Simmons, did not realize the significance of their load cell. To them it was a means to an end.

Ruge saw the Clark & Daetwyler publication only in February 1939, when he was already well on the way to commercializing his invention, and found himself pre-empted by Simmons' work. (The proceedings were only printed in January 1939). The Baldwin Southwark Company got the two inventors together and the bonded resistance wire strain gage became a commercial reality.

It was named the SR-4 Strain Gage, S for Simmons, R for Ruge, and 4 for the four men involved, Clark and MIT's A.V. de Forest. It was de Forest's previous contacts with Baldwin Southwark which led Ruge to them. They were manufacturing de Forest's Scratch Gage, a mechanical strain gage. The contract for the Baldwin-Southwark production of the gages was signed September 3, 1940.

Baldwin Southwark changed its application for a patent on Ruge's invention to a basic patent for Simmons and a string of improvement patents for Ruge. Each remained protective of his piece of the pie.

There were ongoing problems with the patent and the related royalties. While the wheels of justice were slowly grinding, Simmons had worked as a radar engineer at the Sacramento Air Depot during the war and then returned to Pasadena to work for the Rheem manufacturing company but a court decision in his favor changed all that. Ed pursued many interests he was fond of and established the Simmons Research Foundation, but did not involve himself in the strain gage business.

Tatnall nominated Simmons in 1944 for the Edward Longstreth Medal of the Franklin Institute of Philadelphia, (Tatnall was on the Nominating Committee) which awarded about 15 medals each year for 'contributions to the arts and sciences of the world, to the good of mankind and to the advancement of science. The Franklin Committee cited Simmons for his 'valuable contribution to engineering and research ... (his device) has proven essential in engineering design of aircraft and other powerful instruments of war, and will be as valuable in peace.'

In his book Tatnall described the ceremony: 'Medal Day begins with a formal luncheon at noon followed by meetings with the medalists, press conferences for them, publicity photographs and other customary formalities. Simmons did not show up, so I just explained that he was embarrassed, knowing that he wasn't at all, he just did not care. Simmons was still absent when we dressed for dinner, Medalists in white tie and tails, others in black tie. When the Medalists filed into their designated places at the head table, I had the nerve to look up see if my boy was at his place at the table. When I did get up the nerve to look my heart jumped with joy. There he was sitting between the great chemist Dr. Leo Baekelund, inventor of Bakelite, tall, moustached and impressive, and on the other side Dr. Harlow Shapley, famous astronomer, Director of the Harvard Observatory both in white tie and tails. Ed Simmons was looking very small, very young and very bored and he was in his familiar tennis clothes, or a slightly enhanced version of them. I think, but I am not sure, that he got the biggest hand of all from the 450 or more prominent people attending the dinner.'

In 1987 Simmons also received the Inventor Award from the New York Academy of Sciences

In later years Simmons chose to dress in Renaissance costume complete with tutu and appropriate shoes. He maintained that this garb was more comfortable than ours. He was a familiar sight around Pasadena which he did not leave even for the 50th Anniversary celebrations of the commercialization of strain gages in 1988 which I arranged in Portland, OR, Cambridge, MA (the home of M. I. T.) and in Houston, TX.

He attended the Feb. 15, 1989 Southern California Section meeting of the Society for Experimental Mechanics at the Peppermill Restaurant in Pasadena, and the 61st Shock & Vibration Symposium, October 1990, Pasadena CA, where Ed was a featured and honored guest. While we were on stage at the Hilton at that meeting, his home of 50 years was being demolished by a bulldozer under orders of the Pasadena Health Department as being a health hazard. We stood outside the fence watching helplessly. The remains of his library and laboratory were piled in the front yard. Somewhere in there was his Silver Edward Longstreth Medal from the Franklin Institute of Philadelphia, but no one would listen to our pleas to allow him to look for it. Some very early load cells and strain gages he had built for the Impact Lab at Cal Tech, and the entire collection of the Impact Lab Reports (the last copies!), oscilloscopes, amplifiers, delicate galvanometers bridges, motors, fans – his life-time collection of things with which he loved to tinker, were bulldozed over pellmell. I still have some photos of the mess.

Well past his 90th birthday, Ed had been a long-time consultant to InnerSpace Corporation in Pasadena, CA, solving problems which baffled younger engineers.

As time went on Ed was plagued by legal and physical problems that would consume much of his time, money and health. I was able to gain the support of many people to offset his financial obligations, however his health concerns took over and Ed passed away quietly and peacefully on May 18, 2004.

Ed, so many of us are making a living from your invention! THANKS!■

— Peter K. Stein