ChE educator

John H. Seinfeld

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BY HIS COLLEAGUES AT
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John Seinfeld was born in Elmira, a small city in upstate New York about thirty miles from Ithaca. His studious tendencies showed themselves early, and at age twelve he was a national finalist in a public-speaking contest sponsored by the Optimist Club. As in many small towns in those days, high school athletics was king—baseball and golf became his sports. He was a good enough golfer to play on his high school golf team and, later, for the University of Rochester. After being named "most likely to succeed" in his high school graduating class, he went on to the university where he chose chemical engineering as a major because he liked math and chemistry.

He entered the freshman class at the University of Rochester and found himself a classmate of many students from New York City schools who had already had calculus and other "advanced" subjects. He requested that he be placed in the advanced math track but soon found he was swimming upstream. In the end, he managed to solve every problem in Thomas's calculus book on his own, and received the highest grade in the freshman calculus course.

As an undergraduate in chemical engineering, he was strongly influenced by two faculty members in that department: Stan Middleman (now at the University of California, San Diego) and David Smith (now at du Pont). John recalls fondly the famous summer unit operations laboratory taught by then department chairman, Shelby Miller. Lab reports returned by Shelby, covered with corrections in his infamous green ink, were dreaded by the students and were their first experiences with critical report writing. John graduated first in the College of Engineering at the University of Rochester and decided to attend Princeton for graduate work. He had used Leon Lapidus's book as an undergraduate and that, together with Princeton's substantial reputation, caused him to chose Princeton.

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At Princeton, he decided to work for Lapidus, who was one of the earliest to introduce mathematical methods and process control into chemical engineering. The Princeton chemical engineering department was a stimulating place under the combined ministrations of Lapidus, Dick Wilhelm (one of the early pioneers of chemical reaction engineering), and a new faculty member in the field of fluid mechanics, Bill Schowalter. Although John was pursuing a thesis in optimal control theory, he took every fluid mechanics course offered by Bill Schowalter. "He was such a good teacher that he actually made me believe that I understood all the tensorial manipulations in rheology," John says.

While at Princeton, John shared an apartment with Steve Jaffe (now at Mobil Research and Development) and Dale Seborg (now professor of chemical engineering at the University of California, Santa Barbara). Stories of practical jokes played on one or another of the three by the other two keep Steve, Dale, and John laughing to this day. In his final year at Princeton, he received the Wallace Memorial Fellowship in Engineering, traditionally given to the most outstanding graduate student in engineering.

One afternoon at the Princeton bookstore, one of the other chemical engineers pointed out, with reverence, another shopper—James Wei, who was on sabbatical at Princeton from Mobil. Much later it turned out that John formed a professional and personal friendship with Jim.

The late 1960s were an exciting time to be a graduate student in chemical engineering at Princeton, and many of the graduate students have gone on to distinguished careers in industry and academia. The nightly midnight run to the King's Inn for pizza and beer was almost a departmental function.

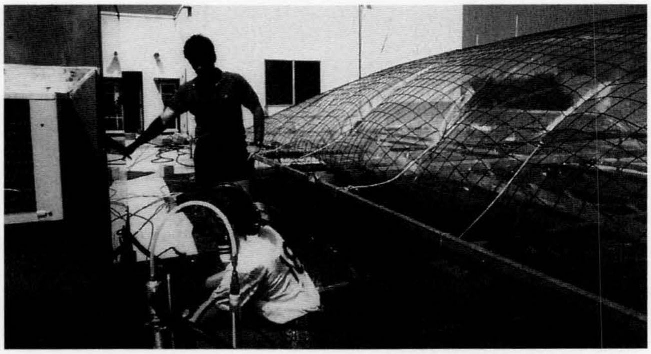
Because of the influence of Leon Lapidus, Dick Wilhelm, and Bill Schowalter, John decided he wanted to pursue an academic career. There were not a lot of faculty openings in 1967, but Bill Corcoran of Caltech had written Dick Wilhelm about an opening in that school's department. John flew out for an interview, and when a position was offered he eagerly accepted it. He joined the Caltech department in the fall of 1967.

Chemical engineering at Caltech essentially started in the early 1940s under the leadership of Will Lacey and Bruce Sage and the old American Petroleum Institute Project 37 which dealt with thermodynamic properties of hydrocarbon mixtures. It had become clear by the mid-1960s that it was time to form a modern department of chemical engineering at Caltech. Bill Corcoran was appointed as executive officer (the term used at Caltech for a department chairman position), and he proceeded to hire Sheldon Friedlander from Johns Hopkins in 1964 and George Gavalas from the University of Minnesota in the same year. Fred Shair was added in 1965, and John joined the department in 1967. An exciting period of growth followed in which, within a span of five years, Bob Vaughan, Gary Leal, and Henry Weinberg were added to the department. Caltech was well on its way to having one of the premier chemical engineering departments in the country.

Having done his thesis in the area of optimal control theory, John continued his research in this area after coming to Caltech. He was particularly interested in optimal control and parameter estimation problems involving partial differential equations, such as tubular flow reactors and petroleum reservoirs. He received the American Automatic Control Council's 1970 Donald P. Eckman Award for contributions by a young researcher in the field of control theory.

While some of his colleagues spent their lunch hour swimming or jogging, John has always been an avid lunch-goer, especially at Caltech's renowned faculty club, the Athenaeum. And it was during one of those lunches that Shel Friedlander interested him in the newly emerging field of air pollution. John immediately saw an opportunity for someone who was deeply trained in mathematical methods, numerical analysis, and modeling to apply those approaches to atmospheric air pollution. So around the year 1970, John started shifting the emphasis of his research program from control theory to air pollution. One of his research ambitions has been to introduce and apply to the analysis of air pollution the level of rigor that has characterized the traditional approach to chemical reaction engineering. The soup of both natural and anthropogenic compounds, most present only at trace levels, leads to phenomena as diverse as greenhouse warming, stratospheric ozone depletion, urban and regional smog, and acid rain. John's research has been a broad, but deep, attack on virtually all aspects of the chemistry and physics of air pollutants in the troposphere.

The atmosphere is a giant chemical reactor, with processes occurring on spatial and temporal scales ranging from a few centimeters to thousands of kilometers and from milliseconds to tens of years. In an era when air quality was studied with box, plume, and puff models, John undertook the development of air quality models that would apply reaction engineering techniques to an entire airshed. It was natural to apply these models to Los Angeles, which, in addition to being among the most polluted cities in the United States, offered the most data on emissions and air quality. This effort produced the first large-scale urban air pollution model, the precursor of the one now used nationwide by the Environmental Protection Agency. Efficient and robust numerical techniques are of paramount importance for spatially resolved modeling of chemical reactors with volumes of several thousand cubic kilometers. Efforts to develop suitable techniques began with the 1974 thesis of graduate student Steve Reynolds, and culminated with that of Greg McRae in 1981. Those methods form the basis for most airshed modeling even today. John and his student Donald Dabdub are currently exploring how air quality models can be implemented on Caltech's massively parallel computers to further increase the capabilities of the models.



Studying atmospheric chemistry in the real atmosphere is difficult because the air is always moving. At Caltech, John and Rick Flagan use a large outdoor Teflon reactor, a so-called "smog chamber," to study atmospheric chemistry under well-controlled conditions. Here, Spyros Pandis and Suzanne Paulson are conducting an experiment on the atmospheric chemistry of biogenic hydrocarbons.

As the airshed models were developed, it became apparent that a lot of important data were either missing or uncertain. This led John to study the details of the chemical mechanisms and reaction kinetics and to develop techniques to assess the sensitivity of complex reaction mechanisms to the rate parameters employed in the models. While John's understanding of the atmospheric chemistry grew, that chemistry was only part of the problem. The atmosphere is full of particles, haze, fog, and clouds. Indeed, one of the aspects of air pollution that is first noticed is the haze that forms at the end of atmospheric reactions. Much less was known about the atmospheric aerosol. New instruments providing a picture of the size distribution of the atmospheric aerosol showed that the particles accumulated at diameters comparable to the wavelength of light, making them very efficient at light scattering. People had studied coagulation equations, but there were no comprehensive models to describe how aerosol particles form and grow in the atmosphere.

John set out to advance aerosol modeling to the level of the gas-phase reaction models, studying methods for solving the aerosol dynamic equations as well as the basic physics of aerosol particle formation and growth. A breakthrough was made in 1979 by John's student, Fred Gelbard, with his development of the first codes to track the evolution of the aerosol distribution of chemical composition as a function of particle size. John's continued work in aerosol modeling has probed the aerosol chemistry, incorporating models of chemical and phase equilibria into the description of the atmospheric aerosol.

A recent get-together of John's research group at his house. At the bottom of the photo is the youngest chemical engineer in the group, John's son Benjamin.

The developments on the modeling frontier were not enough for John. After years of work in refining the reaction and aerosol models, major gaps remained—particularly with respect to the atmospheric aerosol. Field studies were useful but not sufficient, since the chemical history of the air being sampled at any particular time depended on the vast pollutants emitted into it and the detailed reaction history. Experiments were needed to acquire the missing data. The basic tool was a smog chamber system developed by Shel Friedlander. This permitted the study of reactions and aerosol development in a captive parcel of air in a large (up to 60 m^3 volume) Teflon balloon reactor, located on the roof of the Keck Laboratory so that the sun could drive the photochemistry as it does in the atmosphere. The small surface-to-volume ratio of this large reactor made it ideal for the study of the atmospheric aerosol since wall losses of submicrometer particles were relatively small. Shel used the system to study the aerosols produced by photochemical reactions by adding reactants of interest to air drawn from the Pasadena atmosphere.

In 1975 a young assistant professor of environmental engineering science, Rick Flagan, joined Caltech, coming from mechanical engineering at MIT where he had pursued a thesis in the area of combustion. He was interested in the generation of pollutants in combustion processes, with special interest in aerosols. Rick Flagan is widely acknowledged as a superb experimentalist, and shortly after he arrived at Caltech he and John began a close to twenty-year collaboration on experimental atmospheric chemistry and aerosols.

Following Shel Friedlander's departure from Caltech, John and Rick joined forces to revive the smog chamber facility. Although great for demonstrating atmospheric aerosol dynamics, the existing system was ill-suited to John's needs for better data on atmospheric reactions since all sorts of contaminants were brought into the chamber with the Pasadena air. Graduate student Joe Leone modified the air-handling system so that it would clean the air to a small fraction of a part per million and began John's experimental studies of atmospheric photochemical reactions. The smog chamber studies were so demanding that a tradition was established of teaming a student working on the gas-phase chemistry with one working on atmospheric aerosols. The smog chamber provided tantalizing insights into the ways that homogeneous nucleation and aerosol thermodynamics influence the atmospheric aerosol.

The smog chamber studies were augmented by more controlled bench-scale studies as well as theoretical investigations. These included laboratory studies of the rates and mechanisms of gas-phase reactions, studies of the fundamentals of nucleation theory, and development of mathematical models for atmospheric phenomena. Following a recent major gift of analytical instrumentation, the focus of the atmospheric reaction studies has turned to molecular identification of both aerosol products and gas-phase intermediates. Using new instrumentation that makes it possible to make real-time measurements of the aerosol and the analytical facilities, John and Rick have just begun a new research initiative, attempting to understand the aerosol processes that act to control cloud formation and albedo over the earth's oceans. This program will involve aircraft-based measurements of aerosols in the marine boundary layer, to be carried out by Lynn Russell, a graduate student in chemical engineering.

In addition to the graduate courses in air pollution, John has over the years taught every undergraduate chemical engineering course offered at Caltech except thermodynamics, and is the author of seven books. His 1986 text, *Atmospheric Chemistry and Physics of Air Pollution,* has been adopted worldwide as the standard senior- and graduate-level text in air pollution. The two-volume set consisting of that book and a second, coauthored with Rick Flagan, *Fundamentals of Air Pollution Engineering,* constituted Caltech's unique year-long course sequence in air pollution, covering combustion fundamentals, gas cleaning, aerosol science, atmospheric chemistry, and atmospheric transport and diffusion.

John Seinfeld has been described by some as fanatically organized—perhaps it was this character flaw that led to his being asked to assume the

Betty and John outside Tokushima during a visit to Japan in 1986.

position of executive officer for chemical engineering in 1973, only six years after he joined the department as an assistant professor. Then in 1990 the Caltech administration asked him to take over as chairman of the Division of Engineering and Applied Science, Caltech's equivalent to dean of engineering. What makes this unusual is that chemical engineering at Caltech is part of the Division of Chemistry and Chemical Engineering, not with the other ten or so engineering departments in the Division of Engineering and Applied Science. This was just enough of a challenge to induce John to agree to take on the job. He likes to point out that at two of the three schools (Berkeley, Caltech, and the University of Illinois) where chemical engineering is not administratively grouped with the other engineering departments, the dean of engineering is a chemical engineer. (Bill Schowalter is currently Dean of Engineering at Illinois.) An inspiration for John in his administrative roles has been his acadmic grandfather, Neal Amundson. When a particularly burdensome nonessential memo or request crosses his desk, he frequently asks himself, "What would Neal do with this piece of paper?" The answer, of course, is that Neal would throw it away. John is known for discarding all but the most essential paperwork—which could be how he keeps such a neat office. At Caltech, perhaps uniquely among universities, when one assumes a division chairman position, one works even harder on research. Currently, John has a research group of about a dozen graduate students and postdocs. "My graduate students take precedence over everything," he says, so short of a call from Caltech's president, they get top priority on his time.

John has been called on numerous times for national service and has served on or chaired some of the most influential national panels in the field of air pollution and atmospheric chemistry. From 1989 to 1991 he was chairman of the National Research Council Committee on Tropospheric Ozone Formation and Measurement. This committee produced the highly influential book, *Rethinking the Ozone Problem in Urban and Regional Air Pollution,* which has had an enormous effect on redirecting the nation's efforts toward reducing ozone pollution at the urban and regional scale. He has just accepted chairmanship of the National Research Council Panel on Aerosol Radiative Forcing and Climate. Global climate change as a consequence of anthropogenic changes in the chemical composition of the atmosphere poses scientific questions of a nature and interdisciplinary scope that are unprecedented. Uncertainties in forecasts of climate change are large and thus far have hampered development of a clear world plan for mitigating against unacceptable effects. Uncertainties in the forcing of climate by changes in atmospheric aerosol and clouds represent the most important uncertainties in this entire area, and this new panel will attempt to formulate a national multiagency research plan to address these uncertainties.

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While he has received numerous honors and awards, John considers his most lasting accomplishment to be the role he has played in the education of his forty-five PhDs and his current group of ten graduate students. Faculty members alone, among his PhDs, include Don Cormack (University of Toronto), Tom Peterson (University of Arizona), Ted Watson (Texas A&M), Greg McRae (MIT), Costas Kravaris (University of Michigan), Panos Georgopoulos (Rutgers University), Gideon Grader (Technion), Sonia Kreidenweis (Colorado State University), Spyros Pandis (Carnegie Mellon), Tony Wexler (University of Delaware), Suzanne Paulson (UCLA), Barbara Wyslouzil (Worcester Polytechnic Institute), and Frank Shi (University of California, Irvine).

John was elected to the National Academy of Engineering in 1982 at the age of thirty-nine, and in 1991 he was elected a Fellow of the American Academy of Arts and Sciences. In addition to the 1970 Donald P. Eckman Award mentioned earlier, John has received awards too numerous to list here, recognizing his outstanding contributions to the profession over the years.

In 1980 John met Betty Becker of Los Angeles and they were married in 1983. Betty is a former junior high and high school home economics teacher. Their five-year-old son Benjamin keeps them both hopping. Betty is an avid quilter who, unfortunately, doesn't have as much time as she would like to pursue quilting. A couple of years ago she was president of the Caltech Women's Club, a social organization of faculty and postdoctoral wives and staff women.

John admits that he is a workaholic, but Betty has been able to get him to see the value of a vacation away from phones, faxes, and e-mail. John has also resumed his golfing pursuits—if there is a challenging course nearby he can be easily persuaded to hit the links. ❐