ChE educator

Warren E. Stewart
of Wisconsin

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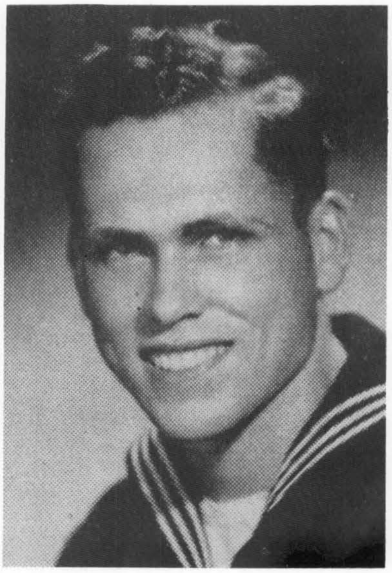

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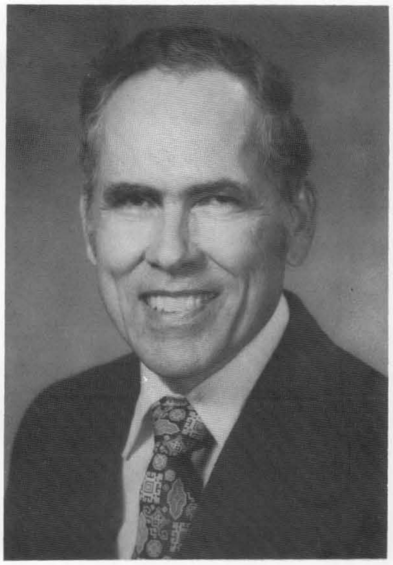

1988

Warren received his BS and MS in chemical engineering at the University of Wisconsin in 1945 and 1947 respectively, and then he migrated eastward to study at MIT, where he received his ScD in 1951. I started graduate school at Wisconsin in 1947 and just missed meeting Warren then. However I heard many tales about him from the chemical engineering students at the AXΣ house who had been classmates of his. They uniformly sang his praises and mentioned time and again what a brilliant student he was, how they always got help from him on difficult homework problems, and that he was the first person to go through the undergraduate chemical engineering curriculum with a straight-A average. Within a few months he had become a legendary figure, and it was with this mythical Warren Stewart that I became acquainted in 1947.

In 1948 I took Joe Hirschfelder's course in quantum mechanics. Joe assigned Pauling and Wilson as the text for the course but said that we might find it helpful to study some mimeographed materials that he distributed to the class. These were Warren Stewart's notes of Joe's lectures in 1946, and Joe said they were much better than his own. So my next encounter with Warren was by studying quantum mechanics from his careful transcriptions of Joe's lectures.

After graduate work at MIT, where he did his thesis on heat, mass, and momentum transfer, Warren became a Project Engineer at Sinclair Research, Inc., in Harvey, Illinois. There he participated in the development of a catalytic reforming process and also in early work on computerized process simulation.

. . . in 1960 the hardback textbook *Transport Phenomena* appeared. Warren was a superb contributor to the project for a number of reasons: he has exceptionally high standards for teaching and writing; he has a photographic memory of where things are in the literature; he insists on accuracy.

In 1953 I joined the chemical engineering department staff at UW. Here Warren's name came up often in conversations when faculty members recalled how scary it was to teach classes in which both Warren Stewart and Ed Daub were present (Ed was another legendary figure whose scholastic performance and keen mind had dazzled both staff and students).

In 1956 I finally had the chance to meet Warren, when he came to the department to interview for an assistant professorship that had opened up; shortly thereafter he joined our faculty. This was the beginning of a long friendship which I have very much valued through the years. Warren lived up to the legend, and more. I found him to be a great scholar with an awesome grasp of science and engineering, as well as a compassionate teacher, a dedicated family man, and a marvelous raconteur of jokes. Those who see only the serious side of Warren don't realize that his repertoire of jokes, puns, and conundrums is every bit as impressive as his uncanny ability to solve complex scientific problems.

By 1957 Warren Stewart, Ed Lightfoot, and I had joined forces to prepare mimeographed material for a new course on transport phenomena. This occupied much of our time in the fall of 1957 and the spring of 1958; our green paperback book, *Notes on Transport Phenomena*, was published by Wiley in the fall of 1958 as a "preliminary edition." Then we spent another two years revising the "Notes," and in 1960 the hardback textbook *Transport Phenomena* appeared. Warren was a superb contributor to the project for a number of reasons: he has exceptionally high standards for teaching and writing; he has a photographic memory of where things are in the literature; he insists on accuracy; he is a meticulous proofreader (his ability to detect the smallest of errors earned him the nickname "Gimlet-Eye"); and—very important in book-writing—he has a wonderful sense of humor. During the manuscript preparation I felt that I was continually learning about transport phenomena from Warren (just as I had learned quantum mechanics from him a decade earlier). He had had, after all, a lot of experience in transport phenomena in boundary layers during his thesis work at MIT as well as some five years of practice in solving industrial problems. That period of intense work, 1957-1960, formed particularly strong bonds within the triumvirate—bonds that have survived for many years.

A few years later Warren started studying Spanish, an effort which has given him another "dimension." He has made Latin America his primary overseas field of interest. He provided assistance to the translator who prepared the Spanish Edition of *Transport Phenomena.* He was a Visiting Professor at the Universidad Nacional de la Plata (Argentina) in 1962, and a Visiting Lecturer at the Instituto Tecnológico de Celaya (México) in 1983 and at the Universidad Nacional Autónoma de México in 1985. He has also given seminars (usually in Spanish) at a number of other Latin American institutions. It is rare for engineering professors to take the trouble to learn another language well enough to be able to lecture in it. Of course, this carries with it certain dangers. Warren attained instant fame in Mexico because of a linguistic blunder he committed in a lecture at the Instituto Tecnológico de Monterrey. Someone in the audience asked him a question to which he unfortunately didn't know the answer. So he wanted to say to the audience something like, "I'm very embarrassed that I don't know the answer to that question." Now when

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Warren and Jean (bottom row) in 1982 at a family gathering.

we speak foreign languages we often encounter words that are not in our vocabulary and so we make a guess and hope the listeners will understand. This works pretty well for an English speaker talking Spanish. Warren didn't know the word for "embarrassed" but boldly produced the sentence "Estoy muy embarazado, que no se la respuesta a ese pregunta" (instead of "Es embarazoso, que. . . ."). Well, it turns out that "estoy muy embarazado" means "I am very pregnant." Understandably the audience exploded with laughter. (See what fun you miss out on if you don't try learning a foreign language!) This story popped up in a limerick read at Warren's 60th birthday party on July 2, 1984:

He tackles tough tasks with bravado
With the verve of a wild desperado—
But he's really quite droll
When he talks español
And says that he's "embarazado."
Anne Nonimus

Despite his occasional problems with Spanish, Warren has for several decades administered the departmental PhD Spanish reading exam. He and his wife Jean, (who for many years has been the "alderperson" for Madison's 20th District), have often shared the hospitality of their home with visitors from Latin America (and from other parts of the globe as well). They and their children have been gracious hosts on many occasions, and countless visitors will long remember their pleasant evenings at the Stewart home.

Warren's linguistic accomplishments are not restricted to Spanish. He is also very fluent in "Alfalfa."

This is a pig-Latin-like way of speaking where you insert "LF" in the middle of the predominant vowel in each word; thus "seem" transforms into "seelfeem." Since I also learned "Alfalfa" as a youngster, Warren and I often carry on long conversations in our "secret language" much to the astonishment of bystanders. Warren can even speak Alfalfanized Spanish!

But, we digress. Let's get back to Warren and chemical engineering. Warren is one of the most versatile people that I know. I think he has taught almost every course in the department. His list of research publications is also characterized by great diversity. How many chemical engineers could write significant contributions on such widely varying topics as prediction of vapor pressures; reciprocal variational principles; kinetics of benzene hydrogenation; multicomponent diffusion; orthogonal collocation; measurement of diffusivities; droplet vaporization; kinetic theory of rigid-dumbbell suspensions; tokamak reactors; thermal diffusion; catalysis; corrosion; parameter-estimation; Bayesian statistics; viscoelastic fluid dynamics; sensitivity analysis; and distillation column design? Whereas most professors work in rather narrow areas, Warren has been an impressive generalist. When he was chairman of the chemical engineering department (1973-1978), he was able to discuss details of research projects being carried out by all of his departmental colleagues; no other chairman before or since has been able to do that. This was one of his great strengths when he served the department so ably as our chairman.

Warren's enormous breadth of interest has re-

STEWART'S TOP TEN

1. Forced Convection in Three-Dimensional Flows: I. Asymptotic Solutions for Fixed Interfaces, by W. E. Stewart, *AIChE Journal,* **9** 528-535 (1963). This deals with the prediction of heat and mass transfer in thin boundary layers at rigid interfaces, with given interfacial shape and velocity gradient. A prediction of the Nusselt number for a packed bed is given. The importance of this paper was not widely appreciated until the publication of [6] eleven years later.

2. Matrix Calculation of Multicomponent Mass Transfer in Isothermal Systems, by W. E. Stewart and R. Prober, *Ind. Eng. Chem. Funds.,* **3**, 224-235 (1964). This paper (and another that year by Herb Toor at CMU) showed how to solve a large class of multicomponent mass-transfer problems realistically by transforming the problem to a set of binary problems; this method is used extensively in the current literature on distillation and absorption.

3. Solution of Boundary-Value Problems by Orthogonal Collocation, by J. V. Villadsen and W. E. Stewart, *Chem. Eng. Sci.,* **22**, 1483-1501 (1967); *ibid.,* **23**, 1515 (1968). This paper (which was designated as a "Citation Classic" in *Current Contents* on 9/21/81) has been widely adopted by reactor designers for calculating radial profiles in reactor tubes and catalyst particles. This method of computation combines the simplicity of collocation with the efficiency of orthogonal polynomial interpretation.

4. Forced Convection in Three-Dimensional Flows: II. Asymptotic Solutions for Mobile Interfaces, by W. E. Stewart, J. B. Angelo, and E. N. Lightfoot, *AIChE Journal,* **16**, 771-786 (1970). Here single-phase transfer coefficients in fluid-fluid contactors are related to the fluid properties and interfacial motion. This theory should eventually supplant the penetration and surface-renewal theories, and it includes time-dependent and turbulent flows. Comparisons with experiment show good agreement.

5. Practical Models for Isothermal Diffusion and Flow in Porous Media, by C. Feng and W. E. Stewart, *Ind. Eng. Chem. Funds.,* **12**, 143-146 (1973). This paper gives extensive data on 3-component diffusion in catalyst pellets and thereby tests several diffusion models; it has been widely cited in works on realistic modeling of catalyst particle performance.

6. Computation of Forced Convection in Slow Flow Through Ducts and Packed Beds, by J. P. Sørensen and W. E. Stewart, *Chem. Eng. Sci.,* **29**, 811-837 (1974). In this 4-part pioneering study the fluid dynamics and mass-transfer processes in regular packed beds are studied. Impressive agreement with experiments is found for the appropriate ranges of Reynolds and Peclet numbers.

7. Computer-Aided Modelling of Reaction Networks, by W. E. Stewart and Jan P. Sørensen, in *Foundations of Computer-Aided Process Design* (R. S. H. Mah and W. D. Seider, Eds.), Vol. II, Engineering Foundation, New York, 335-366 (1981). This survey paper summarizes the work of Warren's group on digital analysis of reaction models and on parameter estimation from multiresponse reactor data. "Expert" programs are provided for use by kinetics researchers. The programs automatically evaluate reaction schemes for their fit of data and then estimate the parameters that are determinable from the data given.

8. Simulation of Fractionation by Orthogonal Collocation, by W. E. Stewart, K. L. Levien, and M. Morari, *Chem. Eng. Sci.,* **40**, 409-421 (1985). Whereas in [3] above Jacobi polynomials were found to be optimal for continuous systems, here it is shown that for discrete systems Hahn polynomials should be used. Hence, stagewise processes can be analyzed and designed very effectively.

9. Sensitivity Analysis of Initial-Value Problems with Mixed ODEs and Algebraic Equations, by M. Caracotsios and W. E. Stewart, *Comput. Chem. Eng.,* **9**, 359-365 (1985). This work gives an efficient method for computing the sensitivity of a process model to its parameters. The algorithm is implemented on a modern differential-algebraic equation solver and is illustrated by a reaction modeling problem. Sensitivity calculations are widely useful in modeling, control, and optimization.

10. Forced Convection: IV. Asymptotic Forms for Laminar and Turbulent Transfer Rates, by W. E. Stewart, *AIChE Journal,* **33**, 2008-2016 (1987); **34**, 1030 (1988). Here "dominant-balance arguments" are used to get information about heat and mass transfer rates without integrating any differential equations. New results are obtained for turbulent flows, and this work supplements [1] and [4] above. The celebrated Chilton-Colburn j-factors correspond to the leading term of the long-time expansion.

sulted in the fact that he frequently functions as an "in-house consultant" to colleagues and students in chemical engineering as well as from other departments. It's not unusual to see him conferring in his office with a professor of zoology on heat transfer through fur, with a student from nuclear engineering on a problem related to controlled nuclear fusion, or with a chemical engineering graduate student on viscoelasticity. I've never heard of an undergraduate or graduate student ever being turned away by Warren. His door is always open for interruptions, and he has always been very generous with his time and very patient with his "customers." His willingness to help others by sharing his talent is the subject of this bit of doggerel:

A student came in to see Warren
And said in a voice quite forlor'n
"I can't find a path
Through this quagmire of math;
These nablas are terribly foreign."

So Warren (who's also called Earl)
Proceeded to help this young girl.
Without using a book
He unflinchingly took
The Laplacian of grad div curl curl.
Anne O. Nimes

Well now you know what the "E" stands for in Warren E. Stewart.

All researchers have publications of which they are especially proud. Warren feels that the box on the opposite page lists his ten best research publications. He is currently working on the manuscript of a book on computer-aided modeling of reacting systems which promises to be a thorough, scholarly, and useful work.

Warren is a quiet and modest person. He never talks about the many awards that have come his way, including honorary membership in Phi Beta Kappa, the ASEE Chemical Engineering Lectureship Award, the Alpha Chi Sigma Award and the Computing in Chemical Engineering Award of AIChE, the Benjamin Smith Reynolds Teaching Award at UW, and the McFarland-Bascom Professorship at UW. In 1989 he will receive the Murphree Award of ACS. He should also receive a special award for being able to meet deadlines in a photo-finish. At 10:59 am he can be seen frantically xeroxing materials for an 11:00 am class. At 11:59 pm on April 14th he can be seen speeding up to the main post office in Madison with his income tax return. And I recall the time when several of us decided to see Warren and his family off at the airport when they were headed for the Middle East where Warren was to give some lectures. At 10 minutes before plane time, the Stewarts were still not at the airport; at –5 minutes still no sign of them; at –2 minutes they scrambled out of a taxi cab and they *did* make the plane. Apparently Warren thrives on the excitement of seeing how close he can come to not quite missing a deadline.

Warren takes time out of a typically busy day to welcome a visitor.

One of Warren's most outstanding contributions has been the development of the powerful technique of "orthogonal collocation," and according to Harmon Ray it is probably one of the most significant original contributions to numerical analysis ever made by a chemical engineer. Here again, this activity has been memorialized in a poem inflicted on the audience at Warren's 60th birthday party:

He's often referred to as "WES".
He's known from Rangoon to Loch Ness
For fast collocation
In flash distillation—
And multicomponent, no less!
U. N. Bekannt

No doubt about it—Warren has had a distinguished career. And he is still going strong with a very active research program, book-writing activities, consulting, memberships on editorial boards, public and community service activities, and music (he plays the trombone!). He has certainly earned a place in the "ChE Hall of Fame."

ACKNOWLEDGEMENT

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