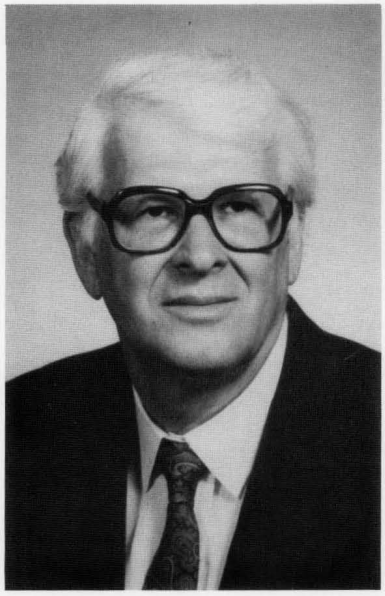
ChE *educator*



LARRY DUDA

of Penn State

BY HIS COLLEAGUES
Pennsylvania State University
University Park, PA 16802-4400

J. Larry Duda was born and raised in Donora, Pennsylvania, a small steel-mill town twenty miles down the Monongahela River from Pittsburgh. It was considered a good omen when he was delivered by the high school football team physician since his was a family in which most of the sons went to college on football scholarships. In spite of his lack of weight, skill, and interest, when he finally got to high school he too fulfilled the family obligation of trying out for the "Donora Dragons," which had given the country not only such great players as "Deacon Dan" Tyler, "Pope" Galiffa, "Bimbo" Ceconi, but also Stan Musial. Although Larry did not make the team, he did hear the first pep talk wherein the coach indicated that there were two paths down from the football field, which towered on the hill above the town—"One can graduate from high school and go down into the mill, or one can play good football and go to college." Fortunately, Larry found a third path: a scholarship at Case Institute of Technology. He decided to study chemical engineering because he liked math and chemistry and also because he was fascinated by the old lead chambers which produced sulfuric acid in the zinc works section of U.S. Steel.

He started out as a mediocre student at Case, hampered by a poor high school background and a dyslexia problem which he did not recognize at that time. He was struggling along with Cs and some Bs until he took his first chemical engineering course in stoichiometry and found that his forte was in solving problems. Even in high school, when he had difficulty with formal algebra, he found he could always solve the statement problems through his own devious techniques. As a consequence, he excelled in stoichiometry and became the top student in the class. Upon graduating, he decided to go to graduate school since he felt he did not yet fully understand chemical engineering and was a little fearful of going out and practicing the subject with his limited knowledge.

THE DELAWARE YEARS

Larry blossomed as a graduate student at the University of Delaware and was particularly stimulated by research and interactions with such chemical engineering greats as Bob Pigford, Art Metzner, and Kurt Wohl. An outstanding group of graduate students who were at Delaware at the same time also contributed to the exciting intellectual climate. In addition to learning how to do research under the tutelage of Art Metzner, he honed his tennis game, helped integrate restaurants in Delaware, and met his future wife, Margaret Barbalich. He worked in the area of catalysis with ion exchange resins and likes to joke that he did so poorly that neither he nor Art Metzner ever worked in that area again. Larry reminisces that his years at Delaware were the best, blending an intensity of research studies, sports, and personal life. The specific subjects studied at Delaware were quite sec-

Larry joined the Process Fundamentals Group of the Dow Chemical Company . . . , and . . . his long and successful collaboration with Jim Vrentas began. . . it was [there] that they forged their friendship and created one of the most productive teams in the profession. They represented a contrast in styles and abilities, yet had an abiding respect for each other's points of view and contributions.

ondary compared to the enthusiasm he gained for learning and the creation of new knowledge through research.

THE DOW DAYS

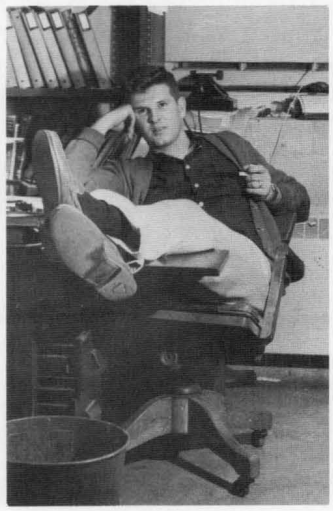
In 1963, Larry joined the Process Fundamentals Group of the Dow Chemical Company in Midland, Michigan, and it was there that his long and successful collaboration with Jim Vrentas began. Although the two knew each other in graduate school, it was in the Process Fundamentals Laboratory that they forged their friendship and created one of the most productive teams in the profession. They represented a contrast in styles and abilities, yet had an abiding respect for each other's points of view and contributions.

Their differences were demonstrated by an incident one Friday when they had a very difficult problem which they could not solve. Late that afternoon, Larry concluded that they had been pounding on the problem too long and had actually begun recycling potential solutions that they had already considered. He felt they were burned out, and he was going to take the evening off, see a play with Marge, have dinner, and hopefully wake up the next morning with fresh insight. In contrast, Jim decided to stay on through the wee hours of the night, continuing to work on the problem. When Larry and Marge returned home later that evening, they found Jim's solution nailed to their front door! He wanted to make it crystal clear that he had come up with the solution first, just in case Larry woke up in the morning with a bright idea of his own.

Larry and Marge quickly established a family in Midland, and within less than three years had four children (twins John and David, Paul, and Laura). Larry likes to kid the Dow people that there was nothing else to do in Midland in those days.

During the Dow days, Larry and Jim's basic work in the area of diffusion in poly-

THE DUDA DISGUISES



Cleverly disguised as a young student, circa 1962, at Brown Laboratory, University of Delaware (right)

. . . and . . .

as jolly old Saint Nick himself (below), with co-disguised John Phillips in an interesting impersonation of an elf . . .

. . . and . . .

as the Shiek of . . . ah . . . University Park

. . . and . . .

as . . . whatever . . .
with sons Paul, John, wife Marge, son David, and daughter Laura all getting in on the act.

mer systems was initiated. To their dismay, however, they were not free to continue along the paths of scientific interest—instead, they had to respond to the more direct economic needs of the company. Nevertheless, they were at Dow during the golden days when great advancements were being made in polymer science, led by such individuals as Turner Alfrey and Ray Boyer. It was natural that in this environment they would be drawn into considering problems associated with polymer production and processing. In addition to Jim Vrentas, Turner Alfrey and Art Metzner (as a Dow consultant) also exerted great influence on Larry's professional development.

Despite Larry's successful career development at Dow in the late 1960s, he and Jim decided that they should consider academia if they wanted to continue along their main avenues of interest. In his last years with the company, Larry made his most successful contribution through his work on designing insulation systems for the trans-Alaskan pipeline that would keep it from melting the permafrost during the short Alaskan summer.

. . . it became clear to him that he would rather stay at Penn State without research and just teach than to take a position where he could concentrate on his desired research with no opportunity for teaching.

Although Larry left Dow for Penn State in 1971, he has maintained strong contacts with Dow. In many ways, Larry has tribal instincts and develops a strong devotion to groups he lives and works with. In addition to his family, he still has vital attachments to his home town of Donora and to the Dow Chemical Company. He stays in touch with several friends at Dow, including Doug Leng and George Shier. Larry was most recently named a charter member of Dow's Academic Advisory Council.

THE PENN STATE YEARS

Over the past twenty years, Larry has devoted most of his energies to the development of the Department of Chemical Engineering at Penn State. The dominant characteristics of Larry's work are in its diversity and its strong emphasis on collaboration. He has conducted collaborative research work with almost every member of the chemical engineering faculty as well as with several researchers outside the department. Besides his work with Jim Vrentas in the general area of diffusion in polymer systems, Larry has made contributions in many other fields, most significant of which has been his joint research with Elmer Klaus in the area of tribology.

Although Larry was attracted to academia because he sought to define his own research work, he quickly became enthralled by teaching. In fact, within a few years it became clear to him that he would rather stay at Penn State without research and just teach than to take a position where he could concentrate on his desired research with no opportunity for teaching.

The meetings of his research groups with their inevitable interplay of ideas are the most enjoyable parts of Larry's working schedule, and the most attractive feature of these interactions comes from the general thrill of exploring the natural world. In these group meetings, Larry often makes bets with Elmer Klaus that the results of the new experiments will turn out a certain way. But Elmer is an expert at oracle statements, and no matter which way the results come out he can be counted on to argue that he had already predicted the results.

Second only to chemical engineering is Larry's continued interest in tennis. In fact, it is rumored that Lee Eagleton originally hired him only because they were great tennis partners who together could take on opponents from the chemistry department. At present, Jack McWhirter and Larry offer a standing challenge to take on any two students in the department.

On the home front, Larry is proud of his belief that the way to educate people is to help them become themselves. This freedom of spirit is strongly exhibited in his children. None of them has become an engineer, or has even gotten close to engineering—they have been students of art, English literature, and medicine. Now that the children are grown, Larry and Marge are able to nurture their interest in international travel, and when at all possible they try to couple it with Larry's technical interests and Marge's photographic interests.

DUDA—THE RESEARCHER

Through the years at Dow and at Penn State, Larry's work has exhibited a common thread of research on polymers and transport phenomena. His well-known collaboration with Jim Vrentas on molecular diffusion in polymer systems has yielded many results which have been presented in over seventy journal publications.

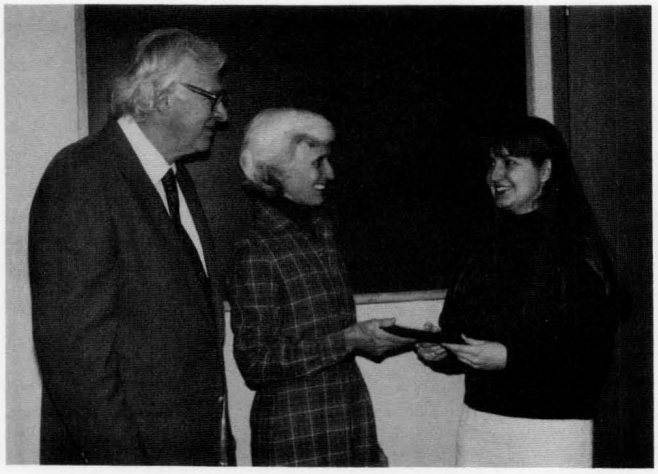
At the time Duda and Vrentas initiated their work, the area of diffusion in concentrated polymer solu-

tions and melts was in a state of disarray, and no techniques were available to the design engineer for the prediction or even the correlation of diffusivity data. In fact, available experimental data revealed many apparent contradictions. Some experiments showed that the binary mutual diffusion coefficient in polymer-solvent systems were strong functions of concentration, while in other studies these coefficients were found to be independent of concentration. Some investigators found that diffusion in polymer systems depended strongly on temperature and did not follow an Arrhenius-type behavior, while other studies indicated that the data could be correlated with the Arrhenius equation with relatively low activation energies for diffusion. Superimposed on this perplexing situation were the experimental observations that, in some cases, diffusion in concentrated polymer systems did not even follow Fick's law. Numerous investigations showed that anomalous effects were present which were not consistent with the classical diffusion theory.

In response to this situation, the studies of Duda and Vrentas led to the concept that molecular diffusion processes involved the coupling of migration and relaxation of molecules. Up to this time it had been implicitly assumed that the molecules participating in a diffusion process could relax very quickly to new equilibrium states and that local thermodynamic equilibrium was maintained. Duda and Vrentas quantified their theory with the introduction of the diffusion Deborah number, which is the ratio of the characteristic relaxation time of the molecule to the characteristic time of the diffusion process. This dimensionless group revealed under what conditions classical diffusion theory is appropriate for the description of diffusion in polymeric systems.

Probably the most important outcome of the collaborative work of Duda and Vrentas is the development of the free volume theory in which the viscous behavior of polymer melts is coupled to the diffusional behavior in binary solutions. Their theory allows the prediction of diffusion coefficients as a function of temperature and concentration from viscosity and thermodynamic data obtained essentially for pure component systems. The free volume theory as developed by Duda and Vrentas has been shown to be applicable up to at least 80 °C above the glass transition temperature and for concentrations as high as 70 weight percent solvent. Interestingly, the theory is also capable of predicting anomalous abrupt changes in the diffusivity observed in the vicinity of glass transition temperature.

Concurrently, Duda and Vrentas developed experimental techniques and associated analyses for the determination of accurate diffusivity data over the wide ranges of temperature and concentration needed for various polymer processes. Their work led to the development of a widely used high-temperature sorption apparatus as well as a novel oscillatory sorption experiment. The latter technique is the only method available to study unambiguously the coupling of diffusional transport and molecular relaxation.



Duda and Mary Eagleton presenting the Lee and Mary Eagleton Design Award to Heather Bergman.

Not well known to the academic chemical engineering community are Larry's contributions to the area of tribology and lubrication. Larry recognized how fundamental principles of chemical engineering can be successfully applied to bring order into a traditionally empirical field of research that has remained largely proprietary over the years. This led to his collaborative research with Elmer Klaus, the results of which are summarized in over forty publications.

Probably the most important outcome of this research has been the development of a micro-reactor technique to study the thermal and oxidative degradation of lubricants under conditions that simulate automotive engine tests, heavy-duty diesel engine performance, electrical power generating equipment, and gas turbine engines. The test has been adapted by over fifteen industrial research groups as a way to minimize costly engine tests and has been successfully used to study the performance of lubricant additives as well as the catalytic effects of metal surfaces on lubricant degradation.

Another important result from this research is the development of a novel lubricant delivery system,

for applications at elevated temperatures. In this system, a lubricant film is formed on a hot surface from a homogeneous vapor phase. The lubricant-forming vapor is adsorbed on the solid surface and reacts to form the lubricant film. This new lubricant system is being evaluated for applicability in diverse areas, including the lubrication of an adiabatic ceramic engine and metal-forming operations. Duda's work has also led to development of methods for the rheological characterization of lubricants under extreme conditions of temperature, pressure, and shear rate.

By his work, Duda has taught his colleagues and students how to carry out fundamental research that leads directly and tangibly to industrially significant results. A unique indicator of this success is the fact that virtually all of his research support comes from industry.

DUDA—THE TEACHER

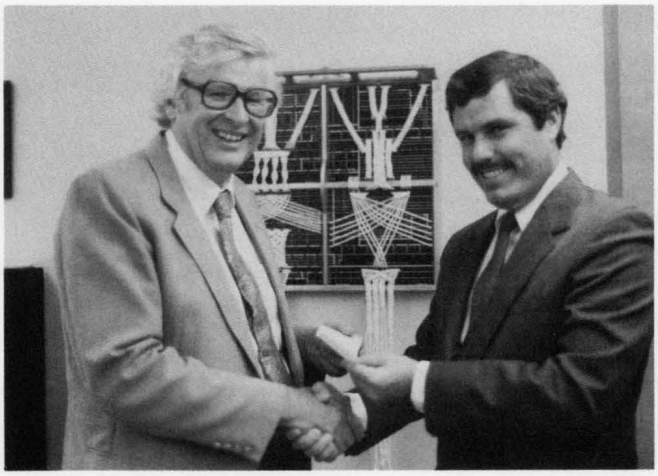
Larry has been a teacher with great impact. Over the years he has developed a unique teaching style and educational philosophy. For example, he starts out each lecture in his graduate course with a quote from a famous engineer, scientist, philosopher, or religious leader. He feels that each lecture should not only present some specific segment of technology, but also should incorporate some thought or philosophy concerning the general aspects of life itself. To illustrate, one of his classroom techniques is role playing. He will introduce himself as an inventor, while the students play the role of engineers in a company that is considering buying the inventor's latest creation. His "inventor" is usually a super-salesman who is very close to playing a con game. The students' roles are to analyze the proposed invention for its scientific merits and to find its fatal flaws, if any. A quote from Harold McMillan sets the stage for this particular lecture: "Nothing that you will learn in your studies will be of the slightest possible use to you in the afterlife. Save only this: that if you work hard and intelligently, you should be able to detect when a man is talking rot, and that, in my view, is the main, if not the sole purpose of education."

Larry's classroom emphasis is on creativity and the ability to solve unique problems, as opposed to the mere accumulation of specific knowledge or solution of conventional problems. He stays awake at night thinking up problems for homework or exams which at first glance appear to be unrelated to the topic at hand but that can be solved by using the course fundamentals. For example, to illustrate the use of the Flory-Reiner model for crosslinked polymers, he considers the case of how the ancient Egyptians cracked stones in their quarries. They drove a wooden wedge into a crack, poured water on the wedge, and let the swelling wedge crack the rock. By giving properties of polymeric wood, students can develop equations to predict the pressures that such swelling wedges will develop.

Larry's success as a teacher stems not only from his classroom lectures, but also from his close work with undergraduate and graduate students in their research. He has advised sixty-one masters' students and thirty-two doctoral students at Penn State, including the forty-six students who have worked with him and Elmer Klaus in the area of tribology. It is fair to say that almost every industrial tribology researcher with a chemical engineering degree has been trained at Penn State. Duda is a much sought-after member of graduate student thesis committees. Over the last twenty years, in addition to the students whose work he has supervised he has also served on 100 doctoral committees and 120 masters' committees. The students have been from chemical engineering, chemistry, polymer science, petroleum engineering, mineral processing, agricultural engineering, fuel science, bioengineering, etc. An important reason for the diverse backgrounds of students seeking Duda's guidance is the active collaboration Duda has developed and maintained with over twenty faculty members in other disciplines. He has also been unusually active in guiding over seventy undergraduate students on their honors research projects. Many of them have gone on to graduate schools, inspired by their research experience.

HONORS AND AWARDS

Larry has been recognized for his teaching and research through a number of awards. In 1980 he received the Outstanding Research Award from the Pennsylvania State Engineering Society, and in 1981 Larry and Jim Vrentas were co-recipients of AIChE's William H. Walker Award in recognition of their work on molecular diffusion in polymers and the analysis of complex transport phenomena. Larry was chosen by Penn State's senior ChE class as the Outstanding Professor in 1983, and in 1989, along with Jim Vrentas, he received the Charles M.A. Stine Award in Materials Engineering and Sciences from the AIChE Materials Division in recognition of their development of the free volume theory and the oscillatory sorption technique. Also in 1989, Larry was selected to receive the ASEE Chemical Engineering Lectureship Award. The Pennsylvania State Engi-



One of Duda's happier duties as Department Head—receiving a check for the department!

neering Society honored Larry and Jim Vrentas in 1991 with its Premier Research Award, and also in that year Larry was chosen as the Alumni Delegate representing the Class of 1963 at the 1991 Commencement Ceremony of the University of Delaware.

DUDA—THE ADMINISTRATOR

Larry has been an unusual department head for the past ten years. He has demonstrated that taxing administrative duties need not diminish one's intense involvement in teaching, research, and guiding students. Under his stewardship, the department has increased its visibility, with many of the faculty receiving national awards from AIChE, ACS, ASEE, ASME, etc. The department has recruited several outstanding young faculty in John Frangos, Kristen Fichthorn, Lance Collins, Ali Borhan, Wayne Curtis, and Themis Matsoukas. Two of these new faculty, Frangos and Fichthorn, were honored with Presidential Young Investigator Awards. The department also added two nationally prominent senior scientists to its ranks in Art Humphrey and Paul Weisz. Duda's leadership has been responsible for the creation of a strong research program in biotechnology at Penn State, capped by the recruitment of Art Humphrey as the Director of the Biotechnology Institute.

PROFESSIONAL INVOLVEMENT

Larry has been a spokesperson for academic interests to industry. His own experience of having almost all of his research sponsored by industry gives him unusual insights into the mechanisms for and the benefits of university-industry collaboration. He has been a member of the Council for Chemical Research (CCR) for the past ten years and served on its Governing Board and on the latter's Executive Committee. He has served on the CCR Committee on Industrial College Relations and as CCR Liaison with the NSF, and has also been active on the Academic Advisory Council of Dow Chemical. His advice as an educator has been sought after by other departments of chemical engineering: he has served as the external reviewer for Rutger's University; he has served on the Promotion and Tenure Review Committees of the Illinois Institute of Technology and the University of Rochester; he serves on the advisory committees of the chemical engineering departments at West Virginia University, University of Delaware, and Carnegie-Mellon University. An example of the esteem in which Duda is held by other department heads is their election of him as the Chair of the Board of Judges for the McGraw-Hill Kirkpatrick Award in Chemical Engineering.

Larry has been active in the AIChE in a number of ways. He has served as a member of the National Program Committee, Public Relations Committee, Polymer Engineering Subcommittee of the Research Committee, Walker Award Committee, Charles M.A. Stine Award Committee, and the National Awards Committee. He is currently a Director of the Materials Engineering and Sciences Division. He also serves on the Publications Committee of the ASEE.

DUDA—THE PHILOSOPHER

Larry has made unique contributions to his field through his role as a philosopher of graduate education. His three articles in *Chemical Engineering Education,* "Common Misconceptions Concerning Graduate School," "Graduate Studies: The Middle Way," and "Graduation: The Beginning of Your Education" are necessary reading material for all graduate students. They outline a philosophy that has guided Duda's work and offer much-needed perspective to beginning graduate students. To quote from the conclusion of the second article, Duda says

> *From my presentation, you might conclude that there is a middle way in every aspect of graduate work that is the most appropriate approach. Although I have attempted to illustrate that this is certainly true in many instances, there is one very important exception. Some students say to themselves, "This is not the best that I can do but it's good enough." Well, it's not good enough. Push yourself—take time and make the effort to perform at the very highest level of which you are capable. There is no middle way when it comes to the pursuit of excellence.*

Duda's contributions to chemical engineering epitomize the above philosophy in action. ❐