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# ROBERT L. PIGFORD

*1917—1988*

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*A Biographical Memoir by*
RICHARD E. EMMERT, HAROLD S. KEMP,
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R. L. Pigford

# ROBERT L. PIGFORD

## A Prince Among Men

*April 16, 1917–August 4, 1988*

BY RICHARD E. EMMERT, HAROLD S. KEMP,
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ROBERT L. PIGFORD WAS born on April 16, 1917, and died on August 4, 1988. Thus, his lifetime spanned the full period of the early dynamic growth of chemical engineering and of the maturing of the chemical engineering profession. He was one of the best known and most admired leaders of his profession and his name was synonymous with erudition and rigor, with warmth and helpfulness to his colleagues everywhere, and with Southern gentlemanly courtliness and elegance.

Born and raised in Meridian, Mississippi, he was encouraged to excel in whatever he undertook. Early interests embraced the emerging marvels of radio as well as music—interests never fully set aside, even though the chairman of the chemistry department at his undergraduate school, Mississippi State College, swayed his professional interests. Early projects at home included construction of model airplanes and of a crystal set, and as a teenager he assembled the first of an unending array of ham radios. Principal preoccupations during the teenage years were his studies, these hobbies, and music. He was a leader in his high school, Mississippi State, and R.O.T.C. bands as a youth. One of the few academic activities in which he did not excel was a high school course in economics—a subject taken only at the

insistence of a father who felt his son would profit from instruction in this subject. This academic excursion into an area in which he had no interest cost him the opportunity of becoming the valedictorian of his class: this distinction went instead to Marian Pinkston, whom he married in 1939.

Upon receiving his baccalaureate in 1938 from Mississippi State College, he enrolled in graduate studies at the University of Illinois. This was a great blow to the pride of his father who had assumed his son would surely learn all that was necessary as an undergraduate! Graduate studies enabled Robert Pigford's enthusiastic immersion into the frontiers of his profession. M.Sc. and Ph.D. degrees were awarded in 1940 and in February of 1942, respectively. The Pigfords moved to Delaware in August of 1941 when he accepted employment with the technical division of the Engineering Department of E. I. duPont de Nemours and Company, Inc., in Wilmington. Here he encountered the professional invigoration of a host of very able colleagues, of the laboratory director, Thomas H. Chilton, and of numerous consultants who visited regularly, including Allan P. Colburn (University of Delaware), Thomas H. Drew (Columbia University), and William H. McAdams (Massachusetts Institute of Technology). This industrial laboratory was conducting research to build, from the most modest base which existed at the time, fundamental knowledge which could be used in design procedures and standards. This work required research measurements and their correlation; the development of models to represent processes; and the translation of all of this into usable design methods. Much of the basis for this work came from troubleshooting and analysis of actual processes. Working in this challenging environment, Robert Pigford contributed significant advances in a variety of areas. A partial listing of these is as follows:

• The operation of both spray-type and plate-type absorbers was studied for the recovery of selected components of a gas stream. Increased recovery (with concomitant pollution abatement) and increased equipment capacity were the usual goals sought. This work also provided an early contact with absorption accompanied by chemical reaction, a subject in which he was to become a leader in his subsequent academic career.

• Experiments on laminar, turbulent and boiling heat transfer, leading to improved correlations of rate coefficients, were carried out on both laboratory and semi-works scales.

• Computations of the power requirements needed for separation of isotopes by diffusion cascades and by centrifuges were made for wide ranges of molecular weight ratios, pressures, flow rates and degrees of separation, all in support of his corporation's involvement in the Manhattan Project.

• Measurements of the atmospheric dispersion rates of droplet clouds, of interest in both defensive and offensive chemical warfare during World War II, were carried out using balloons to carry the experiments aloft. This led to one of his most celebrated mishaps, when a large balloon carrying harmless simulants broke loose and drifted across the river to New Jersey. The civil defense forces identified the intruder as the onset of an enemy gas attack and mobilized the military over a large area to initiate a counter attack.

• Use of plant-scale studies of packed distillation columns and extensive calculations for plate columns, when hold-up of liquid in the column is a significant fraction of the batch charge, were made to improve separation processes for specialty chemicals of high cost and of small production. Such production facilities were characteristic of

many products needed during World War II. This familiarity with distillation would serve him well later when, in the early days of numerical calculations, exhaustive studies of distillation process transients were needed to improve the productivity of the Savannah River Plant for the production of heavy water.

• Application of differential equations to the solution of chemical engineering problems, practiced routinely in his work, led him and a colleague, the late W. R. Marshall, to offer a course on this subject at the University of Delaware. Their ensuing textbook, *The Application of Differential Equations to Chemical Engineering Problems*, long out of print, is still requested regularly to this day—nearly half a century later.

Shortly after joining DuPont, Robert Pigford began his association with the University of Delaware on a part-time basis, teaching evening and weekend courses. Some of those enrolled were full-time graduate students, but most were industrial colleagues interested in strengthening their professional backgrounds through formal associations with this unique scholar. Chemical engineers in the Delaware Valley soon learned that this university's Saturday morning extension courses were occasions for intense and warm professional socializing as well as for vigorous scholarship, as young, full-time students and experienced professionals wrestled together to master the apparently unending store of intellectual challenges which Robert Pigford and his associates continued to provide.

In 1947 Allan Colburn, noting that Robert Pigford was spending increasing fractions of his evening and weekend hours on campus, invited him to come to the University of Delaware during weekday daylight periods as well. The invitation was to provide an appointment to him, at age thirty,

as chairman of the department. Robert Pigford consulted his industrial friends and supervisors about the wisdom of such a move; their response was to advise him to make a two-column listing of the objective advantages under each career alternative. Of course, they were confident that a continuing productive career in the nation's leading chemical company would appear much more attractive than the alternative of work in a fledgling department in an underdeveloped university with no Ph.D. programs and with few resources. And, just as they had anticipated, when the listing was made, nearly all of the objective advantages were with the industrial option. But, of course, there were also non-quantifiable, subjective attractions to the university option: that of forging a new department and, indeed, of assisting in the development of an entire university; the opportunity of working with succeeding generations of young scholars and of assisting in a developing renaissance of his profession; and the opportunity, in Robert Pigford's words "to have fun professionally."

We all know what his choice was, but this story was the basis of his frequent advice to students and to younger colleagues in subsequent years: "Always choose the professional alternative which you would find to be the most enjoyable. It is only by making this choice that you will throw yourself into your work with sufficient enthusiasm and vigor to become an accomplished professional and, as a by-product, a serene and supportive spouse and parent."

And what fun it was for all of us who were to be associated with him! We learned to laugh together as well as to work together, and to live together: Marian and Robert Pigford opened their hearts as well as their home to our families, and we benefitted unashamedly from their devotion to this their family of scholars. Former graduate students remember Saturday night parties in the Pigford home,

where they were introduced to the Pigford love for music and to the myriad joys which accompany a family setting. Comparably, faculty colleagues were introduced to colleagues in other departments, and to the university administration, in a gracious social setting conducive to discussion of their diverse interests, opportunities, and problems. If any of us who were long-term friends of the Pigfords developed some altruistic qualities it would have been due, in large measure, to their inspired example.

Administration of a leading department brings with it the need for resolution of generic university problems as they tend to arise earlier in these situations than elsewhere on a campus. Robert Pigford did not enjoy the many administrative chores his position implied, but he dealt with them forthrightly. Several of his colleagues remember his unique manner of seeking advice on major administrative issues. All faculty offices, in those long ago days in Brown Laboratory, were along one corridor, with the chairman's at one end and the most recently appointed assistant professor at the other. Robert Pigford simply gathered any papers necessary for a discussion of the issue in one hand and, with a pad and pencil in the other, proceeded to interview each faculty colleague in turn. When he came to the end of the hallway, perhaps no more than thirty minutes later, he had all the information he needed for an informed decision—and none of his colleagues were diverted from their activities for more than a few minutes each. How nostalgically one looks back upon such a straightforward procedure in these days of excessive committee responsibilities! Once, in a social gathering at which this Pigford procedure was described to a faculty friend from another department, the latter queried, "But how could you be sure he would accept your advice?" We who were his friends were speechless: this was simply an unthinkable question,

an unthinkable occurrence in the Pigford department. Of course he would accept advice if he requested it; his generosity of spirit was such that intrigues between him and his colleagues were simply unthinkable. In turn his colleagues were usually equally ready to grant him discretion in use of any advice he sought. Such indeed was the Pigford department: one administered by mutual altruism. And his vision for his university was that all departments would some day, too, share in such altruism. Can there be a more beautiful legacy?

Professionally, under Robert Pigford's leadership the department developed rapidly to become one of primary stature nationally. He became one of the most vigorous and most effective advocates of the need to combine engineering science with industrial practice to develop the *art* as well as the *science* of the discipline, and of the need to graduate practitioners with creative as well as analytic skills. Professor Pigford had major impact on the profession through his books, lectures, and extensive research papers, and through the activities of a large group of former students and visiting faculty who have become leaders in the field around the world. He was one of the earliest proponents of the use of computers in engineering, and built several for both instruction and research before the widespread availability of such equipment.

At the time, one of the modern subjects for attack by extensive numerical calculations was that of mass transfer accompanied by chemical reaction. While empirical correlations, restricted to very specific chemical systems, had been available for some time, there was little scientific material of any generality. Indeed, the bulk of the literature on this subject, circa 1950, consisted of largely qualitative physiological observations reported by medical practitioners. Buoyed by his earlier industrial exposure to this subject,

Pigford and his students set forth with vigor using first their homemade computers and then a giant vacuum-tube-based-machine at Aberdeen Proving Ground, one of only a few available nationally and which the military made available to him on the midnight–6:00 a.m. shift. Robert Pigford, long a late-night worker, availed himself of this computational opportunity with enthusiasm, some of his graduate students less so. The interstate highway network had not yet been developed, and the thirty-five miles separating Aberdeen and Newark were on roadways shared with cruising teen-agers on the evening trip to Aberdeen and with sleepy long-distance truck drivers on the return. Those of us who were early risers viewed our rumpled and bleary-eyed colleagues when they returned to the Delaware campus at about the time other people go to work. Students enthusiastically anticipated the end of these all-night vigils when the university purchased its first computer. Their joy was short-lived, however: while the administration was pleased to make this modern tool available, they could not be convinced that "machines" needed to be air conditioned to work properly in the heat of the Delaware summer. And, if they were, would all the faculty not also clamor for such an effete frivolity? Consequently, for some time, this computer, too, could only be employed at night except during the winter months. However, the seventy-mile roundtrip to Aberdeen was happily avoided. The activity also led faculty from other departments to begin serious computational activities and, shortly, under Pigford's leadership, to the establishment of a computing center for the university community.

Professor Pigford's long career with the University of Delaware was suspended for a decade beginning in 1966 while he served as professor of chemical engineering at the University of California at Berkeley. By that time he was no stranger there, having spent a semester as a visiting profes-

sor in the spring of 1954. The faculty of that relatively new department had invited him to come in the belief that an association with this much-admired young chemical engineering educator might provide valuable guidance and perspective. This indeed proved to be the case, and Robert was later welcomed back most enthusiastically by all when he was persuaded to accept a permanent appointment.

During his initial visiting appointment Professor Pigford continued his active interest in computing and conveyed his enthusiasm and valuable knowledge of this new field to other members of the faculty. At that time Berkeley had no computing facilities so that it was necessary to drive about forty miles to the Livermore (Atomic Energy) Laboratory during the night shift when off-peak time was available. A repetition of the Aberdeen Proving Ground saga: on many evenings, with two or three colleagues, he would leave Berkeley about five in the afternoon and not return until two or three in the morning! The early computers at Livermore were IBM CPC models which ran slowly with card input and arduously programmed machine language. To make maximum use of the time Robert would usually run two, and sometimes three of these computers simultaneously, feeding the output cards from one as input to another. As a result of these unusual techniques he became known as "Rapid Robert" to some of his companions. His skill and the results obtained were inspiring and had a lasting influence in bringing the department into the computer age more rapidly than would have otherwise been the case.

During his years at Berkeley Professor Pigford pursued a vigorous program of teaching and research. His thesis supervision covered a wide range of subjects including crystallization from melts, removal of sulfur dioxide from hot gases by chemical absorption, and most notably, development and theoretical analysis of a new technique to en-

hance adsorption by cyclically alternating the temperature levels of columns operating in series. He was awarded a U.S. patent jointly with his graduate students Burke Baker III and Dwain Blum for this process, named "cycling zone adsorption." His research typically involved difficult problems which were in need of experimental insight and theoretical analysis, and also had promise of contributing to industrial practice.

Professor Pigford enjoyed teaching at all levels. In addition to advanced courses he frequently taught a lower division thermodynamics course taken by chemistry and life-science students as well as by chemical engineers. He offered a voluntary course for graduate students in electronics which he believed to be important to the understanding of modern computing and instrumentation. As a member of the College of Chemistry Computing Committee he contributed importantly to the planning and development of computing facilities at Berkeley. In the development of the chemical engineering curriculum he provided a valuable influence in bringing the needs and viewpoints of industry into faculty discussions and into his own courses.

Professor Pigford was amazingly versatile and quick to learn new subjects. At Berkeley he continued his worldwide ham-radio contacts and mounted a three-story antenna tower in his back yard. A skilled craftsman, he enjoyed making pieces of furniture, including grandfather clocks, and electronic devices, and would offer to make these for his friends as gifts. He continued his interest in music by playing clarinet in local orchestras. On the occasion of a celebration of the seventieth birthday of Professor T. K. Sherwood he wrote an arrangement of "Happy Birthday," including the instrumental scores for the unlikely combo of clarinet, oboe, and trombone: the instruments for which talented players were available.

Professor Pigford played a very significant role in the development of chemical engineering in the University of California. When he decided to return to his first academic love, the University of Delaware, all at Berkeley felt a sense of great loss. Robert and his wife, Marian, had become a valued and highly respected part of the university community. And, in view of his earlier service on athletic boards, it was difficult for his Berkeley colleagues to accept his preference for a university having a blue hen as a mascot over that of a handsome golden bear!

In addition to creating new knowledge by research, throughout his career Professor Pigford contributed much to the chemical engineering literature, including books and numerous papers in technical journals. Notable books include: *The Application of Differential Equations to Chemical Engineering Problems* with W. R. Marshall; *Adsorption and Extraction,* 2nd ed., with T. K. Sherwood; and *Mass Transfer* with T. K. Sherwood and C. R. Wilke. *The Diffusional Operations, Gas Absorption* and *Distillation* sections of *Perry's Chemical Engineers' Handbook,* 3rd ed., were coauthored with A. P. Colburn, and the *Gas Absorption and Liquid Extraction* section of the 4th edition of the handbook with R. E. Emmert. A major publication activity, and a tremendous and time-consuming service to the profession, were his quarter century's service as the editor of the *Industrial and Engineering Chemistry-Fundamentals Quarterly.* During his editorship Professor Pigford spent countless hours reviewing and arranging the publication of hundreds of manuscripts from all around the world. His reviews of papers and decisions were always made with great courtesy and constructive comment for the authors.

Robert Pigford's advice was sought by numerous industrial, academic, and governmental institutions. He served as a member of the U.S. Army's Research Council, the Sci-

entific Advisory Board of the U.S. Air Force, the Department of Energy, the National Research Council, the American Society for Engineering Education, and the advisory committees for chemical engineering departments at Massachusetts Institute of Technology and Princeton University. He was deeply concerned by, and interested in, the ethical dimensions of science and technology, and served much time on national committees devoted to clean air standards and to the safe disposal of nuclear wastes. In this latter activity he worked closely with his younger brother Thomas, a distinguished nuclear engineering faculty member at the University of California at Berkeley. From 1983 until his death, Robert Pigford served as the gubernatorially appointed faculty representative on his university's Board of Trustees.

Professionally, Robert Pigford received almost all the awards for leadership in research and education of his principal professional society, the American Institute of Chemical Engineers. On the occasion of the institute's seventy-fifth anniversary he was named as one of thirty pre-eminent leaders of the chemical engineering profession. He was elected to the National Academy of Engineering in 1971, and to the National Academy of Sciences in 1972—one of only a very small number of scholars nationally to have been accorded this honor. The University of Delaware recognized Pigford's distinction by bestowing on him the unique title of University Professor in 1975, and by naming him as its first Alison scholar in 1977. His own alma mater, Mississippi State College, granted him its Outstanding Achievement Award in 1978, on the centennial of that institution's College of Engineering. In 1988 he was named Delaware's Engineer of the Year by the Delaware Society of Professional Engineers.

Too sensitive to criticize others openly in view of his

Southern heritage, he nevertheless enjoyed opportunities to expose any charlatan. Opportunities to do so arose with considerable regularity, and can be exemplified by the following anecdote. Hot-wire anemometry was in its golden era in the years following World War II, with progressively finer wires being produced by engineers of many persuasions, to enable their probing of progressively higher frequencies of the turbulent flow spectrum. These were, of course, very difficult to produce and to operate as any impinging speck of dust would cause their destruction, and wind tunnels of the era were not noted for their cleanliness. On an occasion when the Pigford department was being regaled by a visiting seminar speaker who claimed he could decrease the diameter of these wires *by an order of magnitude* from the best then available, his assertion was met with great disbelief by the graduate student body, many of whom had struggled valiantly to attain far more modest gains. The speaker stood his ground, however, against an increasingly hostile onslaught of skeptical queries, claiming that 0.1 micron wires would be produced in his laboratory "within days," and mounted in the anemometer by simple "hold-it-in-your-fingers-and-solder-it" techniques. When an impasse appeared to be fast approaching, Professor Pigford entered into the discussion with what appeared initially to be an alarming and one-sided joining of forces with the visiting speaker: "I am quite willing to believe you can indeed produce such a fine wire, if you state you can do so. However, noting that its diameter is smaller than the wavelength of visible light, if you did produce it, would you be able to find it?" Could there have been any gentler, more elegant and yet more conclusive finale for this discussion?

For all the professional achievements of the man, Robert Pigford was an uncommonly sensitive and human individual. Those who knew him knew a gentle, unassuming

person, always concerned about the feelings of others. He constantly tried to help those around him achieve excellence, and he managed to do it in a non-competitive way. At the same time, he insisted on working on things that were relevant. In these ways, he had an immeasurable uplifting influence on not only his students and associates, but on the many people in the organizations with which he worked as a consultant. It was surely this human side of the man that caused such an outpouring of affection on the occasion of a special seventieth birthday event held in his honor at the University of Delaware, and several of the stories told on that occasion warrant repetition here.

One former graduate student recalls receiving a Saturday midnight call from a colleague in the laboratory advising that a considerable flow of water was cascading into the basement below Professor Pigford's office. Could its source possibly be in your laboratory just above the office? A quick trip to the laboratory confirmed the worst of the student's fears. Undoubtedly, the flow of water from his laboratory must have soaked the Pigford office, the books and papers of the departmental chairman, on its way to the basement. Dare one call the chairman at this hour of the night? But there seemed to be no alternative as any delay would only multiply the damage already done. And, in due course, Robert arrived in overalls, with a mop and pail, and with the gentlest of all possible admonitions: "Don't worry, these things happen."

He was also ready to help his colleagues with any personal issues they brought before him. One of his colleagues, knowing Robert Pigford to be a lover of music and very able clarinetist, recalls asking for advice concerning the purchase of a clarinet for his child. The response was a very professional one: "Neither the instruments themselves nor the reeds and mouthpieces for clarinets are very reproduc-

ible. In general, however, you should only consider two manufacturers. One of them produces better mouthpieces and the other better instruments. Collect all you can from the several Delaware stores, bring them to our house tonight and we will choose the combination which sounds best." And this was done. The entire Delaware supply of clarinets was brought to the Pigford home and the choice was made by the child and Robert Pigford playing Mozart duets. The visitors to the Pigford home were a part of the extended Pigford family, and, as such, their needs took precedence over any earlier plans for the evening.

Another story with which to close: a new student had been assigned to share a laboratory with another of Pigford's graduate students—the late Robert H. Perry. The latter individual advised the new student that he was in for a demanding but inspiring experience, for, he said, you will be working with "*A prince among men.*"

How many times have each of us, the numerous authors of this tribute, witnessed Robert Pigford as a productive engineer, as an educator, as a scholar, as a friend, and thought, "Yes—a prince among men." We are privileged to have been among his colleagues.

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