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Frederick Wells Leavitt: a pioneer in adsorption technology

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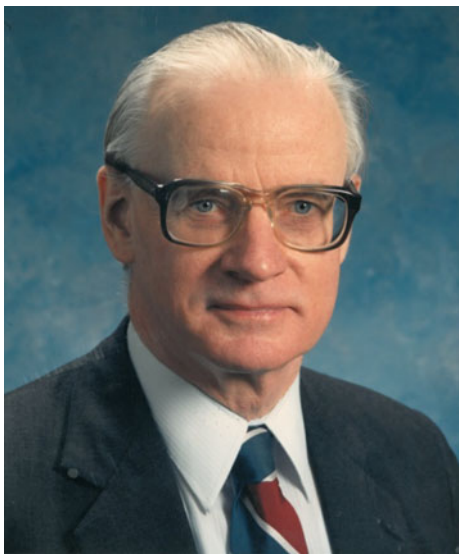

Fred was born in Elizabeth, New Jersey in 1928. He attended Union Junior College from 1946 to 1948 and Newark College of Engineering from 1948 to 1950 (both in New Jersey) where he obtained his B.S. Ch.E. He then served in the US Army from 1950 to 1952, with subsequent employment with the US Army Chemical Corps. Fred was admitted to the Chemical Engineering Graduate Study Program at Rensselaer Polytechnic Institute (RPI) in 1954 and completed a M.S. Ch. E. in 1955 and his Ph.D. in June 1957 (Leavitt 1957). On his application for admission to graduate study at RPI, Fred indicated interests in "heterogeneous systems, especially those containing dispersions of small particles …. study of solid–liquid–vapor equilibria, heat and mass transfer mechanisms, reaction kinetics, and the motion of small particles in resisting media." In the career that followed, Fred made significant contributions in all of these areas.

Fred joined the Molecular Sieve Group at Linde Air Products Company (Division of Union Carbide Corporation[1]) in 1957. This timing is particularly significant to the field of adsorption due to the following events of the 1950s:

- The development and commercialization of synthetic molecular sieves at Union Carbide (Milton 1959; Breck 1974).
- Skarstrom PSA process development covering both drying of gases and air separation (Skarstrom 1960).

While much attention was on the development of zeolites, a few engineers and scientists were working on applications of these materials in large-scale separation processes. Skarstrom defined some basic cycles for drying and for air separation and suggested several possible zeolites for achieving these separations. However, there was little fundamental understanding of pressure swing (PSA) and temperature swing (TSA) processes at that time—especially large systems of industrial scale. There was much work remaining to develop the applications for these new synthetic zeolites. Fred, uniquely qualified with a combination of excellent mathematical and engineering skills and a driving curiosity, was positioned at the opportune time. He responded by laying out a fundamental ground-work for adsorption processes. In the short period 1960–1966, Fred authored more than 40 detailed internal

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[1] The Linde Division of Union Carbide Corporation was spun off as Praxair, Inc. in 1992

development documents covering essentially the entire range of adsorption topics required to successfully implement real processes, e.g. steady state transfer zones, multicomponent isotherms, thermal regeneration and thermal pulse desorption, non-isothermal effects in large beds, adsorptive mass transfer, estimation of mass and heat transfer coefficients in adsorbent particles, adsorption thermodynamics, pressure drop and flow distribution in packed beds and PSA and TSA adsorption cycles. Even more surprising was his development of computer models capable of simulating adsorption processes—remarkable given the state of computer and adsorption technology at that time. One colleague of that era remarked that "Fred put Union Carbide at the forefront of zeolite adsorption process technology."

Adsorption, particularly adsorption processes, lacked formal structure and was not fully developed as a scientific discipline in the 1960s. There were no textbooks on adsorption of the caliber of those available today, e.g. spanning equilibrium, kinetics, theory, experiment, modelling and processes (Yang 1987; Ruthven 1984; Wankat 1986; Ruthven et al. 1994). It is noteworthy that these four classic textbooks were all published between 1984 and 1994. In addition, there was an abundance of excellent technical articles being published during this time as computational advances were occurring in parallel. Imagine my amazement after arriving at Praxair in 1991 (fully armed with all the latest adsorption technology) only to discover the 1960s internal teachings of Dr. Fred Leavitt—many of which mirrored the fundamentals appearing in the classic adsorption textbooks published nearly two decades later. I studied many of Fred's documents carefully—particularly those relating to steady state transfer zones—because they added much to my understanding and complemented well my academic training. I later came to appreciate Fred as one of a few mentors that left an indelible impression upon my career.

While much of Fred Leavitt's early work on adsorption was never published, there are three well-known original contributions. "The importance of heat effects in adsorption column dynamics appears first to have been recognized by Leavitt (1962) in the early 1960s…." as noted by Ruthven (1984). This work included both theoretical and experimental results for steady state transfer zones and non-isothermal/adiabatic behavior in large adsorption beds. The second major contribution was the development of the loading ratio correlation (LRC) multicomponent isotherm model (Yon and Turnock 1971) that has been widely applied to adsorption of permanent gases on zeolites. This work was published by others long after it first appeared in Fred's earlier internal development memorandums. However, the authors fully acknowledged "Dr. F.W. Leavitt, who developed the original concept of the loading ratio correlation." Thirdly, he developed design practices for fixed-bed molecular sieve drying and purification systems (Collins 1967). This article was based upon the earlier steady state transfer zone work of Dr. Leavitt that advanced the application of the length of unused bed (LUB) concept to large scale fixed bed adsorbers. These three works contribute to the core of adsorption process technology embedded today in many commercial gas separations.

From 1966 to 1984, Fred consulted on many projects through his new position in the Engineering Sciences/Computer group within Union Carbide. He became a troubleshooter in a diverse range of activities and made contributions affecting metals processing technologies, magnetic separations and no-lead fuel development—to name only a few. Because of his exceptional mathematical and solid chemical engineering skills, Fred was in high demand for the most difficult problems. Occasionally this problem solving role brought him back to various adsorption process issues such as the application of pressure equalization to UNOX oxygen supply systems for waste water treatment.

Fortunately for Praxair and the Adsorption Community, Fred returned to Adsorption (his passion) in 1984 to a special team tasked with the development of ambient temperature adsorption processes for the production of N_2 and O_2. As a leading member of this group, he set forth a priori the critical adsorbent capacity and selectivity requirements of the desired adsorbents. These challenging requirements inspired the identification and development of Li-exchanged zeolites, as well as the many process and equipment innovations that followed, e.g. including fast cycle and low pressure ratio processes and radial flow adsorbers. This team was eventually responsible for the development and commercialization of vacuum pressure swing adsorption (VPSA) O_2 production technology which was recognized in 1992 with the Praxair Chairman's Award. As a result of these efforts, Praxair continues to offer a very successful VPSA product line that supplies customers with 90 % purity O_2 from 10 tons per day (tpd) to more than 200 tpd.

This new venture seemed to reignite Fred's career in adsorption and he became a prolific inventor with twenty-eight US patents issued between 1989 and 2003. Inventions related to air separation included N_2 production (US Patent 1989), low pressure ratio cycles (US Patent 1991, 2003), N_2/O_2 co-product cycle (US Patent 1992a), self-refrigeration (US Patent 1992b), auto-tuning VPSA process control (US Patent 1995a), processes incorporating O_2-selective adsorbents (US Patent 1999a, 2002a), layered beds (US Patent 1997a, 1998a), enhanced cycle performance (US Patent 1995b, 1995c, 1998b) and rate-enhanced gas separations (2002b). Many of his inventions reach well beyond the production of O_2, e.g. ion exchange processes for Li recovery (US Patent 1995d, 1997b, 1998c), production of mixed cation adsorbents (US Patent 1997c, 1999b, 2001a), duplex cycles for high purity and high recovery (US Patent 1992c, 2002c), multi-thermal pulse regeneration (US Patent 1998d), PSA prepurification (US Patent 1998e, 1999c), CO_2 recovery (US Patent 2001b)

processes utilizing adsorbent mixtures (US Patent 2000) and adsorber vessels (US Patent 1998f). In addition, Fred submitted more than 200 internal technical suggestions for new processes.

With all of this success, Fred remained grounded. He was and is always a gentleman in all situations. Although reserved and often preferring to work alone, Fred was generous with his time and was always willing to offer help. One young engineer got his start in industry working with Fred in the early 1960s. Even though Fred was near the beginning of his own career, he assumed the role of mentor to this young man. This colleague attributes "the very good start" to a long and successful career to mentoring provided by Fred. Although I only worked with Fred during the last 6 years of his professional career, my experience mirrored that recalled by earlier colleagues. Fred had great enthusiasm for technical challenges and was always willing to share his experience and knowledge. Fred is not without a sense of humor, but his is a "dry wit." One of his favorite sayings is "theory guides but experiment decides." Perhaps lesser known, Dr. Leavitt's contributions are no less significant. Frederick Wells Leavitt is a gentleman, a scholar and a true pillar of adsorption technology. Fred retired from Praxair in 1996 and resides in the Buffalo, NY area.

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