ChE founder

In this issue, CEE begins a new department that will feature some of the founders of our chemical engineering profession. This article deals with the graduate (and earlier) university career of Allan P. Colburn, who has been described by Professor Olaf Hougen of the University of Wisconsin as "one of the most inspiring friendly and intellectual teachers and leaders in chemical engineering." The article is written by Professor Hougen, who was his Ph.D. advisor.

ALLAN P. COLBURN**

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ALLAN PHILIP COLBURN was my first student in graduate research directed towards a doctorate degree in chemical engineering.

Allan was born in Madison, Wisconsin, on June 8, 1904. His father, Willis P. Colburn*, at that time, after twelve years of high school teaching, was enrolled as a student in philosophy at the University of Wisconsin. Upon graduation in 1905 Willis accepted a position as principal of the high school in Rhinelander, Wisconsin. It was here that Allan spent his childhood and received his elementary and high school education. In June 1922 the Colburn family moved to Wauwatosa, a suburban city adjoining Milwaukee, where Willis was employed as principal of a local high school.

In June 1922 Willis Colburn came with his son Allan to my office to consider enrolling him in the College of Engineering of Marquette University in Milwaukee for a period of two years prior to enrollment in chemical engineering at the University of Wisconsin. [The chemical engineering building was then located on the south shore of Lake Mendota at the foot of Park Street.] From Allan's superior high school record and his unusual intelligence, I readily agreed that this plan had much merit not only in the economy of living at home but also in the cultural advantages associated with a sectarian school of high repute. At Marquette University Allan received undergraduate instruction in general chemistry, mathematics, physics, English, shopwork and surveying. Imagine! Surveying was a required course in many curricula of chemical engineering 44 years ago. On September 12, 1924 Allan enrolled as a Junior at the University of Wisconsin. I served as his adviser in his junior year; and Professor Otto L. Kowalke in his senior year.

The period 1920 to 1930 was critical and transitional in the development of chemical engineering education. The year 1923 marks the beginning of the American system of education in chemical engineering with the publication of the text, "Principles of Chemical Engineering" by William H. Walker, Warren K. Lewis, and William H. McAdams. At Wisconsin the curriculum was at that time predominant in conventional engineering courses with instruction in chemical engineering slowly emerging from descriptive courses in industrial chemistry supplemented by laboratory experiments largely empirical in nature.

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*The records of Platteville Normal School (now Wisconsin State University—Platteville) show that Willis Paul Colburn, a resident of Grant County, Wisconsin, attended Platteville Normal School in three school years 1886-87 and 1889-91 receiving a diploma in 1891. After graduation he served as high school principal at Potosi, Cassville and Viroqua, Wisconsin. He married Jennie Grimm of Cassville. In 1903 he attended the University of Wisconsin in Madison as a student in philosophy receiving a bachelor of philosophy degree (BPh) in June 1905. In later life he returned for graduate courses in Education in 1914 and in the summer session of 1929.

**This sketch was prepared for the dedication ceremonies of the Allan Philip Colburn Chemical Engineering Building at the University of Delaware, Sept. 20, 1968.

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ALLAN SET HIS GOAL EARLY at the highest professional level not only towards advanced studies and research leading to the doctorate degree but also in seeking a career of high professional and civic responsibility. A humanitarian goal in life was manifest in his selection of liberal elective courses essential for a well rounded citizenship. In this selection Allan was guided by his father whose own major college studies had been in philosophy and by Professor Kowalke. In liberal courses he was fortunate in choosing five of the most popular and inspirational professors at Wisconsin, namely, William H. Kiekhofer in Economics, Louis Kahlenberg in the History of Chemistry, Max Otto in Philosophy, A. A. Vasiliev in Hellenistic Civilization, and Daniel W. Mead in Contracts and Specifications. Mead's course was essentially one in engineering ethics based upon Mead's world wide experiences in the construction of dams and power plants. Professor Kiekhofer was the campus spark plug of enthusiasm in his animated lectures on conventional principles of economics injecting life into an otherwise dull subject. Professor Max Otto held a similar position in philosophy and logic. The course in Hellenistic civilization described the Golden Age of Greece, the causes of its origin and decline. With a delightful sense of humor Kahlenberg portrayed the joys and frustrations of scientific discovery in the lives of great chemists. These five professors, combined with parental influence and that of Professor Kowalke gave Allan an altruistic outlook on life and in his dedication to highly ethical and benevolent standards. This served him well in his later administrative responsibilities and projects of community welfare. **The present day stress on the importance of liberal courses in training of engineers was met by Colburn 40 years ago. In his college years, Allan became a proponent of the Single Tax theory of economist Henry George. This typified student protest forty years ago in contrast to the violence of today.**

The professional staff of the Chemical Engineering Department in 1924 consisted of Professors Otto L. Kowalke, Oliver P. Watts and myself. Courses in industrial chemistry and unit operations were given by Professor Kowalke, applied electrochemistry by Watts and a calculation course, applied thermal chemistry, by myself.

Allan was graduated in June 1926 with a bachelors degree in science (BS) and high honors. An Engineering Fellowship was awarded him for continuation in graduate studies and research. This fellowship was later renewed for two additional years. At this time a new dormitory system for men was established at the University of Wisconsin. Allan was one of the first graduate students to be appointed as House Fellow. The responsibilities of this position entailed living with undergraduate students as counsellor, guide and friend.

Allan received his MS degree in 1927 and PhD degree in 1929.

In his graduate years Allan's two closest friends were Kenneth M. Watson and Louis F. Warrick. The former became a prominent chemical engineer in his contributions to education and industrial practice and the latter became the young State Sanitary Engineer of Wisconsin in 1927. A recent letter from Louis Warrick restores an intimate insight into Allan's zest for living and some of the extra curricular activities he enjoyed during student days.

Before accepting a position with du Pont, Warrick and Colburn had made enthusiastic plans to form a partnership as consultants in solving problems in the abatement of water pollution and disposal of industrial wastes. Already forty years ago these two young men were aware of the dire consequences of water pollution, the irrevocable evils of which are so strikingly evident today.

THE RESEARCH PROJECT assigned to Allan for his doctorate thesis was to obtain experimental data on heat and mass transfer coefficients in the condensation of water vapor from saturated air streams in a tubular gas condenser and to formulate correlations based thereon useful for design and operation. This project differed from conventional dehumidification in that it involved air saturated with water at high temperatures with great reductions in volumetric and mass flow rates of the gas-vapor stream during cooling and condensation.

The Committee on Condensing and Scrubbing of the American Gas Association had collected operating data on tubular gas condensers used for refining crude coal gas with its high initial content of water vapor, hydrogen sulfide, ammonia, cyanogen, naphthalene and tar. These data were gathered from commercial plants scattered widely throughout the United States. Professor Kowalke, as a member of this committee, assigned to me the task of trying to calculate and correlate the overall heat transmission coefficients from these data in terms of operating variables, physical properties and gas composition. I was unsuccessful in making any meaningful correlations. Indeed, correlation in terms of the geographical location of the plants seemed to be better than any rational attempt. The decision was made to establish data from carefully controlled operation of a laboratory scale tubular condenser using saturated air-water vapor mixtures under industrial conditions of operation.

In the period 1926-29 few graduate students were enrolled in chemical engineering at the University of Wisconsin. Prior to 1929 only three doctorate degrees had been granted. In guiding research towards a doctorate degree Allan was the only student assigned to me.

A preliminary study of the condensation of water vapor from air saturated at high initial temperatures in a tubular condenser revealed many complexities. Three fluid stream resistances were involved, the air-vapor stream, the condensate layer and the stream of cooling water, besides the resistance of the metal barrier. The heat transfer coefficients of these three streams were to be established each in terms of its independent variables. Because of large variations along the length of the condenser it was evident that coefficients of the individual streams should be determined at short intervals of condenser length. Calculations of average heat transmission coefficients of the vapor stream from usual logarithmic mean values of temperature drops at terminal conditions were meaningless, indeed, the temperature drop at the midsection of the condenser was usually greater than at either terminal. In retrospect, considering the primitive status of scientific information and the complexity of the problem, this investigation would at that time justify three projects with independent approach to each.

A vertical tubular condenser, six feet long, was constructed of three concentric pipes, 3, 7 and 10 inches nominal diameters, well insulated on the outer shell. Cooling water flowed through the inner pipe and saturated air flowed downwards through the two annular channels; the outer outer annular space served as a guard ring together with external insulation to minimize the outward flow of heat. With only $100 available for mechanical help and additional apparatus over a span of three years, the equipment and instrumentation had to be assembled from supplies available in the stock room or borrowed from distressed laboratories, including piping, pumps, thermocouples, orifice meters and potentiometers.

Colburn's genius consisted in his extraordinary capacity for intensive concentration with a mind unusually well organized for retention and retrieval.

Allan constructed and calibrated all thermocouples and orifice meters. The construction and location of thermocouples were critical for meaningful measurements. Multijunction couples were constructed for measuring average temperatures of the gas stream at each level of cross section. Single couples were located in isothermal areas to avoid errors by conduction. A traveling thermocouple was constructed and installed for measuring the temperature of the cooling water. Temperatures of the three adjoining fluid streams and the central pipe wall were measured simultaneously at successive short intervals of length. Under commercial conditions of operation natural convection predominated in the stream of cooling water; both laminar flow and turbulence occurred in the gas stream; the condensate accelerated from laminar flow to turbulence with rippling at the bottom of the tube.

THE MEASUREMENT AND CORRELATION of heat transmission coefficients of fluid streams was in a primitive stage in 1926 when Colburn began his experimental and theoretical studies. Most published experiments had been conducted within the preceding ten years. The most significant work had been carried out in Germany. This appeared in the German language without published translation in English. In the United States chemical engineers required that formulations of transfer coefficients be expressed in terms of molecular properties and operating variables. Other engineers were still satisfied with specific values of overall coefficients and physicists had virtually abandoned the field upon discovering the empirical nature involved. Principles of heat conduction in solids had been well known for over a century starting with the mathematical theory of Fourier in 1822 for the unsteady state. These formulations were extended in the texts of Ingersoll and Zobel in 1913 and by Carslaw and Jaeger in 1921.

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The analogy between mass, heat and momentum transfer in flowing fluids was presented by Prandtl in 1910 based in part upon pressure drop formulations of Reynolds in 1874. In England work was reported in 1916 by Pannel for air flowing through tubes and by Stender in Germany for water flowing through tubes. A theoretical equation for the transfer of heat by free convection in fluids was developed by Lorenz in 1881 and greatly improved by Nusselt in 1915. Nusselt in 1910 also pioneered in deriving theoretical equations for the transmission of heat through condensate layers flowing over vertical surfaces and horizontal cylinders.

At the time of Colburn's studies and just prior thereto five books on general heat transmission appeared in Germany, namely, by Grober (1921 and 1926), by Merkel (1927), Bosch (1927) and Schack (1921). These were then without English translation. The first authoritative book on heat transmission printed in English and applicable to general engineering processes was that of McAdams in 1933 but this book did not appear until seven years after Colburn started his research. McAdams' text and researches generated wide attention to research in heat transmission throughout the United States and among other branches of engineering besides chemical.

Allan proceeded at once to read intensively the German sources relying on his high school instruction and his preparation for absolving the German language requirement of the doctorate degree. The extraction of complex theoretical principles from lengthy German dissertations required exceptional capacity for intensive concentration. Allan studied the original German sources with intense concentration over long intervals of time to the point of pain and fatigue. Colburn had exceptional capacity for retaining the arguments and voluminous observations of previous investigators with subsequent instant recall. **Colburn's genius consisted in this extraordinary capacity for intensive concentration with a mind unusually well organized for retention and retrieval.**

In his graduate years Allan devoted fully half of his time to theoretical studies and experimentation related to his thesis over a period of three years. In his efforts to establish simultaneously the principles of heat and mass transfer in fluid streams, condensate layers and water streams with free convection, Allan suffered many periods of despair and frustration especially in his efforts to reconcile his data with the formulations of others. But he always bounced back with a zest for scientific discovery and to infuse the same spirit in others.

FROM HIS BOYHOOD DAYS in the recreational area of Northern Wisconsin with its forests and lakes, it was natural for Allan to seek relaxation from his strenuous intellectual pursuits and frustrations in out-of-door sports the year around, in tennis, canoeing, golf, fishing, skating, and iceboating.

In connection with recreation his friend Lou Warrick records a vivid and humorous account of Allan's discovery of 'hot ice'. In iceboating together on Lake Mendota their speeding boat struck rough ice and Allan was projected therefrom at high speed over the rough surface on the seat of his pants. Upon recovery Allan feeling his posterior exclaimed, "Gee, Lou, this is the first time I realized that ice can get hot!" Because of the great tragedy in health which befell Allan a few years later few people were aware of his early athletic prowess.

Colburn's computational facilities were limited to the use of the slide rule, to laborious calculations and plotting by hand. In experimental work he received some aid from two seniors working for academic credit, namely Robert E. Zinn and George F. Hrubesky. Today Allan's monumental task would be greatly facilitated by electronic computers with generous financial subsidies for experimental and computational aid. It should be recalled again that Allan had only $100 available for research aid.

In his graduate years Allan restricted his advanced studies to scientific work related to his thesis. Liberal reading became extra curricular. His advanced studies included a course in heat conduction under Professor Leonard R. Ingersoll, higher mathematics under Professor R. W. Babcock, and advanced chemistry courses under Professors J. Howard Mathews, Farrington Daniels, and John W. Williams. Allan was also fortunate in taking courses under two visiting professors, with the Russian chemist A. M. Frumkin in col-

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identification of properties of a system which are purely consequences of its being an assembly of weakly interacting parts or particles as distinguished from those which reflect the intrinsic physical nature of the isolated particles.

It seems to the author that while such insights depend upon understanding the general theory of stochastic processes, they do not come without deep study and comparison of specific processes. Therefore, the statistical theory of particulate systems is truly an engineering science, approachable in a useful way from the base of the analysis of engineering problems.

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HOUGEN ON COLBURN (from p.171.)

loidal chemistry and Peter Debye in the kinetic theory of gases.

AFTER SECURING HIS DOCTORATE degree in 1929, Colburn was employed in the Engineering Experiment Station of the E. I. Du Pont de Nemours Company under Thomas H. Chilton. The du Pont Company very generously supported Allan in his undertaking to derive independently the mathematical formulations for mass and heat transfer in fluid streams covering a wide variety of industrial devices and conditions. These formulations appear in Chapter VII of the pioneer bulletin "Studies on Heat Transmission" by Colburn and Hougen [Bulletin 70 of the Engineering Experiment Station, College of Engineering, University of Wisconsin, October 1930]. Otherwise this bulletin is based on Colburn's doctorate thesis. The rough draft was improved by the critical review of K. M. Watson.

Colburn was an ideal student, scientist and engineer. In conversation and public lectures he had an unusual capacity for clarity of expression. He met unsound criticisms and arguments of his audience with patience and encouragement, never with disparagement, seeking not personal acclaim but rather promoting self confidence and ambition in others. My technical correspondence with Allan continued for fifteen years following his academic career but terminated when I no longer could keep pace with his ever expanding scientific speculations.

My last meeting with Allan occurred in London in September 1951—an unexpected meeting at the time of the Festival of Britain. Mrs. Hougen and I met Mrs. Colburn accidentally on a London bus on our way to the Tate Art Gallery. Allan arrived in London one week later while we were awaiting boat reservations for a return trip to the United States. The four of us spent a pleasant summer evening together at the amusement section of the Festival of Britain. We enjoyed watching the teenagers on the roller coasters and whirligigs. In turn the British teenagers enjoyed our strange use of the English language.

As an epilogue to this sketch I should add one additional incident. In the fall of 1963 a young coed, Miss Nancy Hall, a graduate student and research assistant in the Department of Oncology at the University of Wisconsin came to my office to inquire about the possibility of a young man, Willis Colburn, entering the University of Wisconsin as a Senior in Electrical Engineering. This was easily arranged. When Willis appeared on the campus, his similarity to his father 40 years previous was most striking and brought a surge of nostalgic memories. And thus this account returns full circle to its beginning, starting with a meeting with Allan and his father Willis in 1922 and ending with the enrollment of his son Willis 42 years later. Nancy and Willis were soon married. Both continued as research assistants and graduate students for two or three years in their respective fields. And thus three generations of Colburns have touched my life over 46 years of time. I understand the fourth generation has recently arrived.

I shall close with one sentence from the letter of his college friend Louis Warrick "How proud the parents (of Allan Colburn) would be to know of this latest honor to the memory of an outstanding son." This applies to all who knew Allan Colburn.