ChE department

STANFORD

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Chemical Engineering at the Leland Stanford Junior University became a discipline within the Department of Chemistry during World War II and was directed for about a decade by Carl Lindquist and Bob Paxton. In 1955 Dave Mason and Neal Pings of Cal Tech moved northward across the Tehachapi mountain range to Stanford and were the two sole faculty members of chemical engineering which that year became a division of the Department of Chemistry and Chemical Engineering. Bill Schwartz joined the faculty in 1957, Bob Johnk in 1959, John Zahner and Andy Acrivos in 1962, Michel Boudart in 1964, Bob Madix in 1965, John Lind in 1967, Bud Homsy and Channing Robertson in 1970. Neal reversed his trek and moved southward across the Tehachapis to return to Cal Tech where he now heads up the Chemical Engineering group and is Dean of Graduate Studies there; Bill Schwarz returned to teach at his Alma Mater, Johns Hopkins; Bob Johnk chairs the Department of Chemical Engineering at San Jose State University, and John Zahner is an industrial tycoon in the field of catalysis with Mobil Research and Development Corporation.

In 1960 Chemical Engineering became a separate department in the School of Engineering, but we have endeavored to maintain close intellectual ties, as well as geographical propinquity, with the Chemistry Department. Two of our eight members currently have joint appointments in the two departments, and our facilities are in the midst of the Chemistry complex. In 1955 we occupied a dilapidated one-story sandstone storage building fondly known as the "outhouse" which with all its nostalgia was razed in 1965. That year the Department moved into a new laboratory and gazebo conference building, made possible by a grant from the National Science Foundation with matching gifts from Mr. John Stauffer and other private donors.

Our undergraduate student body is small, with an average of seven bachelors degrees having been offered per year in the past decade. Most of our baccalaureates go on to graduate school, usually at other institutions. During this decade our graduate program has expanded in scope and degrees awarded increased from 4 M.S. and 2 Ph.D. to 25 M.S. and 8 Ph.D. About one fourth of our doctoral students have perpetuated the species by going into teaching at institutions all over the U.S., the remainder going into industrial positions.

THE FACULTY

Our current faculty can be best characterized by the group shot down in Figure 1 taken during a recent typical faculty meeting in which we were discussing whether or not one of the best graduate students ever to come here, Warren Wonka, had passed, conditionally passed, or conditionally failed his Ph.D. qualifying examination. Michel has elegantly spoken his piece and has turned to the more serious matter of planning a lecture junket to Brussels via Tokyo. Dave has a class coming up and is anxious to spend a few mements culling out his lecture notes from the voluminous University committee reports in his

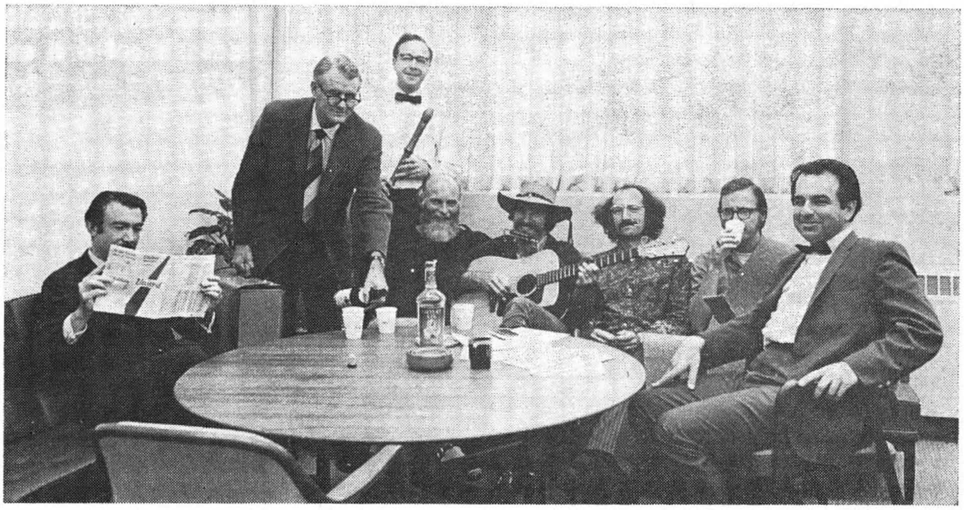

Fig. 1. Full attendance at the "ChE Faculty Club" includes (left to right) Professors Boudart, Mason, Lind, Wilde, Madix, Homsy, Robertson, and Acrivos.

brief case. He is vainly attempting to get the debate off dead-center by offering to his colleagues several different cuts of Stanford spirits from our unit operations, 20-plate bubble cap column. To help make the deliberations even more mellow, a trio consisting of John, Doug, and Bob have just completed a rousing rendition of "The Rose Bowl Fighting Song" with the Ithaca recorder in the key of B^b, the Palo Alto Irish tenor in C^-, and the Urbana guitar in G#. Bud and Channing, being newcomers to the faculty, are totally perplexed and dismayed by the whole proceedings. Andy seems particularly pleased at this point for, most unusual for him, he is about to pull a coup and end the debate with a stunning motion that Wonka be passed conditionally provided that the Ph.D. research in "social thought" he has proposed, be done in another department or university. The deadlock was broken, and it took merely two more liters of Stanford spirits and three more musical verses before the phrasing of the motion was letter-perfect and we stood adjourned.

THE TEACHING AND RESEARCH PROGRAM

After faculty meetings, we wend our way back to our research lairs and offices and purportedly engage in the following research activities which are listed in the order of the faculty member's surname — not necessarily in descending order of relevance and importance.

ANDREAS ACRIVOS — Laboratory for Fluid Mechanics

A distinctive feature of the research effort in this laboratory is that the research is directed toward a number of very basic rather than applied problems in fluid mechanics, whose solution will strengthen the theoretical foundations as well as our overall understanding of many of the key principles in this broad field. With this general goal in mind, then, the research students in this laboratory are encouraged to examine a number of such problems before selecting a particular project which to them would seem to offer the best opportunities for an important contribution of a scientific type.

The projects currently under study both theoretically and experimentally are as follows:

Steady High Reynolds Number Flows with Closed Streamlines — It is well known that the classical laminar boundary-layer theory applies only as long as the flow remains unseparated and that at present no theories exist for describing high Reynolds number steady flows in separated flow regions or regions with closed streamlines. The aim of this project then is to develop such a theory, not only because this would be of interest in itself, but also because such a theory is essential before many of the most basic laminar flows can be properly understood.

The Motion of Freely Suspended Particles in Shear Flow — An important area of fluid mechanics, deals with the motion of small spheres and cylinders in shear flow. The main objective of this part of our research program is to investigate, both theoretically and experimentally, a number of key problems within this broad category, with a view to obtaining a firm understanding of some of the phenomena involved, principally those associated with the rate of heat and mass transfer from the particles to the surrounding fluid.

The Development of Constitutive Equations for Non-Newtonian Fluids — Knowledge of the constitutive equation for non-Newtonian fluids is an obvious prerequisite for any successful study of flow phenomena involving such complex fluids. So, one of our efforts has been to try and obtain such constitutive equations from a more physical point of view using suspension theory.

Elastic and Thermal Properties of Composite Materials — A theoretical analysis has been initiated, whose aim is to relate the bulk elastic and thermal properties of composite solid materials to the corresponding properties of the constitutive parts. Specifically, one desires to find out to what extent the addition of relatively small amounts of suitably chosen foreign substance can affect such parameters as the bulk elastic modulus or the thermal conductivity of a simple solid. There are valid theoretical reasons for believing that the effects of such inclusions could be substantial, especially when such inclusions consist of long and slender particles whose net effect is to render the material non-isotropic.

MICHEL BOUDART — Laboratory for the Study of Adsorption and Catalysis

In building up this laboratory at Stanford University, our guiding principle has been to create a place where a small number of graduate students and post doctoral fellows interact with visitors from university and industry in the pursuit of knowledge in the various active areas of research in heterogeneous catalysis.

Thus, no exclusive emphasis is placed on any particular book, technique or method of approach. Rather, each member of the laboratory is encouraged to follow his own interest and, in so doing, he stimulates the other members of the group engaged in their independent work.

Low Energy Electron Diffractions (LEED) — This technique provides information on the arrangement of atoms at the surface of single crystals. The rearrangement of surface atoms following adsorption or reaction, as well as the superstructures exhibited by adsorbed atoms and molecules, may explain some of the characteristics of solid catalysis. The adsorption and decomposition of hydrocarbons on metals are under study in the LEED apparatus, now provided with Auger electron spectroscopy.

Catalytic Activity of Supported Metals — The stereospecific hydrogenation of complex molecules on various metals is being used as a

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test reaction to determine how selectivity and activity of a reaction depend on dispersion of the metal.

Infra-red Spectroscopy of Surfaces — The performance of crystalline alumina-silica catalysts in the cracking and isomerization of hydrocarbons is strongly dependent on the type and concentration of exchangeable cations present in the crystal. The role of these cations in physical and chemical adsorption of gas molecules is being investigated with infra-red spectroscopy.

Mössbauer Spectroscopy of Surfaces — Mössbauer spectroscopy is now used systematically as a tool to investigate surface states of zeolites and various commercial and theoretical catalysts. The characteristics of Mössbauer spectra throw a bridge between surface chemistry and Mössbauer spectroscopy.

Electronic Defects as Active Centers — The low temperature activation of hydrogen as indicated by the hydrogen-deuterium exchange reaction is studied on semiconductor surfaces containing foreign transition metal ions in certain oxidation states. New active sites have been identified with esr spectroscopy.

GEORGE M. HOMSY — Laboratory for Fluid Mechanics and Stability

This program has just been initiated and will have as one of its goals the treatment of applied engineering problems using a rational approach firmly based on continuum mechanics. Initially at least, the emphasis will be on theoretical analyses. Projects are contemplated in the following areas:

Fluidization — Although the motions of fluidized beds are felt to be describable by continuum equations, the exact form of these equations remains a source of controversy. In postulating constitutive equations for the bed and the mathematical form of the particle interaction terms, one is almost forced to rely on intuition. It is proposed to put the phenomenological treatment on a sound basis using results from suspension theory when possible. The problem of bubble genesis in fluidized beds will be viewed as a stability problem. Such an approach requires a wider interpretation of stability than the classical linear sense, and relies heavily upon energy considerations.

Stability of Thin Films — The flow of liquid films under the action of gravity and influenced by surface active agents is of central importance in chemical engineering. Although the linear theory of the stability of such films is reasonably well understood, the mechanism of the growth of disturbances to an equilibrium amplitude and the accompanying changes in heat or mass transfer rates have not been considered.

Rotating Fluid Mechanics — Rotating fluids seldom behave in a manner predictable from our knowledge of non-rotating systems. In many instances the fictitious Coriolis and centrifugal forces exert extraordinary control over fluid motions, making predictions of (say) the heat transfer behavior difficult. Studies of thermal convection and instabilities in geometries of engineering importance are contemplated.

JOHN E. LIND — Laboratory for the Study of the Properties of Fluids

This research is directed toward an understanding of the molecular structure of Newtonian fluids and of the relation between this structure and the transport properties. Momentum, mass and charge transport, as characterized by the coefficients of viscosity, diffusion and electrical conductivity, are of primary interest. The properties as well as the equilibrium thermodynamic properties are being measured over a wide range of temperatures and pressures for various model systems.

Fused Salts — Of prime importance is the question of how greatly the coulomb interactions in a salt melt or a concentrated solution contribute to transport in the melt. Contributions by these long-range coulomb forces are difficult to evaluate from theory. Therefore, an estimate of this contribution is being obtained experimentally by the direct comparison of the transport properties of nonelectrolytes with those of salts whose molecules are essentially isomorphic to the molecules of the nonelectrolyte except for the charge. This comparison is made with the solvent and salt at the same temperature and density. A comparison equilibrium thermodynamic properties such as the compressibility also gives indications of the differences in the microscopic structure of the liquids, and perturbed hardsphere equations of state are used to understand the phenomena.

Concentrated Solutions — The understanding of fused salts is being extended to the structure of salts when very small amounts of nonelectrolytes are added to the salts. Such solutions provide a very sensitive probe into the correlational effects arising from the coulomb field in the salt.

ROBERT J. MADIX — Laboratory for the Study of the Reactivity of Solids

The research in this laboratory is directed toward the study of collisions between gases and solid surfaces. In particular, modulated molecular beam techniques are employed to study corrosion processes which lead to the formation of volatile products. In addition, the energy transfer to solids accompanying exothermic solid-catalyzed reactions is being investigated. The objective of this research is the simultaneous determination of the energy accommodation and recombination coefficients of atoms on solid surfaces.

Molecular Beams — In order to study the elementary steps of adsorption and catalysis, gas molecules in well-defined energy states must be allowed to interact with well-characterized single-crystal surfaces and the ensuing reaction events observed. Furthermore, if reactions on the surface are to be understood, the nature of the surface intermediates must be known.

For such fundamental studies, the modulated molecular beam offers maximum definition of reactant conditions. A beam of gas molecules in a selected energy state is directed on a single-crystal surface and the reaction products are observed mass-spectrometrically. The beam is interrupted periodically by a shutter so that the product signal may be detected at a particular frequency. This a.c. detection technique allows the determination of rate constants on clean surfaces.

Energy Transfer in Reactive Collisions — The energy accommodation of hydrogen atoms recombining on solid surfaces was studied with a diffusion tube. Atoms were generated by an electrical discharge at one end of a closed Pyrex tube. Since the atoms recombined on a metal surface at the opposite end of the tube, a concentration gradient was established along the tube axis. Determination of this gradient allows calculation of the recombination coefficient on the metal surface. The energy accommodation coefficient was determined by measuring the heat input to the metal per recombining atom. It was found that, in general, the molecules formed left the surface

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hot. The energy accommodation was as low as ten percent in some cases.

DAVID M. MASON — Applied Chemical Kinetics Laboratory

Our group is engaged in research directed at a better understanding of the physical and chemical processes underlying combustion, direct energy conversion, and industrial reactions.

Heat Transfer in Reacting Systems — We are currently investigating the role chemical kinetics plays in the transfer of heat, mass and momentum in flowing fluids. With fast, exothermic reactions, unusually large heat-transfer rates can occur in such devices as chemical reactors, rocket chambers, and space-vehicles undergoing aerodynamic heating upon re-entry.

Oscillating Chemical Reactions — The mechanism of oscillating chemical reactions is being investigated with the sodium dithionite reaction in aqueous solution as the experimental model. An electron-spin-resonance spectrometer is available to detect possible oscillations in the concentration of free radicals that are present in this system.

Effect of Pressure on Reaction Rate Coefficients — The effect of very high pressure in increasing the rate coefficients of gaseous chemical reactions is being studied in an attempt to be able to predict in general pressure effects in reactions of industrial importance.

Fuel-cell Electrode Kinetics — The rate and detailed chemistry of the oxidation of hydrocarbon fuels at electrodes are a central problem in the generation of electrical energy by oxidizing readily available hydrocarbons on inexpensive electrode-catalysts at room temperature. With fuels like hydrogen and methanol, platinum is currently the best electrode material as far as giving sufficiently high reaction rates for practical use. We are attempting to learn more about the nature of electrocatalytic processes with selected hydrocarbons with the hope that a less expensive catalyst can be found for use in practical devices.

CHANNING R. ROBERTSON — Biomechanics and Environmental Sciences Laboratory

The objectives of the research program in this laboratory have a dual nature. One aspect of our work deals with the application of basic transport theories to biological systems, whereas the other stresses the use of these same theories in obtaining a better understanding of man's effect on the biosphere. A unique feature of this work is its interdisciplinary nature.

Biomechanics — In recent years engineers have been playing an ever increasing role in providing original and unique insight into the functioning of the human body. At Stanford we have established the Stanford-Ames Biomechanics Group to bring together the combined talents of people from several departments, Applied Mechanics, Aeronautics and Astronautics, Electrical Engineering, and Chemical Engineering. In addition, scientists from the Ames Research Center of the National Aeronautics and Space Administration and faculty from the Stanford Medical Center are also participating in the joint effort.

The primary goal of this research is to increase our knowledge of bodily processes which will then result in new and improved diagnostic techniques and prosthetic devices.

Our laboratory is planning to conduct studies in the area of hemodynamics, in particular, blood flow through pumps and valves. Important unsolved problems include wall-erythrocyte interactions which are thought to be fundamental to the formation of thromboses.

Environmental Sciences — It is a simple fact that no living system can survive in its own waste, and largely because of this, many researchers in various fields of specialization have turned their attention to seeking new ways of preventing further deterioration of our biosphere. The effort in this laboratory is focused on obtaining new knowledge about mechanisms of dispersion and transport of pollutants in the atmosphere, river systems, lakes, and oceans.

DOUGLASS J. WILDE — Optimization and Control Group

This group is engaged not only in establishing fundamental, rigorous principles in optimization, but also in applying these concepts to large, complicated industrial systems of economic and social importance. Optimization theory involves the mathematics of achieving economic minima or maxima.

Current theoretical work in optimization involves generalized polynomial optimization, direct elimination optimum-seeking methods, combinatorial optimization and optimization under uncertainty. □