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IMPRESSIONS OF ENGINEERING EDUCATION IN THE SOUTHERN TIER

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THERE'S A REVOLUTION in chemical engineering education in Brazil, Argentina, and Chile—the Southern Tier. It coincides with rising enrollments and expanding expectations. Leading the movement are dedicated engineers whose motives are predominantly idealistic and nationalistic. They and the younger rank-and-file look first of all to North America and Europe for models they can adapt to their own institutions. Increasing numbers of able Latin American engineering instructors are going overseas for postgraduate education, and in preparation for the roles they will play upon returning they need broader experience than they are likely to get today. In the Southern Tier the need is growing for visiting foreign professors who are not only effective teachers but also top-flight engineers and researchers.

These are among the most important impressions from a visit of a month-and-a-half I made in the fall of 1969. They are reinforced by reports reaching me by mail and from more recent travelers. During my visit I spent four weeks at COPPE, which is in essence the postgraduate school of engineering of the Federal University of Rio de Janeiro (UFRJ, known as the University of Brasil until the mid-1960's). There I taught an intensive short course in fluid mechanics, gave seminars, and interacted with the faculty in a broader sphere. Thanks to F. M. Tiller, in charge of the Agency for International Development contract with the University of Houston which sponsored my stay at COPPE, I was able to proceed on to Argentina and Chile, stopping en route in São Paulo and Pôrto Alegre in Brazil. D. H. Scriven, my wife, was able to join me before I left Rio. Since our return we have been asked how, as norteamericanos, we were received. We were received as individuals, welcomed with open arms and swept off our feet by wonderful hospitality. On no occasion in our peregrination did we encounter hostility.

Stark contrasts exist among engineering schools in South America. At COPPE a graduate school has emerged, rather loosely connected to its university. At São Paulo a once dynamic institution lies crippled in the middle of the most heavily industrialized area in Latin America. At Pôrto Alegre in Southern Brazil engineering appears to be antediluvian. At Bahía Blanca in South-Central Argentina an industrially-connected undergraduate quasi-department is leading a forward-looking provincial university. At Buenos Aires engineering has been emasculated and a beautiful, modern chemical engineering building stands empty of its planners, with only a skeleton of a modern faculty. Nearby at La Plata two departments that together are the strongest chemical engineering research center in Latin America harbor some of those who should be in the capitol. At Concepcíon in the industrial heartland of Chile a distinguished South American university limps along on lottery proceeds but nevertheless is, or was, evolving into a modern institution. The chemical engineering department, indeed the entire school of engineering, has come to rely on income from contracts for testing and development work for industry. Some of the faculty are refugees from the Universidad Técnica Frederico Santa María in Valparaíso, outstanding until it was severely disrupted not long ago (the first doctorate in engineering in Latin America was awarded there in the mid-1960's).

The norm in Latin-American universities was described in plain terms by Professor H. Moysés Nussenzveig, a Brasilian physicist now working in the United States. Anyone curious about the contrasts, or unimpressed by the achievements at COPPE, La Plata, Bahía Blanca, Concepíón, and two or three other places (Salta and Santa Fé in Argentina, Santiago in Chile), should turn to Professor Nussenzveig (**Science, 165,** 1328- 1332, 26 September 1969). He happens to include accounts of events in São Paulo and Buenos Aires among his examples. More recent episodes in Argentina and Brazil are subjects of N. Geschwind's and P. W. Wygodzinsky's letters (**Science,** 6 March and 3 July 1970; see also Vásquez and Robertis's letter 7 August 1970). A more detached, short but revealing description of most Latin-American universities can be found in a two-year old article by Tiller, a chemical engineer, and R. E. Hattwick, an economist (**Engi-**

Gold Medalist of the University of California at Berkeley in 1952, L. E. Scriven took his graduate degrees at the University of Delaware and was a research engineer with the Shell Development Company from 1956 to 1959. At Minnesota he is Professor of Chemical Engineering and a member of the Graduate Faculties of Fluid Mechanics and of Biology. Chief among his research interests are continuum theory of transport and transformation processes, dynamic instability and pattern interface and contact-line physics, and interphase transfer. In 1968 he was an invited speaker at the NATO Meeting on Transition from Laminar to Turbulent Flow in London, in 1969 at the National Heat Transfer Conference in Minneapolis. In March and April 1963 he was Guest Investigator in cell biology at The Rockefeller Institute; in Fall 1967, Visiting Professor at the University of Pennsylvania; in September and October 1969, Visiting Professor in the engineering graduate school, COPPE, at Universidade Federal do Rio de Janeiro, after which he lectured in Argentina and Chile. With C. V. Sternling he received the 1960 Colburn Award of the AIChE. In 1966 his university bestowed a Distinguished Teaching Award on him, and in 1968 he received the Chemical Engineering Division Lectureship Award of the American Society of Engineering Education. He is a consultant to Mobil Research and Development Corporation and the 3M Company, an advisory editor to the Prentice-Hall Series in the Chemical and Physical Engineering Sciences, and, as of recently, an associate editor of the *Journal of Fluid Mechanics*. With other enthusiasts he engages in a special experimental dynamics of a particle in a box — handball, which, like the mountain world, is a lifelong avocation and, it might be added, as strong an influence on his family as his vocation and travels.

neering Education, 58, 509-516, February 1968).

Incidentally, my chance conversation with a couple old-style 'professors' bore out all I had read and been told: they are semi-educated, intellectually stunted, professionally downtrodden men eking out a middle class income by marathon lecturing at two or three different universities. There are those with backbone, but they are almost certain to be fractional-time 'professors' whose commitment is to their income-producing activity outside the university. No wonder that Latin students often feel themselves better qualified than their teachers to govern a university! The shame is that engineering students have so long been accustomed to copying down dictated notes in interminable lectures and parrotting them back in examinations, never working a problem, that they are likely to object vociferously if not violently when young reformers get control of a curriculum and expect them to become genuine students. There have been disturbances on just this account, mild ones in Bahía Blanca and destructive ones, I gathered, in Santa Fé, Argentina and Valparaíso, Chile.

Here are reports on three institutions at which I visited longest. The reports are followed by some important conclusions.

COPPE-UFRJ

PROTECTED BY ITS PSEUDONYM, **Co**ordenacão dos **P**rogramas **P**os-graduacão de **E**ngenharia (= "Office for Coordinating Postgraduate Programs in Engineering"), is now a graduate school of chemical, mechanical, electrical, metallurgical, civil, naval, nuclear, production (industrial), and bio-medical engineering, with a degree program in applied mathematics and computer science the next likely addition. An outstanding feature is its utter informality: faculty, staff and students mix thoroughly, everyone is on a first-name basis—and the graduate students seem quite aware of the goals and workings of the operation. Today COPPE is housed is well-appointed, partially air conditioned buildings on the new campus, Ilha da Cidade Universitária, not far from the international airport. It was not always so.

Alberto Luiz Coimbra in 1960 was a relatively young professor of chemistry and chemical engineering who had taken an M.S. at Vanderbilt University in 1949 and who heavily supplemented his academic salaries from two universities with consulting and partnership in a small engineering design firm. Inspiration somehow seized him and with O.A.S. sponsorship he managed to tour U.S. chemical engineering departments early in 1961. He often says he was especially impressed with Neal Amundson's magic, which was then transmuting Minnesota. He turned to Frank Tiller of the University of Houston for liaison and secured support from the Organization of American States, the Fulbright Commission and the Rockefeller Foundation. He found a domestic source of funding in the Brasilian National Bank for Economic Development (BNDE), which eventually freed him from the internecine politics within the university and further insulated his organization. Coimbra launched a postgraduate program in chemical engineering in cramped quarters on the old campus in 1963. Donald Katz from Michigan and Louis Brand from Cincinnati visited and taught in the first year. So did Neil Pings from Caltech, for a six-week period. (Later came Ernest Henley, Ray Fahien, John Howell, and others for extended periods.) Two young Brasilian chemical engineers, Affonso Telles and Giulio Massarani, returned with M.S. degrees from University of Houston to teach. Telles later went back to Houston for his Ph.D., now heads the mathematics group at COPPE, and just spent a year at Imperial College. Massarani later went to Toulouse to begin his doctorate, which he is finishing with nice experimental research at COPPE on flow through porous media. Some who graduated with M.S. degrees that first year are very much in evidence, notably Carlos Perlingeiro, who came back with a Ph.D. from Stevens to head the chemical engineering program.

Each year the best graduate students are singled out for appointments as "monitors" (teaching assistants, roughly) and often are invited to plan on joining the faculty. The pattern is to spend a year or so as an instructor after receiving the M.S. and then, seasoned and well-motivated, to go overseas for the doctorate. From chemical engineering there are men at Imperial College, Leeds, Stanford, and Minnesota right now. I was told that so far everyone who has completed a doctorate has returned to COPPE, which is a remarkable departure from the past record in Latin America. A few instructors have continued graduate study at COPPE, and the first Ph.D., are being awarded this year. The recipients are likely to go abroad for a year of post-doctoral study.

From 20 to 30 students each year enter chemical engineering, 55% completing two semesters of course work and 45% actually receiving the M.S., which requires a thesis (the total enrollment in all branches at the beginning of last year was 190 full-time students plus 185 part-time, production engineering being most popular by a fair margin). In chemical engineering, at least, all the students received fellowships, the stipends of which start low and rise rapidly with achievement. The best graduate students are very good indeed. A couple years ago COPPE began to send recruiting teams all over Brasil. Pairs of faculty members fly to a region and visit every undergraduate department in their field (more and more departments have COPPE alumni returning to their staffs, by the way.). Almost unconsciously they are making COPPE a communications center for modern engineering in a country where one of the major hindrances to development is poor communications. Goading them on is a new element of competition: PUC, the Pontifícia Universidade Católica do Rio de Janeiro, has started a graduate program in engineering (though not yet in chemical engineering) and last year began to beat the bushes.

One thing that helps attract students to COPPE is the availability of foreign professors there. I met long-term visiting professors from the U.S., Great Britain, Canada, France, Soviet Union, and Germany, most of them sponsored by their governments. U.S. aid of this sort has diminished of late. I was impressed by the fact that the program heads at COPPE are quite deliberately drawing on visitors for philosophies and practices of foreign educational systems, selecting from them, and synthesizing their own schemes.

ANOTHER IMPORTANT THING is the quiet, long-term campaign to reform undergraduate engineering education in the Federal University of Rio de Janeiro. A few professors in COPPE have gotten membership in the faculties of chemical engineering, engineering or mathematics, and each year more manage to do so. Already metallurgical engineering has fallen to them: Walter Mannheimer, who has degrees in chemical engineering and industrial chemistry and a Ph.D. in metallurgy from Carnegie-Mellon and is one of the brightest lights in COPPE, heads the undergraduate department as well as the graduate program. Naval engineering has also been captured, and chemical engineering will probably be next.

COPPE has not had close liaison with industry. In chemical engineering there is little industrial support except for partial sponsorship of a research project on permselective membranes by BNDE and Petrobras (the national petroleum production and refining combine) involving three or four people, a project on sulfur from coal pyrites sponsored by the National Coal Commission, and a small project concerned wth maleic anhydride manufacture. Moreover the faculty is deficient in industrial experience and contacts. But Coimbra has been trying to set up an industrial research institute, referred to as "COPPETEC," which could go a long way toward rectifying the situation. Unfortunately the dominant industrial center is São Paulo, and there is strong rivalry between that city and Rio.

COPPE: PROGNOSIS

IN 1969 COPPE WAS providing fairly sound M.S. degree programs for training modern engineers and teachers of engineers, except that more emphasis on laboratory, design, and practical problem solving was needed. The ultimate goal was, and is, to educate creative engineers and professors of engineering who measure up to the world's best and will lead Brazil's future technological development. Whether Professor Coimbra's brainchild, now in vigorous adolescence, will develop to its full potential and achieve the high standards he is aiming for is not clear. On the one hand he has built up a competent, enthusiastic, cooperative, fulltime, young staff; those selected for leadership responsibilities are dedicated and conscientious; twenty future staff members are doing postgraduate study overseas; there are some excellent students and, judging from their competence, they have had well-conceived and well-taught courses; the facilities are new and there seem to be no critical shortages of space or funds for equipment; graduates are taking positions throughout Brasil; and now students are being attracted from other countries. Though there is no longer a great need to rely on visiting foreign professors in chemical engineering there are many of them, especially in other fields. On the other hand, the financial basis seems temporary and the relationship with undergraduate education in the university regrettably weak; the programs probably still fall short of true university standards, particularly in the domain of research; the present faculty is overburdened with classroom teaching as well as all the demands of building a new institution and their opportunities for scholarly study and exploring new research directions are few; maintaining contact with mainstreams in the Northern Hemisphere is expensive; library facilities though considerable are still spotty and present arrangements are insufficient for high-quality engineering research; staff members returning from overseas in the future may be in danger of disappointment because they may not share as deeply in the pioneering spirit that is still evident; there is no formal laboratory instruction although many of the incoming students are severely lacking in laboratory experience; there seems to be insufficient emphasis on design in some of the programs; connections with public and private industry need to be greatly strengtheened and many younger faculty members need more firsthand experience with practical engineering. They should also have more and better opportunities to estimate the present and future needs of Brasil. All of these things are evident to Professor Coimbra and his staff.

PLANTA PILOTO

BAHIA BLANCA, A prosperous commercial, agricultural (grain and livestock), and transportation center, is the most important city in southern Argentina. Located on the coast 700 km. south of Buenos Aires, it strikes Southwesterners as Albuquerque-by-the-Sea and reminds Canadians of Saskatchewan. It has two petroleum refineries and plans for a major chemical complex. What was comparatively low level technical college became the base on which, beginning over a decade ago, Universidad Nacional del Sur is being built. There has never been a faculty of law, a faculty of medicine or a faculty of philosophy and so the new university has some enormous advantages over older Latin American institutions. It is fertile ground for educational reforms though the harvest so far seems a mixed bag.

Into this situation about six years ago came Ingeniero Enrique Rotstein, an Argentinian fresh from two years' engineering with Monsanto in Springfield, Massachusetts — a most unusual young man, full of vision and ambition and drive and, as it has turned out, skill in dealing with his elders and an uncanny gift for inspiring his contemporaries and juniors. Within the Departamento de Química e Ingeniería Química he has built what is really a department of chemical engineering and an engineering development laboratory, with a full-time professional staff of about 15 enthusiastic and dedicated young men and women (2), almost all of them from Bahía Blanca and surroundings. But of course it cannot be called what it is—Rotstein's "principle of being a nonentity," which explains certain features of COPPE, as well. For obscure historical reasons, it is the Planta Piloto de Ingeniería Química, and this name is now borne proudly.

All of the staff salaries are paid by the university, but most of the rest of the support comes from industry. The drawing card has been research on effects of agitation by mechanical vibration on transport phenomena and reactor performance, and development of novel apparatus for producing agitation. Engineer Rotstein and his colleagues have revolutionized the undergraduate curriculum in chemical engineering in both style and content, bringing it into the 1960's and doing so with due regard for Argentina's needs. Yet many of the students did not understand and there were problems with them. The best of the students each year have been recruited into the faculty and now, after much deliberate effort, there is good rapport with the undergraduates.

The undergraduate curriculum has been cut from seven to six years, five of which are spent in course work. Eight months of the sixth year are spent in research and then there is a three-month training period in some industry. In chemical engineering the number of classroom hours has been reduced drastically, courses have been consolidated and modernized, textbooks have been introduced and problem solving has been emphasized. In comparison with U.S. curricula, the extra year of study represents subjects important to a plant engineer who must design and specify equipment by himself and immediately play business and management roles as well. The overall level approaches that of many U.S. Master's degrees.

In regard to faculty development Rotstein's program calls for staff members to go overseas once for an M.S. degree, as four have done and others are doing, and then again later for two years of additional study or possibly for a doctorate. Those who have already been seem to have done well: they are an impressive lot. Some tell of the trauma in adjusting to overseas university standards—Rotstein says "cultural shock"—and then of readapting when they return—Edgard Vieira in Rio speaks of the "re-entry problem."

Despite comparatively enlightened administration and many reform-minded individuals Universidad Nacional del Sur still suffers from the traditional afflictions of Latin American universities. Because all appointments down to and including department head are at the pleasure of the Minister of Education in Buenos Aires, whose tenure in office is generally much shorter than even that of the President, the administrative structure cannot help but be permeated with politics, diluted only a bit by distance from Buenos Aires. Since my visit there have been at least two changes of rector (university president). To have the continuity to build anything substantial it is necessary to be a nonentity—a pilot plant, for instance. Recent news that Enrique Rotstein may have to become department head is probably not good news!

DEPARTMENTO DE INGENIERIA QUIMICA

THE NORTHERN CALIFORNIA coastal zone is mirrored by the region around Concepción. The region is also the industrial heartland of Chile: coal mines, steel mill, textile factories, glass manufacture, paper mills and wood products, fisheries (including a whaling station), hydroelectric power, and now petroleum refining and the Petroquímica Chilena complex. Progress in Escuela de Ingeniería, Universidad de Concepción, seems to have been more evolutionary than elsewhere I visited. Established faculty members have taken the lead and strongly encouraged younger men. The Ford Foundation and other international organizations have assisted. From Departmento de Ingeniería Química, Professor Gustavo Pisarro, one-time dean of engineering, and Professor Alfredo Searle, head of the department, have visited Minnesota and elsewhere in the U.S.

In addition to Searle and Pizarro there are four other full professors. Their fields are thermodynamics and kinetics, corrosion and electrochemistry, textile technology, and wood technology. These activities include testing and development laboratories that bring in funds from industry which are vital to the operation of the department. The production manager of the local oil refinery, which is only five years old and is still expanding rapidly, is a part-time professor. Searle himself does a lot of design work as a consultant specializing in drying processes and fishmeal processing (as he points out, Chile is still somewhat surprisingly deficient in protein). Sometimes he assigns parts of his problems to students in the design course. Thus the chemical engineering department at Concepción enjoys intimate relations with industry and has for many years.

Searle studied for a year at the University of Michigan in the early 1950's. In his department he built a very good unit operations laboratory along traditional lines, but by the mid-1960's he was installing smaller apparatus to illustrate transport phenomena directly and now his younger colleagues are doing the same. There are five of them, bright, sound, and committed to the enterprise. Two have come back recently from the U.S. with M.S. degrees, and others are to go overseas for graduate study in due course. One of the department's outstanding former students, Fernando Concha, returned with a Minnetosa Ph.D. in mineral dressing and rapidly rose to a professorship in metallurgical engineering.

Almost all of the graduates of the department have been snapped up by Chilean industry, I was given to understand. The curriculum was extensively revised around 1966 after Searle's visits in the U.S. It still requires six years, of which much of the first would be considered preparatory by current U.S. standards, and most of the last is devoted to business and management subjects, besides a "senior thesis" and a free elective. Elsewhere in the curriculum there are courses in strength of materials, industrial construction, electrical engineering, machines, control, basic measurements, instrumental analysis, etc. But the core is mathematics, physics, chemistry, and the same basic chemical engineering courses that are found in Northamerican departments that have managed to avoid faddish extremes in their development.

The traditional afflictions are not absent. A student strike in 1969 interrupted all classes for weeks and the second semester had to be postponed a month. While the engineering professors lay the blame on students and non-students in other parts of the university, the school of engineering is subject to its own brand of student pressures owing to the existence within the same institution of a "technical university" which awards another kind of engineering degree after only four years of study (as against six). In the last few years there has been rapid turnover of deans and rectors, (all of them elected by students, staff and faculty. One able and respected reform rector simply resigned and left when disruptions became acute and additional problems loomed. According to later reports from Concepción, the debilitating turmoil continues in the university. Engineering in Concepción, even more than in Bahía Blanca, Rio, and elsewhere, will be able to make greater social contributions when day-to-day functioning of the university is insulated a bit from searing political winds—if that ever happens!

SOME CONCLUSIONS

A revolution in engineering education is in progress in Brazil, Argentina, and Chile. Though the movement is still fragmented it has sufficient momentum to reform applied science and engineering in those countries, from what I have been able to learn. Common features of the best developments seem to be inspired leadership, youthfulness, total commitment, concern for students, overseas connections, financial support independent of university and government, and political transparency. (A coincidental feature is many people who speak fluent English, thank goodness.) The motives of the leaders are predominantly idealistic and nationalistic. They are imbuing talented young people with their vision and confidence and they are providing them with the necessary education, first at home and then overseas. Irrespective of political stripe all three governments have powerful arms working seriously for technological development. (General educational development unfortunately lacks such advocates.) Talented and well educated engineers are going to be needed more and more for planning, design, management, development and, eventually, research (beyond research as a concomitant of teaching). One of the aims mentioned in all these countries is to begin offsetting the vast importation of technology, which is quite costly in several regards. The more visionary leaders are hopeful of leapfrogging into the international market of technology, by bringing sophisticated modern science and engineering to bear on problems that have facets peculiar to the geographical, economic, or cultural state of their own and similar countries. In my understanding Japan is the nation that has been notably successful in this regard and it may be that Latin American engineering educators should examine the Japanese experience more thoroughly.

The new breed of engineering professors looks first of all to the United States and Great Britain for models on which to pattern undergraduate curricular reforms and new postgraduate programs. Those who visit overseas are generally mature enough to remain critical of what they encounter, and now they are returning to groups more than sophisticated enough to select and adapt ideas best suited to their own circumstances.

Young faculty members coming to the United States and other countries for graduate study should get broader experience in preparation for the roles they will play at home. For chemical engineers I have in mind summer jobs and temporary jobs just before returning, in the chemical, metallurgical, pharmaceutical, and food processing industries, in research institutes, in government laboratories, and in planning agencies of international organizations such as the UN and OAS. I also have in mind professional meetings, research conferences, visits to plants and laboratories, etc. I wonder about courses and seminars within the university which might have special relevance to developing nations in general and Latin America in particular. It seems unlikely that ordinary courses in management, finance, economics and planning would be suitable. Perhaps with a nucleus of graduate students in engineering from Latin America a university's Office of International Programs could precipitate a worthwhile seminar course. With addition of interested local faculty and invited authorities from outside the university it might grow to dimensions visible from south of the border.

Engineering departments receiving graduate students from Latin America should give more thought to their needs. At the same time, engineers applying from Latin America need more information about programs, departments and universities not only in the U.S. and Great Britain, but also Canada, The Netherlands, and elsewhere. Returnees are comparing experiences and spreading the word that not all departments are equally solicitous of graduate students, not all professors are equally accessible, not all programs are of equal quality, not all universities provide equally stimulating intellectual atmospheres, not all past reputations match current realities.

There is growing need in Rio, La Plata, Bahía Blanca and undoubtedly elsewhere in Latin America for visiting professors who are not only effective teachers but also first-rate engineers and researchers. They must be friendly, forward-looking, and flexible, and they are likely to be appreciated even more if they are willing to wrestle with a little Portuguese or Spanish, and if they can manage to find in their homeland some of the travel funds and financial support they may require. Such persons can, by spending a month, or a quarter, a semester or more, give a real boost to the educational revolution in the Southern Tier.