AN INTERNATIONAL SYMPOSIUM ON INSTRUCTION IN THE MECHANICS OF FLUIDS

SYMPOSIUM INTERNATIONAL SUR L'ENSEIGNEMENT DE LA MÉCANIQUE DES FLUIDES

HYDRAULICS AND FLUID MECHANICS IN LATIN AMERICA

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1. Introduction.

Latin America, the continent stretching from the Río Grande to Tierra del Fuego, is a variegated mosaic of more than a score of countries with total area, natural resources, and population matching those of North America. In most other aspects, the two Americas are quite different, and will probably become more so; as North America seems to approach an asymptotic state of uniformity, heterogeneity appears to be the destiny, if not the choice, of Latin America. It is not easy to treat Latin America as a unit; just because those nations have practically a common language (Spanish and Portuguese, the two dominant tongues, are very similar), the same religion, and rather analogous socio-economic problems, one should not conclude hastily that they are alike in every other aspect. Thus, even when dealing with such a restricted subject as the development and present status of hydraulics and fluid mechanics in Latin America, one finds it necessary to subdivide the continent into several areas. It is only when on ponders on what is not being done, as opposed to what is being done, that a unified treatment becomes plausible.

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2. Early developments.

What is known about early developments of science and engineering in Latin America shows that they followed a saw-tooth line with many ups and downs (Maggiolo 1965). The first universities in the Americas were established by the Spaniards during the sixteenth century; after two centuries of what appears to have been a quiet life, they were thrown by a series of revolutionary actions into a long turbulent period not devoid of a mean supporting flow. At least three of the university revolutions, or reforms, were of great importance. The following words of Caballero y Góngora, Archbishop-Viceroy of Nueva Granada, describe tersely the eighteenth-century reform; "The whole object of the plan is to teach the exact sciences in place of the merely speculative, upon which too much time has unfortunately been wasted hitherto" (Arciniegas 1961). The second reform was brought about by the wars of liberation and the ensuing political independence of Spanish America; old universities were reorganized, and new schools, some destined to a short life, were created to satisfy new needs. The third important reform sprang in 1918 at the already three-century-old *Universidad de Córdoba* (Argentina), and rapidly spread throughout Latin America. Research,

as one of the essential functions of the universities, was one of the goals of the young reformist professors and of the students of 1918; that they were not successful on a large scale is one the tragedies of the university life in Latin America. What they strived for may still be achieved in the near future as a result of the efforts of few isolated pioneers who, in different fields and many times under adverse conditions, established a tradition of scholarly research and study in Latin America. To this, one should add the effects of the policy, that one government after the other is adopting, of founding national councils of scientific and technical research, and of sending an increasing number of persons for advanced studies and training in Europe and the USA.

A number of schools of engineering were created in Latin America during the second half of the past century; in these schools the basic course on fluids was one on general hydraulics—*hidráulica general,* or simply *hidráulica*—in the style of Flamant's *Hydraulique,* Forchheimer's *Hydraulik,* or De Marchi's *Idraulica* more recently. The notes for the courses of hydraulics in *Universidad Nacional de Buenos Aires* and *Universidad de Chile* at the beginning of this century showed a strong French influence, especially from Boussinesq's *Théorie des eaux courantes.*

The oldest schools of hydraulics in Latin America seem to be those at Santiago de Chile (*Universidad Católica* and *Universidad de Chile*) and at La Plata (*Universidad Nacional de La Plata*). In the early 1910's a small instructional hydraulics laboratory (the firts in Latin America) was organized by Ramón Salas Edwards, professor of Hydraulics at the *Universidad Católica.* Salas (1915), in his lithographed notes of 1912 and 1918, and in a paper presented before the Second Pan American Scientific Congress (Washington 1915) introduced independently from B. Bakhmeteff the concept of specific energy, and applied it to open-channel flow. He was the pioneer of modern hydraulics in Chile, and in Latin America through his school mainly represented by Francisco J. Domínguez, one of his students and the author of a highly original book. Domínguez's *Hidráulica,* which has seen three editions of increased content, presents the results of original experiments performed during several decades at the Hydraulics Laboratory of Santiago de Chile by Domínguez and his students. The school of hydraulics at Santiago was for a long time the only one in Latin America with a graduate program.

The school of hydraulics at the *Facultad de Ciencias Fisicomatemáticas* in La Plata was established in 1912; soon plans were made for a hydraulics laboratory with both instructional and research sections (Soldano 1923), but construction was delayed for a long time. In the early twenties, a building was erected only to be abandoned just when experimental work could have been started. It was only by 1939 that a hydraulics laboratory was inaugurated in La Plata. About that time, another laboratory was established at the other end of Latin America, in México (Levi 1963). Both La Plata's and México's laboratories were, for many years, mainly devoted to model studies.

Another early effort in Argentina goes back to the early 1910's, and it seems to have been an important and well directed research activity judging by the doctoral dissertation of Trifón Ugarte (1913) on the subject of turbulent flow of different substances in capillary tubes. Ugarte—who, incidentally, was well conversant in dimensional analysis—found effects due to the chemical structure of different substances which seem to anticipate more recent results on non-Newtonian behavior. Ugarte's advisor, Professor Walther Sorkau, had conducted research on the same subject four years before at the *Escuela Superior de Fisica de La Plata.* To the author, a native of Argentina, it is sad that this brilliant effort had to die at its very inception.

3. Present situation.

Through the initiative of the author, a survey of engineering education in South America, in the area of hydraulics and fluid mechanics, was undertaken three years ago by three young professors: Mr. Horacio Caruso of Argentina, Mr. Alberto Lizarralde of Venezuela, and Mr. Souza Pinto of Brasil. The first and the second covered the south and the north of South America, respectively; the third, his own vast country. Still needed is a survey in Central America and Mexico; for this region, the author will provide a description based mainly on his visits to two of its countries and on his contacts with some teachers and students. He will also assume responsibility for selecting and summarizing parts of the reports by Caruso (1966), Lizarralde (1966), and Sousa Pinto (1965). For this purpose, Latin America will be subdivided in four areas designated below with Roman numerals.

3.1. Area I.

The countries surveyed by Caruso were Argentina, Chile, and Uruguay; no information could be gathered on Bolivia and Paraguay. The three southernmost countries in Latin America have in common strong European immigrations and influences which reflect in the ways of life, and of teaching and learning. Typically, the courses are annual, from March to November, with three hours weekly for lectures, and another three for discussion, problems, or laboratory. The standard sequence for Argentine engineering students is two years of basic science (sometimes together with students of physics and mathematics), two years of basic engineering sciences, and two years of applied subjects.

The way of approaching hydraulics and fluid mechanics in Argentina and Uruguay is determined by the manner in which physics and mathematics first, and then analytical mechanics, are taught to engineers. What has been considered as revolutionary recently in USA—"mechanics with vectors and even tensors"—was practiced in La Plata University as early as in 1933; in addition, Lagrange equations, and introductions to Hamil-

tonian methods and to continuum mechanics were already topics of the standard courses of mechanics taught to students of engineering. Mechanics is usually taught by mathematicians or physicists; fluid mechanics and hydraulics, instead, are taught by engineers, and, depending on their background and professional activities, they may present the subject either as a basic or as an applied engineering science.

According to Caruso, the most common course in fluids in Area I is still the classic *hidráulica general;* however, in some of the Argentine universities several other fluids courses, as aerodynamics, gas dynamics, transport processes, fluid mechanics for meteorologists, are also taught. Engineering students taking one or more of these courses are enrolled in aeronautical, civil, electrical, highway, hydraulic, mechanical, naval, or petroleum engineering. In addition, some of the applied courses contain sections on special topics of fluid mechanics like gravity waves, porous media, transport of sediments, non-Newtonian fluids, and magneto fluid dynamics. It is perhaps of interest that dimensional analysis and similitude were introduced in Argentina and Uruguay not only by hydraulic and aeronautical engineers but also by physicists and applied mathematicians.

Laboratory instruction, when imparted, may include: flow vizualization, use of instruments, laminar and turbulent flow in pipes, hydraulic jump, orifices and weirs, non-uniform flow in pipes, lift and drag, flow with density stratification, flow through porous media, electrical analogy. The type of experiments for laboratory instruction is sometimes determined in response to regional characteristics and needs; for instance, open channel flow may be emphasized in arid and semiarid regions in which irrigation systems are of utmost importance. This influence appears very evidently in Domínguez's *Hidráulica,* and in the laboratory instructions of the *Escuela de Ingeniería of Santiago de Chile* (Muñoz 1962). Laboratory instruction plays an important role in Chile and Uruguay, and in some of the Argentina's schools; among the latter, the *Universidad Nacional de Cuyo* offers since 1943 a course on experimental hydraulics in addition to two courses on general and advanced hydraulics, each with laboratory instruction (Macagno 1964).

According to Caruso again, the use of a single text-book for each course, typical of North American universities, is an almost unexistent practice in Argentina, Chile, and Uruguay; books used in basic course of hydraulics or fluid mechanics in at least two universities are those of Addison, Balloffet (1953), De Marchi, Domínguez (1959), Escande, A. H. Gibson, Rouse, Streeter, and Vennard.

3.2. Area II.

In the countries of Colombia, Ecuador, Perú, and Venezuela, there are at least eleven universities in which either hydraulics of fluid mechanics, or both, are taught. Only five of the eleven universities have instructional laboratories for those subjects, but in some cases—as in the very well run laboratory at the *Universidad Nacional de Ingeniería* in Lima—students from two or three schools make use of the same facilities. In Area II, there is a stronger contemporary foreign influence than in Area I; four of the laboratories have been constructed abroad, either in France or in the USA.

According to Lizarralde, some of the professors adopt a single text-book, but most of them still follow the traditional Latin American approach of listing several books and letting the students select those to be used in their study of the subject; the books most often recommended are Becerril, Domínguez, Rouse, Rubio San Juan, Streeter, and Vennard. A few professors prepare mimeographed notes, but the author is not aware of any book on fluids published in this area. Fluid mechanics is slowly being accepted in Area II as a basic engineering science that should precede hydraulics and other specialized fluids courses. There is an incipient activity towards the development of graduate studies in the colleges of engineering, and in some of them a thesis, or a monograph, is required before a diploma in engineering is granted.

3.3. Area III.

In Brasil, engineering is usually taught in special schools which are now part of universities, (some schools were created much before any university would exist in Brasil); but they are not incorporated into colleges of exact or physical sciences, (as in Argentina). Graduate studies for engineers are practically nonexistent, but the requirement of a thesis for professorial appointments has introduced a sort of graduate activity at least in relation to educational, and to a certain extent, research activities. Hydraulics, or fluid mechanics, is taught in Brasil in at least forty schools of engineering, and courses exist, or are being established, in some twenty more schools of chemical, forestal, and agricultural engineering; even in a school of architecture there exists a course on hydraulics.

Hydraulics was taught in a classical French manner in Brasil for many years, but now the trend is one of teaching fluid mechanics as a basic modern science, and hydraulics as an engineering science (Macagno 1966). En 1962, the Brazilian Federal Council of Education passed a resolution adopting fluid mechanics as compulsory for all engineering curricula in the country; hydraulics was classified thenceforth as a subject typical of civil engineering. Apparently, the council recommendation is being adopted with some deliberateness, but a good number of schools offer already fluid mechanics in place of the classical course of hydraulics. In Brasil, fluid mechanics is taught to aeronautical, chemical, civil, electrical, highway, industrial, mechanical, metallurgical, mining, naval, nuclear, and petroleum engineers. Hydraulics is taught to civil and sanitary engineers. The most frequently used books are Azevedo Netto, Balloffet, De Marchi, Nogueira Garcez, Rouse, Streeter, Trindade Neves, and Vennard.

Sousa Pinto reports that nearly half of the engineering schools in Brasil have facilities for laboratory instruction in hydraulics or fluid me-

chanics. Detailed information on instructional programs in Brasil has been obtained only in few cases. A course for mechanical and naval engineers at the *Universidade de São Paulo* includes physical properties of fluids, statics and kinematics of fluids, Navier-Stokes equations, potential flow, vortex motion, boundary layer (dynamic, thermal, and diffusive), dimensional analysis and similitude, flow in conduits and open channels, flow through porous media, gravity waves, pressure waves, lift, drag and propulsion, cavitation, lubrication; ten well-planned experiments for these subjects are included in this course. In addition to this laboratory, the author has visited the instructional hydraulic laboratories at the same university of São Paulo and at the *Instituto Militar de Engenharia,* in Rio de Janeiro; both offer a good set of experiments to be performed by the students.

3.4. Area IV.

In Central America, the status of hydraulics and fluid mechanics bears resemblance to that of Area II; foreign influence comes mainly from USA, and, very recently, from Mexico. Within Latin America, Mexico has a rather old tradition in engineering; Germán Arciniegas (1961), reports that, in the eighteenth century, Mexico's School of Mines was the best in the Spanish world.

As is common in Area I, in México there is a strong trend to do things by one's self. The author has visited the instructional facilities at the *Instituto Tecnológico de Estudios Superiores* in Monterry and the hydraulics laboratory of the *Universidad Nacional Autónoma* in the capital city of México, and in both places he could detect a strong and independent concern for the establishment of instructional laboratories in fluid mechanics and hydraulics, respectively. The *Universidad Nacional Autónoma de México* has created, in 1957, a division of advanced studies in the college of engineering; this department is now designated *División del Doctorado,* and is the equivalent of a department of graduate studies. Master-of-Science degrees are already granted, and some of the students have already initiated work at the doctoral level. The courses offered at the *División del Doctorado* in the realm of fluid mechanics are: General Hydraulics, Transients in Hydraulics, Fluid Mechanics, Classical Problems of Fluid Mechanics, Hydraulic Models, Stochastic Processes in Modern Hydraulics, Turbulent Flow, Numerical Methods in Hydromechanics, Theory of Boundary Layers, Processes of Filtration, Diffusion and Sedimentation.

A book has been published recently by the *Universidad Nacional Autónoma de México* for use as a text of fluid mechanics (Levi 1965); the content of course and text is briefly the following: dimensional analysis and the theory of models, theoretical foundations of fluid mechanics (including Navier-Stokes and Reynolds equations), dynamics of inviscid fluids, mechanics of gravity waves, flow through porous media, flow in conduits, drag and lift, wakes and cavities. By USA standards, this book ranks between the intermediate and advanced levels, and would probably be considered appropriate for a theoretical course leaning more towards hydrodynamics than fluid mechanics.

4. Conclusion.

What is not being done, in contrast to what is being done, is the aspect that strikes most of those who examine the status of any field of endeavour in Latin America. This reaction is not foreign to those Latin American professionals returning to their native lands after being exposed to, or participating in, activities in technologically advanced countries. It is only natural that they voice acerb criticisms leveled at institutions or persons not doing what one would think to be the most logical things to do. Why are graduate studies not established, or if established, why are they not properly stimulated and supported? Why is basic research neglected? Why does industry not help to improve the education of those professionals that it is going to employ, or has already employed? These and scores of other similarly reproachful questions are formulated all the time.

In spite of the atmosphere of frustration that one detects in most of Latin America, I would like to ring an optimistic note in closing this article. To one who over a span of three decades has seen an ever growing activity in hydraulics and fluid mechanics in his own native country and in a good number of the other republics of Latin America, it is obvious that a great deal of progress has been made; it appears to him that the saw-tooth line used by the Rector of the *Universidad de la República,* Uruguay, to describe developments in Latin America is now definitely one of a growing ascendent average slope. Surely, there are still many things that are not done, or done only at too low pace, or too small scale. It is easy to name them: there is little research activity at the universities, and it involves but a handful of students; the thrust and pride of the pioneers in doing things by themselves does not seem to have been transmitted to many of their successors; the fecund activity that brings together professors and students in graduate programs is rarely seen; the ambition and the work essential in developing new ideas and methods, new techniques and instruments, are not powerful enough. In addition to these desired facts and qualities, one would like to see more official and private support for the creative activities of universities and research centers, and a continuous and growing financial support to libraries, laboratories, and specialized journals. In the realm of fluid mechanics, one misses modern text-books and reference books; one sees a much better and abundant production of books on mathematical subjects, for instance, and wonders why Latin American professors of mathematics are more productive than their colleagues in fluids; the same comparison can be made regarding publications in scientific and technical journals, although there is now an increasing number of papers on hydraulics and fluid mechanics coming from Latin American authors both in

their own journals and in European and USA journals.

An encouraging aspect of fluid mechanics and hydraulics in Latin America is the increased contact among professionals and teachers occurring in the present decade. Very significantly, it was the Chilean school of hydraulics that called for the First Latin American Seminar on Hydraulics and Fluid Mechanics in 1962. Since then, two more meetings have brought together hydraulicians of Latin America in regional congresses under the auspices of the International Association of Hydraulic Research, in which entire sessions were devoted to teaching and research problems in hydraulics and fluid mechanics. Three future congresses are already scheduled (Buenos Aires 1968, México 1970, Lima 1972), and hopefully the subject of teaching and research methods and policies will continue to attract the interest of the hydraulicians. Fluid mechanics was less fortunate, in the sense that no second seminar or meeting has been scheduled yet; such a meeting appears as very desirable because, obviously, the hydraulics congresses do not appeal to mechanical, aeronautical, chemical, naval, and sanitary engineers, nor can they be expected to attract physicists, meteorologists, oceanographers, or physiologists interested in fluid mechanics.

The field of hydraulics and fluid mechanics in Latin America appears as one in which there is a ferment and a potential for important future developments and accomplishments; what has been done by a few pioneers should now be done by a large number of teachers and researchers; a good number of schools, in the deep sense of the word, should be formed as centers in which the oldest of the chain reactions, that of masters and apprentices, would be put to work.

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Gravure du XVI^e siècle