

Horizons in Chemical Engineering*

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Dedicated to Professor August Guyer

Summary

Looking back over the last five decades the development of modern Chemical Engineering is traced. Some of the more important milestones in the development are pointed out and it is noted that Professor AUGUST GUYER has been actively engaged in Chemical Engineering through practically this whole period. The possible future course of Chemical Engineering in the light of some of the newer technologies is examined.

During his active industrial life Professor AUGUST GUYER has lived through almost the whole development of the field of Chemical Engineering as we understand it today. To many of us who have watched the growth of this important engineering area a plateau seems to have been reached. Older engineers feel some uncertainty as to which direction future developments will take while faculty and students in our schools are uncertain as to what future curricula should cover, some even going so far as to question whether Chemical Engineering can hold so important a place in years to come as it did in the past fifty years.

Having reached such a plateau it is both interesting and instructive to look back to the horizon of fifty years ago and forward to the decades ahead.

Fifty years ago the American Chemical Industry was in its infancy. The chamber process for making sulfuric acid was widely used and those plants making acid by the contact process were largely designed and indeed often the equipment was built in Germany or Russia. I remember the problems that arose in one American contact sulfuric acid plant when the foreign produced platinum catalyst went dead and no more could be had from the original source. Nitric acid was made by reacting Chile sodium nitrate with sulphuric acid in a batch process. Dyestuffs and pharmaceuticals were made mostly batchwise largely in Germany and Switzerland and in the United States a true organic chemical industry did not exist. To obtain a thorough training with a chemical background the preferred places of study were largely Switzerland or Germany. But even in these countries chemical engineering as such was in a most elementary stage.

To be sure WILLARD GIBBS had already enunciated many of the principles on which the field of Chemical

Engineering was to be built but his writings were in a little known publication (*Transactions of the Connecticut Academy 1873-1878*) and passed unnoticed by engineers for a good twenty to thirty years. Such in brief was the scene when young AUGUST GUYER started as a Chemical Engineer. Little did he realize how much he was to contribute to the growth of this field and to the influence he was to exert on many of its future leaders.

In the past fifty years amazing progress has been made in developing and placing on an industrially important basis many Chemical Engineering principles. In fact, the whole field is but little older than fifty years. Borrowing largely from classical physics and physical chemistry, in the United States the field of Chemical Engineering developed rapidly and expanded in importance to such an extent that today it touches and influences practically all industrial activity.

It is interesting to review briefly some of the more important areas which have contributed to such rapid growth.

Without doubt the enunciation of the so-called unit operations and their statement as quantitative mathematical relations (although admittedly containing empirically derived coefficients) was of great importance in furthering chemical engineering design to an extent such that plants, many operating on a continuous basis, could be designed and their operation foretold with certainty. The classical text in this area was *Principles of Chemical Engineering* prepared by W.H. WALKER, W.K. LEWIS and W.H. MCADAMS in the early nineteen twenties.

The employment of high pressure in industrial chemical syntheses, largely an outgrowth of HABER's successful development of a high pressure process for catalytically synthesizing ammonia from hydrogen and nitrogen, became widespread.

By catalytically oxidizing synthetic ammonia to nitric oxide, nitric acid processes were developed for producing this acid in a very pure state and not dependent on Chile sodium nitrate as a starting material. This opened a whole new area of industrial organic synthesis and in addition by making synthetic fixed nitrogen available at a low cost gave to the farmer an economical concentrated nitrogen plant food. In this way the world's food

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production was greatly increased. The increasing use of ammonia as a fertilizer has continued and even now almost each month new synthetic ammonia tonnage is brought on stream.

From the nineteen thirties onward the world saw the development of the industrial synthetic organic chemical industry on a scale undreamed of before. New products commercially available included plastic-based paints, synthetic fibres (nylon, dacron, orlon) and a host of sheet, extruded and molded plastic articles previously not available. New synthetic pharmaceuticals appeared and many of these, thanks to the development of chemical engineering, could be produced inexpensively and on a large scale often in a continuous process.

During that period beginning somewhat before nineteen twenty the demand for fuel for internal combustion engines became so great it was impossible to supply it from natural gasoline. This demand led to the development of the cracking processes for converting those fractions of crude oil not in the gasoline boiling range into materials suitable for use in internal combustion engines. At first these were almost exclusively moderate pressure non-catalytic thermal processes but later catalysts were developed to direct the chemical changes involved into the direction desired. The possibility of commercially producing from crude oil through catalysis large amounts of many hydrocarbon and related materials previously not available from this source led to the development of the now well recognized petrochemical industry and many industries dependent on a low cost supply of petrochemicals. So rapid was this growth that in some quarters there were serious consequences, as in the case of synthetic detergents being so widely used as to present a possible hazard due to contamination of soil and ground water. In all of this the chemical engineer was the prime operator.

Possibly the most spectacular industrial complexes based on chemical engineering technology are those producing atomic fuels. These are in many respects updated applications of the unit operations previously mentioned, admittedly with important contributions from the field of physics.

Looking ahead to future horizons many areas are at once evident in which the Chemical Engineer is uniquely fitted to bring about great advances. Pollution of ground, atmosphere and water is one of these. The problems here require immediate solution. In fact in major industrial areas the need for remedial action has become so acute that government has felt obliged to step in and set up regulations. It is unfortunate industry and the engineers did not solve their problems before government regulation was felt to be necessary.

Much future progress will involve greatly increased rates of mass and energy transfer. By this is meant order of magnitude increases. This will require original thinking and perhaps so called "engineering break-throughs". These are not impossible. In my lifetime engines for a

given output have been decreased in size and weight over a hundredfold. Also electric motors are now available many times smaller for a given horsepower than that obtainable a scant fifty years ago. Combustion rates in modern gas turbines were undreamed of a half century ago. Even in electronic circuits bulky tube circuits have given way to small transistored units and these in turn are being displaced by ultra-reliable, inexpensive, integrated circuits. Unfortunately the chemical engineer, either too busy with his everyday problems or too well satisfied with his spectacular progress in the past few decades, has not brought about a similar magnitude of change in design and improvement in the apparatus and plants under his responsibility. Without doubt two concepts which would aid greatly in revolutionizing chemical engineering design are a wider appreciation of dynamic frequency response and the very short time sensing of critical operating variables. The engineer dealing with missiles and rockets understands the importance of a rapid dynamic response to the control he exercises on his devices and he so designs his units that they do have the necessary high dynamic frequency response. To a considerable degree he has been responsible for the design of electronic sensing, read-out and computing apparatus which can keep him informed as to corrective action needed in milli- or nanoseconds. In fact, often the needed corrective action is automatically taken by the control equipment without human intervention. The chemical engineer has been slow to appreciate the importance of dynamic frequency response in his designs. The so-called "lag" in distillation columns, in chemical reactors and in furnaces is many-fold the lag in response of flying a modern jet plane not to mention the response needed in a high speed missile.

By designing for high dynamic frequency response and using modern high speed sensing devices already available, the chemical engineer could design his units with much smaller oversize factors. If he can simultaneously materially increase mass and energy transfer coefficients, he will be able to show in his field the spectacular decrease in size and weight and increase in efficiency which engineers in other fields have already accomplished. An airplane designed as conservatively as a distillation column or a petroleum cracking plant could never fly.

In the future, the trend in chemical engineering will be towards greatly increased reaction velocity. This will aid in maximizing production for a minimum of plant investment. Increased reaction rate could result from greatly improved catalysts. These, in turn, will be possible because of a better understanding of catalyst theory. Probably such an understanding will result from a more complete development of molecular orbital theory and a wide application of its principles. The effect of controlled radiation on reaction kinetics has, in general, from an engineering viewpoint, so far offered but little of a promising nature but the whole area is so new and

so little explored as to make definite prediction difficult. It would seem, however, that this field must yield results of great importance in chemical engineering work.

Heat and electricity from atomic power will be available at very low cost in a relatively few years. This will have a profound impact on chemical engineering and many processes now considered economically unattractive for general use will become commonplace including among others desalination of sea water.

The greatly increased technical activity will bring even more vexing problems in air, water, and soil pollution. As has been mentioned the vanguard of these is already with us clammering for solution. In the solutions chemical engineers must play the major role. No other group has the broad background needed for this work and indeed these very problems concerning pollution are in considerable degree the result of widespread chemical engineering developments.

It would seem that the world's food problems, especially the problem of an adequate protein supply only can be solved by a non-agricultural process in which protein is synthesized. This might be done by growing algae continuously in a nutrient broth or perhaps more likely by direct synthesis from air and petroleum, possibly through the aid of a fermentation step. Preliminary work in each of these areas shows great technical promise although the economic feasibility is yet to be proved for the near future.

Biomedical engineering is an area in which a chemical engineering background is especially helpful. We can look for artificial organs to replace diseased or damaged natural organs in a relatively few years. Heart pacemakers are already in use and complete artificial hearts, lungs, and kidneys will without doubt appear in the not too distant future. These will be of such size, weight, and reliability that the wearer will be but moderately restricted in his movements and activities. Chemical engineers are already active in this area.

Unlike the politician, and lately the scientist, the engineer has taken a relatively minor position in affairs of a human relations nature. Because of his training in drawing logical conclusions from an often limited number of facts and because of the necessity of his paying marked attention to economic factors and the interplay of his developments on the social structure he is well equipped to play a much more important role in public life. He should assume the important place to which he has for so long given but scant attention.

And so as one looks forward to the distant horizon a vast new area of activity becomes evident for Chemical Engineering. To be sure this is somewhat different from the ground already covered but it is surely no less interesting, thrilling and useful for bringing to man a happier and more satisfying life.

To assure all of this will require many more inspired teachers such as AUGUST GUYER.