Petroleum Technology and the Scientific Disciplines

By ALFRED CHATENEVER

"Petroleum Technology and the Scientific Disciplines." This is a title to raise some eyebrows if not arguments. However, such is not its purpose; and I think that it could be sufficiently clarified by some definitions so that we may go on to consider some of those aspects which I consider more pertinent.

Let us consider Petroleum Technology as that branch of engineering which is involved in the production of crude oil and gas. Then let us consider Scientific Disciplines merely as a heading to designate physics, chemistry, and mathematics. And now, with the understanding that all traces of snide innuendo are removed, let us proceed to examine some of the interrelationships between the two.

Perhaps this is a good time to ask, "Why? What is so fascinating about petroleum technology among the scientific disciplines that we should dwell upon it?"

Fascination, of course, is a highly subjective phenomenon. But it seems to me that there are certain definite aspects of general interest and particular significance in a consideration of this sort.

Many qualified observers have pointed out that we live today in an age of science and technology; and I doubt that there is any serious argument with this assertion. For us to understand ourselves in this era, then, it becomes important for us to understand the broad pertinent aspects of science and technology, no small facet of which is the interrelationship between the two.

Here, petroleum technology offers interesting possibilities as a subject. It is one of the newer technologies to break forth in modern thinking; and from the point of view of development is still a baby. Living with it as closely as we do today, we are in a position to get an intimate view of the forces, pressures, and interests that go in to shape a technology. Now, a technology has certain interesting relationships with the sciences; especially so the newer technologies such as those concerned with the production of atomic energy or those concerned with the production of petroleum reserves. Probably because of the great developmental flux involved, some of these relationships come into high relief in petroleum technology.

Let us start with a consideration of what petroleum technology comprises. It is beyond my talents to present anything like a comprehensive treatment especially in this one paper. Let me then limit our consideration to only one branch of petroleum technology, preferably one that I have some familiarity with, reservoir engineering.

I would like to offer a nice short definition of reservoir engineering; but I can not think of one that would not leave too much unsaid. It would be better, for our purposes in particular, to go into a more detailed description of its nature and its development.

To begin with, what is its subject matter? First there is the reservoir rock. To the naked eye this often appears as a dense sandstone. Actually, however, it is a porous structure, and it is not unusual for 30% of the bulk volume of a reservoir rock to be void spaces. It is through these void spaces that the reservoir fluids flow. These are three in number, namely oil, gas, and water.

Reservoir engineering, now, is concerned simply with the nature of the movements of the reservoir fluids through the reservoir rock.

Perhaps the question now arises as to why this does not fall within the scope of the scientific disciplines. Actually it might, but not without the scientific disciplines taking on the characteristics of reservoir engineering; and this is essentially the story of the development of reservoir engineering.

Ulterior purpose and inspiration are often obscure and subtle matters in the scientific disciplines. Indeed, instances have been known where obviousness of purpose and inspiration has served to detract from the interest of a scientific undertaking. Probably most of the fundamental developments in the scientific disciplines have had as an immediate conscious motivation little more than a desire to arrive at scientific truths. It is difficult to see what else it might be that, for example, prompted Newton to ponder the nature of gravitational forces, Euclid to develop his system of geometry, or Lavoisier to probe the mechanism of combustion. More recently, we have the development by Einstein in relating mass and energy. Historically, it can be seen that these are not isolated incidents but are related to other developments of the time and might also have been stimulated by them. Certainly their ramifications and applications are impressive and even dramatic as in the case of our atom bomb. Nevertheless, one is unmistakably impressed by the presence of an intense and consuming interest that these thinkers had had for the intrinsic nature of their subject regardless of the possible ramifications and applications.

In general, with reservoir engineering, the situation is a little different. Reservoir engineering follows directly from the need for engineering knowledge pertaining to the production of petroleum reservoirs. That this need may be a compelling one can be seen from the perusal of a few figures. The United States is now producing some 2⅓ billion barrels of crude oil per year. This has a dollars and cents value of almost 6 billion dollars. In considering its value, we must also concern ourselves with the critical role that oil plays in our nation's power production, transportation, and chemicals production. If, now, it is realized that half of our petroleum reserves are being left behind by present production methods, the pressures prompting the development of reservoir engineering became apparent.

The purpose of reservoir engineering is simply to arrive at methods for producing our reservoirs with the most feasible combination of efficiency and completeness.

This is a goal that has hardly ever been lost sight of in reservoir research. Indeed, there have been many places where one could easily have been sidetracked toward the consideration of fundamental physical phenomena; but the prevalent influences have been such that these inclinations were not encouraged unless there was an obvious and direct bearing upon the goal of better petroleum production. This is an attitude that was almost universally subscribed to in the past development of reservoir engineering up until the last few years.

Reservoir engineering can claim a past of hardly more than some 20 years. It was about the early 1930's that serious considerations had begun to be given to a systematic analysis of the behavior of petroleum reservoirs. The oil industry is now about 100 years old and we might well ask why it was that it took 80 years for reservoir engineering to come into being.

The reasons for this are, in my opinion, threefold; and before going into a detailed consideration, I would like to list them. First, petroleum had become big business. Second, competition became significant. And third, petroleum had become a critical commodity in our national economy. It is interesting to note that the state of technical development was not a controlling factor here. Technically, the field was ready for the development of reservoir engineering long before 1930. The fact that it did not take place until this time indicates that other factors were the critical ones.

Let us go back, then, and examine our three reasons for the development of reservoir engineering. First, big business. From 1911 to 1929 our crude oil production had been increased 5 times from about 200 million barrels to about 1 billion barrels per year. By 1950 production had reached about 2 billion barrels per year. Figuring roughly at $2.50 per barrel, this has a value of $5 billion.

Not only had the total volume of business become great but so had basic producing costs. One company gives as its average cost for an exploratory well in 1941, $33,000; and in 1951, $198,000. So, it has developed that it takes a good deal of investment capital to participate in this business.

This has stimulated the development of reservoir engineering in two ways. First, if yields of crude oil were increased even a small percentage by production engineering, the increase in revenue realized thereby would be impressive and repeated year after year. Secondly, only an industry operating on a high financial level could afford to support the development of reservoir engineering.

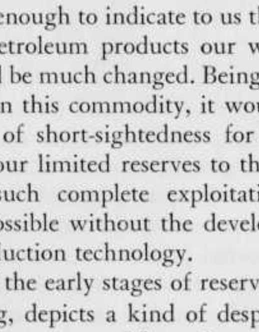
Now, competition. We are all familiar with the intensive advertising campaigns that are sponsored in the competitive quest for gasoline markets. This competition, today, runs right through the industry back to the acquisition of leases. Inherent in this situation are competitive production methods since these go in to help determine the cost of the crude oil. If a company is going to stay in business, it must avail itself of the best methodologies of reservoir engineering; and if it is going to grow and expand, it is going to have to engage in developing the technology along with the others.

Finally, we come to the critical significance of petroleum in our national economy picture. I feel certain that some very convincing figures on the subject could be prepared; but we may be more directly impressed with our personal gasoline consumption, our diesel-driven locomotives, our extensive air traffic, our gas and oil heated homes, and our gas and oil powered factories in realizing how integral a part of our existence petroleum has become. This list, of course, could be extended, but I am sure it is enough to indicate to us that without our petroleum products our way of living would be much changed. Being so dependent upon this commodity, it would be the height of short-sightedness for us not to exploit our limited reserves to their fullest. And such complete exploitation would be impossible without the development of a production technology.

The story of the early stages of reservoir engineering, depicts a kind of desperate groping for answers. Throughout its history, it has been faced on one side by incessant demands for answers to every-day practical problems and on the other by a dearth of fundamentally applicable scientific facts upon which to base these answers. This has resulted in a technology largely based upon a relatively superficial empiricism and operating with varying degrees of success. This, undoubtedly, is a contributing factor in leading one of our foremost authors on the subject to call reservoir engineering "the *Art* of forecasting the future performance of a geologic oil and/or gas reservoir from which production is obtained according to probable and pre-assumed conditions." (Pirson, *Elements of Oil Reservoir Engineering*.)

About the Author

Dr. Alfred Chatenever joined the faculty in 1949 as Associate Professor of Petroleum Engineering and Research Engineer in the University of Oklahoma Research Institute. Before coming to Norman, he had been technical director with the Aquatic Chemical Laboratories, New York City, and a research scientist with Carbide and Carbon Chemical Corporation. This paper was presented in the series of University Public Lectures, February, 1953.



Some of the characteristic attitudes attending the development of reservoir engineering are sharply reflected in the history of its research activity. This began with an investigation into the possibilities of the scientific disciplines in this direction. It did not take long to realize that here were problems that could not be solved by the conventional methods of chemistry, physics, and mathematics. Despite the fact that these fell under headings such as hydraulics, surface properties, differential equations, etc., they occurred in such forms as to be insolvable.

The next approach was that of testing. In what was consciously a probably oversimplified and too optimistic reliance upon the empirical method, it was thought that if simulated reservoirs were subjected to the conditions of reservoir production, data could be gathered which were directly applicable to the oil fields. This is an approach that is receiving strong support even today. As was feared, the hoped-for answers were not so immediately forthcoming nor so simply arrived at.

It was found that petroleum reservoirs could not be validly simulated very easily. The methods of testing introduced complications which overshadowed the system behavior that was being tested. The tests were difficult to reproduce and it was almost impossible to set up feasible standards.

To be sure, a number of empirical correlations had been shown but these were of rather limited applicability. Also, a few generalizations had been strongly enough established to serve extensively as bases for engineering calculations in producing fields. But over and above this, there were gathered volumes and volumes of data with which nothing could be done. Despite the fact that the highest caliber of research talent went in to produce these results, they were inconsistent and confusing and in more than a few instances contradictory.

It became more and more apparent as the years of experimentation went on that somehow the right road had not been found. The mass of conflicting data that had been piling up was hardly conducive to the development of any feasibile theory. Where correlations were arrived at they were of disappointingly limited application. From the volumes of data that could not be analyzed, it was apparent that the researchers were overlooking some factors of significance. Some of these they could guess about but could not control or even measure. But more and more they were given to the feeling that they were not at all sure that they knew of all the factors which went into these phenomena.

This opened the way for a new approach that has just begun to take hold within the last few years: that of studying reservoir phenomena in their fundamentals. Here the development is from the inside out. Here the attempt is first made to delineate and describe the pertinent basic processes of physical behavior which the components of a reservoir system might be involved in, then to examine their significance in petroleum reservoirs, and finally with proper weighting and qualifying to use these in describing practical field behavior. It is anticipated that this approach will be more encouraging to the development of theory and more fruitful in general.

Of critical importance in describing reservoir engineering is a consideration of its fundamentals. By referring to fundamentals, I do not intend to go into a description of the foundations upon which reservoir engineering is built. I mean merely to examine one or two of its basic concepts of formulations with an eye towards their nature, their significance, and the philosophical atmosphere that they reflect.

One of the most important of these fundamentals is what is known as the Darcy equation,

$$Q=\frac{kA(P_1-P_2).}{\mu L}$$

This expression describes the flow of a fluid through a porous solid. It says that the volume of fluid that goes through a section of rock depends upon the cross-section area available to flow, the pressure pushing the fluid through, the length of the section, the viscosity of the fluid, and what is known as the permeability of the rock. It implies further, that these are the only factors that go in to determine the flow.

To avoid any misconceptions, let us review the meanings of some of these terms. By the volume of flow, Q, we mean the volume of fluid that passes through in a given time interval. The pressure that is applied to push the fluid through is expressed as P_1-P_2. L is the length of the section. A is the cross-sectional area available to the flowing fluid; and μ the viscosity. I do not think any of these terms require any further explanation. This leaves k. k is the permeability. This is at once the most important term in the equation and the most difficult to describe, at least out of context. Actually it takes its definition from the equation; but for the uninitiated this is a rather esoteric sort of definition. Let us then look for a definition in more general terms.

Permeability may be considered as that property of the porous solid which permits the passage of fluids.

It is not simply a question of how porous the material is. It would, for example, be more difficult to pass a fluid through many small holes than through fewer large ones, assuming that in either instance the void volume is the same portion of the total rock. Thus, there are other characteristics of the system which contribute to the permeability.

For one thing, it is a property only of the rock and not of the fluids passing through. Regardless of whether it is a heavy, viscous, and difficultly moved fluid that is being pushed through, or a light, low-viscosity, easily moved fluid, the permeability of the rock remains the same. This does not mean that it is just as easy to push the viscous material through as it is the other. It does mean that permeability is a concept that handles these complications in such a way that they cancel out.

Despite the fact that for a given rock, its permeability has but a single value, it is determined experimentally and so reflects a number of microscopic details. As pointed out before, a lower permeability will result when the holes are smaller even if they are more numerous and form as large a void portion as fewer larger ones. Then, consider a series of rocks that might be made up by cementing grains of a certain type. The permeability would vary according to how the grains were packed together.

Now try to imagine the fluid stream flowing through the porous rock. In some rocks, the trip will be fairly straight; in others, it will be twisting, winding, and tortuous. In the former case, the rock would show a high permeability; in the latter a low permeability. One of the factors which affect this is the shape of the grains of which the rock is composed. The more irregular the grains, the more tortuous the stream paths, and the lower the permeability.

All this, then, is what comes from a term arising out of the Darcy equation. The question now logically arises as to how did we come by the Darcy equation. We note that the Darcy equation was first published in 1856. This, of course, was more than 70 years before the era of reservoir engineering. It turns out that the Darcy equation was developed in a study of the flow characteristics of sand filters, probably with no idea that it would be applied to petroleum reservoirs. Indeed, it took roughly seventy years before it began to attract attention on the part of petroleum-conscious investigators.

We note, further, that the attack he used was an empirical one. Even in the light of what we know today, this is the only way he could have done it. He had to take his columns, pack them with sand, run fluids through under different pressures, and after numerous runs arrive at a relationship tying together the flow, dimensions of the flow bed, driving pressure, viscosity of the fluid, and permeability.

What other approach could he have tried? Well, he might have tried an analytical development. This would involve, first, the postulation of a simple mechanism of behavior; then a mathematical formulation to establish a relationship between the various pertinent factors. In this particular case, he would have been stymied in the first step. Today, almost 100 years later we are still looking for a mechanism of behavior; and one of the most significant things that we have learned is that it most certainly is not simple. Little wonder is it then that Darcy should have turned to empiricism to supply his answers.

The analytical approach is quite popular among the scientific disciplines. With it, the physicist can paint a picture of the atom for us, describe the propagation of light, tell us how water flows through a tube or even predict a hydrogen bomb. The chemist can predict the discovery of new elements with known properties, the rate at which a reaction might proceed, the probable pharmaceutical behavior of yet-to-be-developed drugs, etc. Indeed, it is difficult to see how the scientific disciplines as we know them could have developed without this analytical approach.

In the technologies, on the other hand, we find a much stronger subscription to empiricism. This is a program of necessity. We have been able to employ feasibly the analytical approach so far only in systems that could be described in terms of a few well-behaved, orderly variables. It is characteristic of the technologies that their systems, for the most part, are confounded by a multiplicity of factors that interact, one upon the other, in anything but a simple fashion. This being the situation, investigators are not only pleased but continuously surprised that there is something like an empirical approach which can bring order out of chaos and control out of confusion.

Inherent in the empirical approach are certain difficulties. Let us go back to the Darcy equation and examine some of these. Remember, the purpose behind this work was to examine the factors that went in to control the flow of fluids through sand-packed beds. If one were to let his imagination run loose, he could with some measure of justification easily conjure up a multitude of possibilities. For example, he might consider as possibilities the roughness of the sand grains, the density of the materials, etc. He might even, in the extreme, call for a consideration of the position of the moon since its gravitational effects which are reflected in the change of tides might reach out to effect these sand filter fluid systems.

Some of these factors can easily be shown to be spurious; others can just as easily be shown to be significant. Between these two, there is a third group which is much more difficult to analyze, but which must be evaluated, nonetheless. Without this preliminary evaluation, research would be grossly inefficient in giving experimental consideration to all possibilities, feasible and otherwise.

How then, do you choose factors for study? In the simple case, there is a history of similar work having been done before. Here, the investigator is quick to rely upon his predecessors for ideas, and successfully, too, usually. These, however, are not the brilliantly original researches that form the landmarks of development, that build the foundations, that give rise to principles. In these cases, a man has to depend upon a knowledge of and insight into his subject and also his experience. These give him a sophistication to help guide him along productive paths and avoid gross blunders of choosing irrelevant factors.

Then, there appears to be another ingredient. It seems to me that over and above the intellectual aspects of a researcher's background, there is a certain art, an intuition, a feel, if you will, for the productive pursuits. To be sure, this is not always present in a researcher. I think that it is this talent of sensing the significant that sets off the brilliant researcher from his run-of-the-mill colleague.

My guess is that were we to ask Darcy what it was exactly that motivated his particular researches, he would be a little hard-pressed for an answer since such thoughts are infrequently on a conscious level. In any event, he managed to show the significance of the flow bed dimensions, the driving pressure, and the fluid viscosity in flow behavior in porous beds. All other factors, whatever they might be, were lumped into a catch-all term known to us as the permeability of the matrix.

This being an empirically determined term, it is valid only within a limited range of experimentally determined conditions. Some of the conditions are as follows: the pores cannot be too small, nor can they be too large. The fluid that is used must be homogeneous. When it is flowed through the porous bed, it must be done below a certain maximum rate. This maximum rate will vary with the fluid, etc. In general, limitations of this sort arise in two ways. Either experiments had not been carried out beyond the range of conditions indicated in the limitations, or else they had with the result that beyond this point, the equation in question did not hold.

Empirical equations derive their substantiation and reliability only from the number of verifying experiments—the greater the number of substantiating experiments, the more reliable the equations. In general, they have neither the reliability nor the precision of the more fundamental laws found in the scientific disciplines. One would hardly try to calculate a permeability with the exactness that one would employ with the laws of the lever.

The Darcy equation is but one of the principles of reservoir engineering. However it is indicative of a significant portion of the fundamentals of the subject which are based upon empiricism. These reflect the successful application of the empirical method. It must be remembered that while this is a methodology with significant potentialities, it cannot be handled too crudely. If it is to bear fruit at all, one must bring to it a comprehensive understanding of the factors involved. As we noted before, this is a lesson that we learned in the history of reservoir engineering research.

It is of interest to compare the empirical method with an analytical type development in the scientific disciplines. Let us take, for example, the nature and behavior of a gas. It is altogether reasonable to assume that the properties of a gas follow from the fact that the gas is composed of molecules, that the molecules are perfectly elastic bodies, that they are negligible in size, and that their motion derives from the temperature of the gas. Then with no more than a pencil and paper, it can be shown that if you put the gas in a container and increase the temperature, you will increase the movement of the molecules which in turn increases the impacts against the wall and thus increases the pressure. If the walls of the vessel were partially collapsed so that now the gas were contained in a smaller volume, the molecules would hit the wall with greater frequency again increasing the pressure. We could go on to list several other deductions which go to make up what is known as the kinetic theory of gases, all of which follow theoretically from the assumptions. However, I think we can see the point well enough with just these. When experiment is finally invoked in this connection, it is primarily with the purpose of verifying the correctness of the assumptions and reasoning of the theory rather than to arrive at relationships between the factors.

It is to be noted that the factors and assumptions involved in a theory of this sort are relatively few, simple, and unencumbered by complications. It is significant, too, that these factors are such that they can be experimentally isolated and subjected to detailed and intensive examination. This is a situation devoutly to be desired in petroleum technology where the factors involved are many, complicated, and often hopelessly encumbered by interactions of various sorts.

Reservoir engineering is not without its analytical developments. As with analytical developments in general, these are relatively simple in concept, treating but a few factors at a time. However, when it comes to their application, and application is the business of technology, we find that our systems are considerably more complicated than can be comprehensively handled by the analytical formulation. Then regardless of the validity of the analytical formulation, its application becomes a question of empiricism. The more often it works, the more reliable it becomes as an applicable concept. And so, while reservoir engineering in particular and the technologies in general are based upon empirical and analytical developments, nowhere else among the experimental sciences does empiricism play so strong a role.

In concerning ourselves with the nature of reservoir engineering, we have touched upon its history, its development, its influences, and its principles. We have pointed out some similarities and differences between petroleum technology and the scientific disciplines. There is yet another kind of relationship that we should treat before we leave this subject—that of dependence.

This dependence goes in both directions. In this relationship, each area maintains its own characteristics; and in its development simultaneously feeds upon and nourishes the other. It does not take too much inquiry to reveal this as an evident phenomenon. One of the more dramatic expressions of this lies in some of our recent developments. The cyclotron and other particle accelerators are based in part upon the use of electronic equipment. Electronic equipment is based upon an understanding of the nature of matter given to us by the physicists. The particle accelerators are built by engineers for physicists to further study the nature of matter, particularly the atomic nucleus. The new electronic brains which could not be engineered without mathematics provide valuable calculating tools for further mathematics research. Our ability to engineer our large telescopes is a critical factor in pushing back our astronomical horizons.

Many more examples could be found to show this general interdependence between the technologies and the scientific disciplines; but for detail, let us focus our attention upon reservoir engineering. Here, we have a situation where the technology has exploited whatever the scientific disciplines had to offer in its development only to uncover areas where the scientific disciplines have not yet reached. I shall try, without becoming too involved, to indicate some of these.

The physicist has been able to tell us with great precision how it is that a fluid moves through a straight uniform- bore tube. But in petroleum reservoir rock, the channels of flow are not straight but tortuous, not uniform in bore, and not independent but interconnected. With the introduction of these complications, we find ourselves beyond the reach of present day developments in physics. We can and do exploit in empirical attacks upon the problem whatever concepts are available, such as viscosity and driving pressure. But we have been markedly unsuccessful in arriving at the Darcy relationship analytically.

This is the situation for a system involving a single homogeneous fluid. When we get into systems involving two or three immiscible fluids our problems grow geometrically.

The chemist has given the petroleum technologist a useful concept known as surface tension. This is a concept that is very useful in describing, for example, the properties of the surface of a liquid. If a liquid is squeezed from a dropper in drops, it is seen that these drops tend to take a spherical shape. This is so because the surface of the liquid has a tension which tends to force the fluid into its smallest shape—a sphere. It is surface tension, too, that causes a liquid in some instances to rise in a narrow tube.

We have learned a good deal about surface tension—how to measure it on a stationary flat surface, how high it will cause a liquid to rise in a capillary tube, what molecular phenomena cause surface tension, etc. Enough has been learned to indicate that this is indeed a significant factor in reservoir behavior.

In applying this concept to reservoir studies, however, we are soon faced with the realization that we must still learn of the behavior of a surface in a short orifice as against a long tube, the behavior of a surface in motion over and above its behavior under static conditions, the behavior of a surface as it is conditioned by its history, and other related phenomena. These are factors that require clarification before we can study their influences in reservoir systems where we know they are significant.

Mathematics can furnish us with a language to describe the movement of a fluid system so long as the motion is regular and orderly. But in a reservoir system the motions are erratic and discontinuous. In a reservoir system, furthermore, the behavior is not even sufficiently random to permit an easy averaging. For this situation, mathematics has little to offer in the way of a feasible expression.

So it is that a technology, which has much of its basis in the scientific disciplines, finds itself indicating areas that have been left undeveloped by physics, chemistry, and mathematics. It would, I think, be fallacious to treat these as problems of limited scope and peculiar only to reservoir engineering. These are problems in the basic behavior of natural physical systems; and solutions in this area almost always find applications in many diversified fields. It is of interest to note, in this connection, that the porous structure of a reservoir rock bears significant similarities to the capillary structure in the circulation system of the human. In one case at least, steps have been taken to involve a reservoir expert in circulation studies. In my own case, it was the similarity between reservoir processes and diffusion processes used in developing the A-Bomb that brought me into reservoir research. This is a point that needs no elaboration once it is realized that there is an extensive and significant interrelationship among the sciences.

Finding one's self in the throes of a rapidly developing discipline, there is a strong temptation to guess as to what the future developments might be. Also, there is a purpose that is served by such prognostication. If it is based upon an analysis of some sort, it might well serve as a test for the analysis. And so, over and above the fascination attending the possibilities of prediction, it appears that I have an obligation to make some guesses regarding the future of reservoir engineering.

I think that the history of reservoir engineering research will show a marked trend toward a consideration of more basic studies relating to reservoir behavior. I have already pointed out the need for this development. There is also a propitious environment to encourage it. The bulk of reservoir research today is being carried on by our industrial laboratories. It is characteristic of industrial research programs that they will undertake fundamental studies, but only when they can afford it. This is just another way of saying when the budget is big enough. Recent figures indicate that the petroleum industry is spending $100 million per year for scientific research. This is a big enough budget to support a program of fundamental research.

My guess is that this interest in certain designated studies will stimulate some work in the fields of chemistry, physics, and mathematics but that the major portion will be carried out by the petroleum research laboratories.

All of this will be included in a petroleum research expansion program which has shown tremendous strides in the last few years and will continue to grow for probably at least five more.

The findings arising from fundamental reservoir studies will find significance in fields like soil science, public health, medicine, filter engineering, chemical manufacturing, and others.

Finally, reservoir research will be a factor in convincing the petroleum industry that research is an integral part of petroleum operations and absolutely indispensable in the task of completely utilizing our natural resources.

There is no question that there is a whole area of activity peculiar to petroleum technology; and this makes it a specialty. It would be fallacious, however, to carry the thought of specialization so far as not to recognize its interrelationships with other disciplines and the environment in which it grows. To carry specialization too far in any field may prove fallacious, as was the case with a prominent Washington socialite, who on learning that her dinner partner at a large official banquet was a naval surgeon, felt called upon to remark, "My, how you doctors do specialize!"

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Generally, Be Particular

To Generalize is to be an Idiot. To Particularize is Alone the Distinction of Merit. General Knowledges are those Knowledges that Idiots possess. . . .

William Blake, *From Annotations to Sir Joshua Reynolds's Discourses,* 1789.

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There Are Limits

. . . est enim quatemus amicitiae dari venia possit.

. . . there are limits to the indulgence which can be allowed to friendship.

Cicero, *De Amicitia,* XVI, 59

Translation by W. A. Falconer