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Physics in the Petroleum Industry

By Noyes D. Smith, Jr.

SINCE physics is a science which deals with matter and energy in a fundamental way, it is obvious that every purposeful activity has some relationship with physics. Physical problems of importance to the petroleum industry involve to some degree all fields of physics; my task this afternoon is thus to try to convey to you something of the scope of physical research in the petroleum industry and to describe a few areas of physics which are of particular interest to the petroleum industry.

Dr. Paul D. Foote presented a paper entitled, "How Physics Is Applied in the Oil Industry", at the Conference on Industrial Physics, Pittsburgh, November 15, 1935.* Since that time physics has grown so rapidly that it would be impossible for a single individual to speak authoritatively about all its branches. The petroleum industry has also grown, having more than doubled its annual production since 1935. This growth has been accompanied by a corresponding growth in the level of petroleum technology, as required by the rapid expansion of the petrochemical industry and the increasing complexity of finding and producing petroleum. This

more sophisticated technology has led to an increasing demand for the services of the physicist. It would likewise be presumptuous for an individual to speak with authority about the petroleum industry, and I can only report those impressions which I have gained from my experience.

The personal interest of the individual is essential to research. We do not really know why some individuals have a sufficient level of curiosity to be willing to sit up late at night and otherwise make themselves uncomfortable to satisfy this curiosity, but it is certain that many apparently trivial items are important in the matter of arousing interest. One rather infrequently examines the abstraction of what he is doing independently of the common language of the particular culture in which he lives. It is even possible for words to destroy an incipient interest; for example, my wife, although she had not taken any courses in physics, had acquired the impression during her education that physics was a difficult and uninteresting subject. When we were first married, some phenomenon in the kitchen would arouse her interest and she would describe it to me when I got home. If I tried to relate it to physics, she immediately lost all interest.

* Physics, 7, pp. 91-96 (March 1936).

The problems of particular importance to the petroleum industry are of interest to me. There is no a priori reason why any of you should have the slightest interest in these problems. Our common interest is that of physics, and I shall try to describe the physics in the petroleum industry as physics and to indicate relationships to petroleum problems only indirectly.

SOME of the fields of physics in which research is being actively carried on in the laboratories of the petroleum industry are as follows: chemical physics, solid-state physics, nuclear physics, nuclear and electronic magnetic resonances, low-temperature physics, and many fields of classical physics such as rheology; potential theory as applied to gravitational, magnetic, and flow fields; linear and nonlinear continuum mechanics (including elasticity and hydrodynamics); electromagnetism; and the mechanics of fluid flow in porous media.

A number of subject areas which were formerly considered physics are now often thought of as belonging to another discipline such as chemistry or some phase of engineering. However, the physicist, because of his training and interest in basic concepts and rigorous mathematics, can often make contributions to these problems which would be unlikely to originate from a chemist or engineer. These fields are thermodynamics, high-polymer physics, chemical kinetics, heat and mass transfer, hydraulics, physical separation methods, analytical equipment and techniques, instrumentation and control, electron microscopy and diffraction, crystallography, operations analysis, and data handling and processing equipment and techniques. Some of these fields overlap that of *chemical physics*, which is contributing to the understanding of molecular structure and chemical kinetics.

In *solid-state physics* there are problems in the alteration of sedimentary rocks with time involving growth of minerals due to solid diffusion and other mechanisms. Here, times of millions of years are of interest. The mechanical properties of rocks and their behavior under various stress systems are studied. Experiments with single crystals are carried out to determine the physical mechanisms of strain and failure. Strain rates involving times of 10^{-6} second to 10^{14} seconds or more are of interest. The strengths of metals and alloys are being studied because of their importance in the construction of a wide variety of apparatus and equipment. Of particular interest are the surfaces of solids and the interaction of various atmospheres with the solid surface. The adsorption and desorption of gases and liquids on solids, catalytic activity of solids, and problems of corrosion are of special interest.

In *nuclear physics*, radiation damage due to neutrons and alpha, beta, and gamma rays is being studied from the standpoint of the activation of chemical processes and the effect of these radiations on the physical and chemical properties of petroleum and chemical products. Radiation damage occurring naturally in minerals

found in the earth is also being studied with a view to determining the age and temperature history of various earth minerals. Neutron radiation is being used for activation analyses. The scattering of neutrons and gamma rays by rocks is being investigated. A wide variety of instruments have been and are being developed which use nuclear radiation to measure physical and chemical properties of many materials.

Nuclear and electronic magnetic resonances are being used to establish the structures of complicated molecules and to study the interaction of hydrogen-containing fluids and solids.

Low-temperature studies are applied to solid-state problems and to free radicals and their reactions.

Problems in *rheology* cover the behavior of suspensions of clay minerals and colloidal systems important to the chemical and refining industries.

The measurement and interpretation of the *gravitational and magnetic* fields of the earth are of continuing interest, as is the development of appropriate instrumentation.

The *propagation of elastic waves* in layered solids has received wide and continuing attention, particularly for impulsive sources. The propagation of electromagnetic waves in rocks is also being studied. Shock and detonation waves in gases, and the resulting chemical changes, are receiving increased attention.

Studies in *hydrodynamics* cover a wide range of phenomena. The initiation and propagation of ocean waves, the effect of the sea floor on ocean waves, and the effect of waves on typical structural elements are being studied experimentally and theoretically.

The *flow of multiphase fluids* in porous rocks is being investigated at an intensive level.

In the group of subjects formerly considered physics, a wide variety of problems in *thermodynamics*, ranging from the physical behavior of multiphase systems to equilibria in chemical reactions, are being investigated. Work is being carried out in the field of nonequilibrium thermodynamics.

Interest in *polymers* has grown rapidly, and the study of the relationship of the physical properties to the structures of polymers is a very active field.

The field of *chemical kinetics* has been largely taken over by the chemists and is of continuing interest and importance as the variety of new chemical reactions grows. The use of tagged atoms has accelerated experimental studies.

Heat and mass transfer problems are of major importance in refining and chemical processes. The study of fluidized solid systems is of major importance.

The *hydraulics* of single- and multiphase flow in pipes and chambers of various geometries is still an important problem.

Work on *physical separation methods* continues to expand. Areas of interest include distillation processes, diffusion, gas and liquid chromatography, adduct formation, and molecular sieves.

The use of physical *analytical equipment and tech-*

niques continues to increase. These techniques include x-ray, ultraviolet, visible, infrared and radiofrequency spectroscopy, mass spectroscopy—both for analyses of high-molecular-weight compounds and accurate determination of atomic isotopic ratios—x-ray diffraction, and a variety of potentiometric analyses.

The field of *instrumentation and control* involves the adaptation of sensing instruments and feedback loops to control processes. This area of activity is growing rapidly.

Electron microscopy and *electron diffraction* are being applied to the studies of materials ranging from naturally occurring minerals to especially prepared solid catalysts.

Crystallography is important in the study of naturally occurring minerals, metals and alloys, and catalysts.

Operations analysis is an activity of growing importance in the industry, and the training and background of many physicists make them eminently suited for work in this field.

The recording, storage, processing, and presentation of data are receiving wide attention and are growing in importance, particularly in dealing with the experimental field observations used in exploration. The use of more standard computing equipment is contributing to the solution of problems in nearly all fields of research. A large number of medium-capacity and several very large-capacity computers are in service in the petroleum industry.

FROM this listing I hope I have conveyed to you an idea of the range of interest of the petroleum industry in physics. The level of research varies from the narrow application of known techniques to problems in the petroleum industry to broad investigations motivated by a desire for a better understanding of certain physical phenomena. More manpower is required to apply new ideas than to create them; consequently, the more narrowly applied work occupies the bulk of the research effort. This situation is similar to that found in academic research, as demonstrated in the literature—a few papers report new insight into the basic problems of physics, whereas the majority report the development and extension of already discovered areas of knowledge.

The way in which research is carried out is not significantly influenced by the motives of the institution supporting the research. An individual, to be productive in research, must have his curiosity about the problems aroused in a deep and very personal way. In other words, if he doesn't find work on the problem fun, his contributions are unlikely to be significant. Thus the research man has to choose an institution that is interested in backing research on problems in which he is deeply interested—whether it be a university, a research institute, a government laboratory or an industrial laboratory.

However, there are differences in interest between physicists in the academic world and physicists in the petroleum industry. As suggested above, there are prob-

lems in classical physics that remain unsolved. When I first entered the petroleum industry in geophysical exploration, I was confident that the theory of the propagation of elastic waves was well developed theoretically and firmly established experimentally. I was surprised to find that there were many experimental observations in real-world situations that did not agree with intuitive ideas based on classical theory and that no one had been clever or patient enough to calculate theoretical predictions to determine whether or not the theory agreed with the observations. A great deal of good work has since been carried out in this field, but new problems continue to arise as workers in the field become more sophisticated in their interests and demands.

This expansion of a field of science as it becomes applied appears to be a general occurrence. The technology is confronted with complicated real-world situations which often require the gathering of large amounts of data covering a wide range of parameters. The motivation of accomplishing a recognized objective frequently leads to the phrasing of pertinent questions which are crucial tests of the theory. Applied research begins with the results of fundamental research, but the act of application stimulates new interests and opens up new areas for basic research. The time constant involved in this feedback has become shorter in the last few years. Some recent discoveries have been applied commercially within three to four years. Further improvements in communication between university research and industrial research will certainly provide an increase in scientific productivity.

I have tried to convey to you some idea of the range of the petroleum industry's interest in physics, the fact that many of the classical fields of physics offer opportunities for significant scientific research, that there is a rather close analogy between physical research in laboratories sponsored by different types of institutions, and that the improvement of communication between applied research and basic research will stimulate the productivity of both.

Thus far I have considered the role of the physicist in the petroleum industry as a research worker or research administrator. Corresponding to the opportunities for physicists in research are opportunities in operations which are based on applications of knowledge derived from these fields of research.

Now let us consider the training of the physicist for the petroleum industry. As I have pointed out, I think that physics in industry is the same as physics anywhere; and the petroleum industry asks only that an individual be trained as a good physicist. There are many opportunities for narrowly trained specialists, but the greatest need is for those individuals who have a sound training in basic physics. In order for the physicist to become a physicist in the petroleum industry, he must have an interest in the industry's physics problems. This can only come about by an improvement of communications between the industry and the world of academic physics.