THE PROGRESS OF PETROLEUM

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Petroleum, this "flowing gold" of the world, has little in common with the beautiful, sparkling metal which fascinates mankind. For centuries little appreciation has been shown to the black, evil-smelling liquid emerging from the ground, and much time was needed before its value had been realized by man. Even up to now few people have a true picture of the part which petroleum plays in our everyday life although without undue exaggeration, the present period of our civilization may be referred to as The Petroleum Age. Without petroleum we would be unable to develop the wonderful machinery which is now at our disposal, we would have no suitable fuels or lubricants to keep our engines running, and we would not be in a position to manufacture cheaply a large variety of materials indispensable to our comfort. Fortunately for our generation the supply of oil is still plentiful and we have no reason to worry that it will be exhausted in the near future. On the contrary, due to the unceasing efforts of various research organizations generously supported by the large oil companies we may expect that the utilization of petroleum in the future will be even more complete than it is at the present time.

The beginning of the petroleum industry can be traced back scarcely further than a century. For many decades petroleum refining was confined to distillation of crude oil in various fractions supplemented by purification with chemicals. These fractions are known to the general public under the names of gasoline, kerosene, lubricating oils and asphalt, and up to the present time have constituted the major products of the petroleum industry. Little was known, however, about the desirable properties of these products and they were accepted by the consumer without undue complaints on their performance. With the general progress in industrial development and a better understanding of petroleum properties the refiner was in a position to improve the quality of his products and to satisfy the growing demand of the market for petroleum materials.

CONSUMPTION OF PRODUCTS

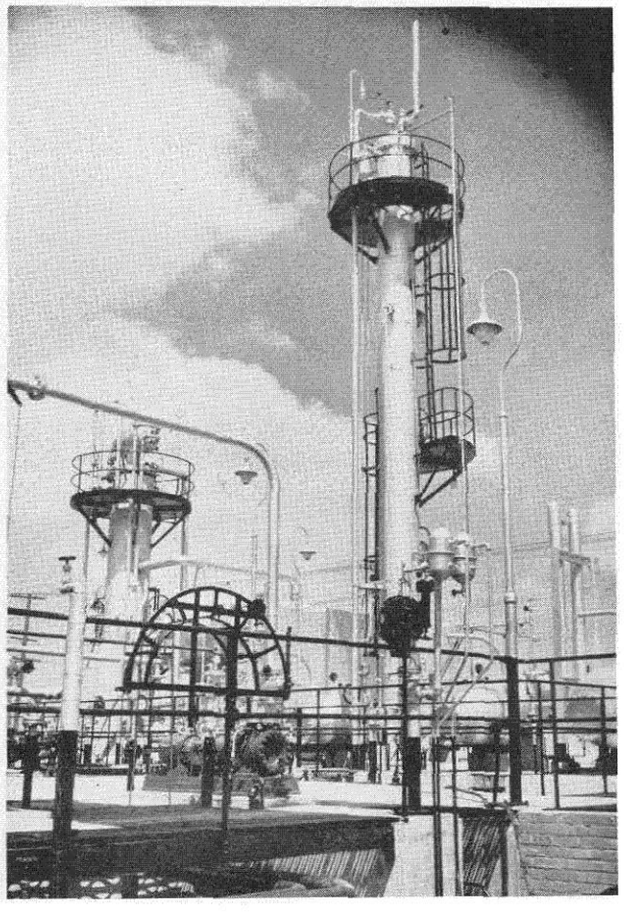
On a volumetric basis the demand for the individual petroleum products is not equal. This may be visualized from the following data showing relative consumption of gasoline and other materials:

Gasoline (Cracked and Straight Run)	1000 bbls.
Kerosene	104 bbls.
Lubricants	45 bbls.
Asphalt and Road Oils	57 bbls.
Fuel and Gas Oils	851 bbls.
Wax	2.4 bbls.
Miscellaneous	139 bbls.
Loss	51 bbls.

The above shows that gasoline is consumed in quantities considerably greater than those which are available in the crude oil. In order to meet the demand and to utilize all the crude obtained from the field the refiner was obliged to develop cracking processes which are capable of converting heavy petroleum fractions into the light ones by application of heat and usually pressure. The gasoline fractions obtained by these liquid-phase or vapor-phase themal cracking processes differ in many respects from the gasoline fractions obtained by straight distillation of the crude. These cracking processes may be, therefore, regarded as the first attempts to synthesize certain materials not found in the crude oil. For many years the cracked gasolines were regarded as inferior to the straight-run products because of their instability and tendency to form gum deposits in service. However, with the advance of high compression engines the true value of cracked gasolines has been gradually realized because of their relative freedom from the tendency to knock in the motor. Simultaneously considerable progress has been made in improving the stability of such gasolines by proper refining, and at the present time the product formerly looked upon with suspicion has become one of the highly desirable gasoline constituents.

In preparing gasoline from the heavy petroleum fractions the refiner was confronted by the problem of improving both the yield and quality of the product. Cracked gasoline is deficient in hydrogen as compared to the straight-run gasoline. The crude oil as a whole likewise contains less hydrogen than its gasoline fractions. This indicated that the problem could be solved by supplying hydrogen during the cracking operations from an outside source. Such considerations led to the development of hydrogenation processes which are capable of converting all the heavy oil fractions into gasoline irrespective of their hydrogen content. Large commercial plants of this type have been constructed, particularly in Europe, where the crude oil supply is scarce and where gasoline had to be produced from materials having exceptionally low hydrogen content such as coal. However, in this country the vast resources of petroleum

ALKYLATION PLANT IN A CALIFORNIA REFIN



and the cheapness of crude oil prevented an extensive development of the hydrogenation processes except for the manufacture of some special products.

Although the relative proportion of hydrogen in the gasoline fraction is greater than in the crude oil itself, the possibility existed of enriching the hydrogen content of cracked gasoline at the expense of the remaining portions of the crude, and thus producing a gasoline which would combine all the desirable properties of cracked and straight-run products. As a result of these considerations the catalytic cracking processes, as represented by the Houdry process, were developed. In the Houdry process the catalyst directs splitting of heavy petroleum hydrocarbons and recombination of the resulting fragments of molecules into materials boiling within the gasoline range and possessing exceptional anti-detonating quality and stability. Although the yield of these catalytic gasolines per barrel of crude oil is less than that obtained by hydrogenation, the expense of supplying hydrogen from an outside source is avoided and the process received a quick recognition on the part of petroleum refiners. As a result a large number of catalytic cracking plants came into existence in this country and abroad supplying the aviation and automobile industry with a premium product but without an increase in cost to the consumer.

SYNTHESIS FROM REFINERY GASES

The attention of the refiner was next attracted by the possibility of synthesizing additional quantities of gasoline from the refinery gases which contain large proportions of reactive hydrocarbons. As a result of these researches a number of thermal and catalytic polymerization and alkylation processes have been developed which are capable of converting gaseous hydrocarbons into liquid gasoline fractions of high anti-detonating characteristics. This placed into the hands of refiners an additional possibility of obtaining high grade products and of utilizing the crude oil to its best possible advantage.

However, the rapid strides of the aviation industry did not permit the refiner to rest on his laurels. The aviation gasoline as now used in the most modern airplane engines must possess exceptionally high anti-detonating properties and oxidation stability. Such products can be obtained only by preparing relatively pure petroleum hydrocarbons in large quantities and blending them in proper proportions in order to meet the required specifications for finished materials. The problem has been solved by the commercial development of selective catalytic and thermal polymerization and alkylation processes which are capable of synthesizing practically pure hydrocarbons of the desired type such as iso-octane (2,2,4-trimethyl pentane) and neohexane (2,2-dimethyl butane). In these processes the raw materials fed to the units are carefully selected among certain gaseous petroleum hydrocarbons in order to minimize the possibility of undesirable side reactions. Subsidiary processes for increasing the supply of raw materials for such plants have been also developed or are in the state of development, thus insuring a plentiful supply of high grade aviation gasolines in this country in the case of national emergency.

SOURCE OF PURE CHEMICALS

The above brief outline of the miraculous progress of gasoline manufacturing in the course of the last few years shows a distinct tendency on the part of the refiners to synthesize their products from more or less pure hydrocarbons rather than be satisfied with the naturally available materials. Crude oil is thus rapidly becoming a source of chemicals which are artificially produced in the course of refining and then blended to the desired product specifications. Petroleum refining is approaching the status of a true chemical industry and it might be expected that in the not too far distant future crude oil will be regarded mainly as a source of carbon and hydrogen and not as a naturally occuring material the properties of which are beyond our control.

While the previously described processes refer to the manufacture of high grade hydrocarbon materials forming the body of commercial gasolines, other methods were developed which permit correction of certain undesirable properties of other hydrocarbon materials without impairing their good characteristics. This is accomplished by the use of additives or substances which, when added in very small quantities, have a remarkable effect on certain characteristics of gasoline or other petroleum products. The use of such additives is now quite universal, as for instance the use of tetraethyl lead to improve the anti-knock characteristics of the basic gasoline fraction. Stability of gasoline with respect to color or gum formation is also often insured by the use of corresponding protective agents and inhibitors. New additives of such types are continually appearing on the market and are utilized to the best possible advantage by the petroleum refiners in their attempts to satisfy the customers with high grade, low cost products.

COMPLEX LUBE OIL FRACTIONS

Up to the present time the complex nature of the crude oil fractions employed in the manufacture of lubricating oils foiled the attempts of research chemists to penetrate into their structure and to evolve methods for synthesizing the desirable hydrocarbons in a way similar to that employed in the manufacture of high grade gasolines. However, some progress in this direction has been made through the synthesis of lubricating oil fractions from hydrocarbon gases by employing aluminum chloride or other catalysts. Both methods of attack are similar in the respect that the crude oil is first converted into simple hydrocarbon molecules which are then reunited to form the desired products. Nevertheless these methods of manufacturing lubricating oils are now only in their infancy.

Although the methods of synthesizing lubricating oils cannot yet be considered commercial, tremendous progress has been made towards isolation of certain groups of compounds which are best suitable for preparation of finished lubricating oil. This has been made possible by the development of the so-called solvent refining processes which permit separation of the desirable constituents present in the charge stock by methods of preferential solubility in certain solvents. Methods of this type have been already in use for a number of years in manufacturing high grade kerosenes from inferior crudes. The lubricating oil fractions obtained by solvent refining are thus freed from asphalt, wax and the unstable hydrocarbon compounds, retaining only the stable, high viscosity index hydrocarbons, i.e. hydrocarbons which show the least change in viscosity with temperature. This latter property is important for lubricating oils intended for use in engines, such as automobile motors, which are frequently heated from the cold. In manu-

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the tin ore deposits in the Kinla valley; there are Diesel-electric locomotives in regular service on the Royal Thai State Railway; crawler type tractors and mechanical earth-moving equipment are used on some jobs; the shops of the Federated Malay States Railway at Kuala Lumpur are well equipped and under the supervision of well trained and competent men, etc. However, in thinking of the technology of these areas one must always remember that the "up-to-date," and that means up to 5 or 10 years ago by our standards, is the exception, not the rule.

THE LURE OF THE EAST

And that is the reason that, as a technical man, I am glad to be back in the United States. The "Lure of the East" is a very real thing. The comforts of having a silently efficient Oriental domestic staff which is not dismayed by the arrival of the Tuan at 7:00 P.M. with four guests for dinner, the joys of having the car washed every morning and polished every Sunday morning by the native driver, the pleasures of belonging to three or four excellent clubs, the social life of a large sea-port where one meets a constant stream of celebrities and interesting people on their way from one end of the world to another, the opportunities to travel and observe the strange customs of many peoples and to see and own the handiwork of craftsmen and artisans whose skill and art are so different from our own, these things more than counter balance the discomforts of a life in the tropics. The heat and humidity, the mosquitoes and insects of every sort, the minor hazards of pythons in the garden, the major annoyance of the ubiquitous mosquito net the indescribable smell of the river at low tide—these undesirable aspects of life in Singapore would never outweigh the

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facturing high grade lubricants the use of additives also became extensive. Some of these additives are employed for reducing the congealing properties of oils (Santopour, Paraflow), others for improving lubricating properties or the so-called oiliness (mildly acidic substances, chlorinated and sulfurized or similar addition agents), still others to combat corrosion (Santolube, various organo-metallic or phosphorous compounds) or improve oxidation stability (phenols, amino- and sulfur compounds). In employing such additives, extensive tests are required in order to insure their satisfactory performance under all conditions of service which necessitates tremendous expenditures for the experimental work conducted by the large petroleum concerns. Moreover different machinery requires different types of lubricants and additive agents thus multiplying the research problems almost to infinity.

Methods similar to those described are also employed in the manufacture of other petroleum products such as asphalts, road oils, waxes, solvents, fuel oils, greases, and related materials. Each one of them presents special problems which are well beyond the scope of this article, although many remarkable inventions and discoveries have been made. Achievements in other branches of the petroleum industry such as prospecting, exploitation, and transportation have not been less remarkable, although they are not covered by the present review. As one example it is of interest to mention that the City of Cleveland is now supplied with natural gas (methane) by pipe lines, and the gas is liquified and stored as a liquid at about -260°F. before it is revaporized and distributed to customers.

INDIVIDUAL HYDROCARBONS ISOLATED

Rapid advances have been recorded recently by the branch of the petroleum industry which is occupied with the production of various chemicals. For a considerable length of time its development was handicapped by the difficulties encountered in isolating the individual hydrocarbons from petroleum for further organic synthesis, and by the relatively slight progress in chemistry and practical utilization of organic substances other than aromatics. Nevertheless these difficulties were gradually overcome and at the present time a large variety of derivatives of various petroleum hydrocarbons is manufactured on a commercial scale and sold to the public. Although the hydrocarbons employed as raw materials are principally the lowest boiling ones, continuous efforts are being made to hroaden the scope of the available raw materials for the manufacture of chemicals and to find new applications for the substances which can be made on a commercial scale. Chemicals which are now produced from petroleum as a starting raw materials include chlorinated and brominated hydrocarbons, alcohols, aldehydes, acids, ketones, glycols, amines, and many others. These compounds are employed for further, more complicated organic syntheses thus presenting unlimited possibilities for the future. Petroleum has ben also found to be a possible source for manufacturing aromatic hydrocarbons which until recently were obtained almost exclusively from the coal tar. Methane at high temperatures is converted into acetylene and further into benzol, while several methods are likewise available for converting certain petroleum hydrocarbons into toluol from which TNT is obtained. Due to these developments the supply of toluol in

case of war is now assured to be plentiful and no shortage of it could be expected as happened during the World War.

In addition to chemicals of the above type, a large variety of other similar materials is obtained from petroleum which find wide applications in various industries and in everyday life. Sulfonic acids of different types are used as detergents, emulsifying agents, and for other purposes. Naphthenic acids found in petroleum are utilized in the form of their various metallic salts in the manufacture of paints and lacquers or as emulsifiers and demulsifiers. Resins, such as bakelite, are synthesized from materials which are or may be obtained from petroleum. Manufacture of rubber from butadiene, a hydrocarbon which is obtained by thermal decomposition of certain petroleum hydrocarbons, is one of the very latest achievements. The resulting rubber is in many respects superior to natural rubber and should find wide application in the tire and other related industries.

PLACE OF DISTINCTION

The above outline barely scratches the surface of the petroleum industry and falls short in fully presenting its various aspects. Nevertheless, it is sufficiently complete to illustrate the complexity of problems which the industry has to meet at the present time and to permit some insight in its future trends. Petroleum is rapidly achieving the place of distinction as the major source of all types of organic chemicals and is already in direct competition with coal tar, from which such chemicals have usually been obtained. Rapid development of our knowledge of organic compounds other than aromatic promises the developments of new and hitherto unknown materials of commerce. This will inevitably lead to an increased everyday comfort directly traced to the petroleum industry which has already given innumerable benefits to mankind. The "flowing gold" of today will continue to be the "flowing gold" of tomorrow, far more beneficial than metallic gold which has only an artificial value as a medium of exchange but which can hardly be considered an asset unless it can be converted into other goods.

MAGNETIC TESTING OF STEEL IN THE PETROLEUM INDUSTRY

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acteristic chart which was obtained from a well test. In this chart the development of fatigue is clearly shown in the rods. To those acquainted with oil production problems the appearance of fatigue near the upset will indicate clearly the case where rods break immediately adjacent to the upset. In the lower chart is shown the characteristics of a number of rods which broke in service. In this case the rods were first run on an experimental basis to determine the characteristics of the rods which later broke in service. By means of charts such as these it is possible to determine the rods which have fatigued the most, and to remove them from service before failure occurs.

Besides the author, who is the inventor of this method of magnetic testing, several other alumni assisted in this development. Among these alumni are Louis Kolb '39, who assisted in the early development, and Don Clark '29, who assisted in the metallurgical coordination of the work. Patent work for the Corporation is being handled by R. M. Bruce '22, who was formerly in the General Electric Company Patent Department. Field development work was assisted by efforts of A. C. Tutschulte '31, in the cooperative work between the Magnetest Corporation and the Associated Oil Company. A great deal of assistance was, also, furnished by Professor Sorensen, particularly in connection with the personnel.

MAGNETIC TESTING
SUCKER ROD CHARTS