AFTER PETROLEUM—WHAT?

By Isaac F. Marcosson

IN VIEW of the now familiar oil overproduction, with its unnecessary drain on the natural reserve, the question of future supply becomes increasingly acute. People are beginning to wonder if the carriage manufacturer is coming back to his former prestige, and whether the faded letters "L-i-v-e-r-y S-t-a-b-l-e," now supplanted by the more æsthetic "G-a-r-a-g-e," on endless buildings, will have to be restored. Is a nation on wheels, as it were, going back to the hoof so far as daily transport is concerned?

There is more truth than idle speculation in this surmise. Although it may be postponed longer than we think, the time is inevitable when we shall be obliged to depend for motor fuel on imported crude or a synthetic liquid distilled from coal, lignite or shale. This concluding article therefore will deal with the vital matter of oil exhaustion and, what is more important, the agencies available to stave off the era of substitutes. Into it must also enter an answer to the pregnant interrogation: After petroleum—what?

It is part of the chronic paradox which is oil that in an hour when superabundance gluts the market and depresses the price, in most instances below cost of production, the specter of famine should arise. This apprehension, however, is both timely and well founded. Check the flow of petroleum and you paralyze power and progress all the way from farm to factory and ship. Petroleum has become increasingly indispensable to civilization on land and water.

In the preceding paper you saw how the current crisis, born of excess, has brought the need of conservancy home as never before, and that some kind of safeguard, whether voluntary or involuntary, will emerge. This is only one phase of a bigger problem. No matter how we bulwark Nature's store, we must be prepared eventually to supplant her gift with a manufactured product. Conservation can merely prolong the life of an essential raw material doomed to ultimate extinction within our confines.

The first step in this final appraisal is a recapitulation of the big facts, notably concerning production. We cannot probe into the future without knowing something about the past. Oil and its products have become so cheap and accessible that few people stop to wonder about their source. In the same way they fail to appreciate the growing depletion of the hoard.

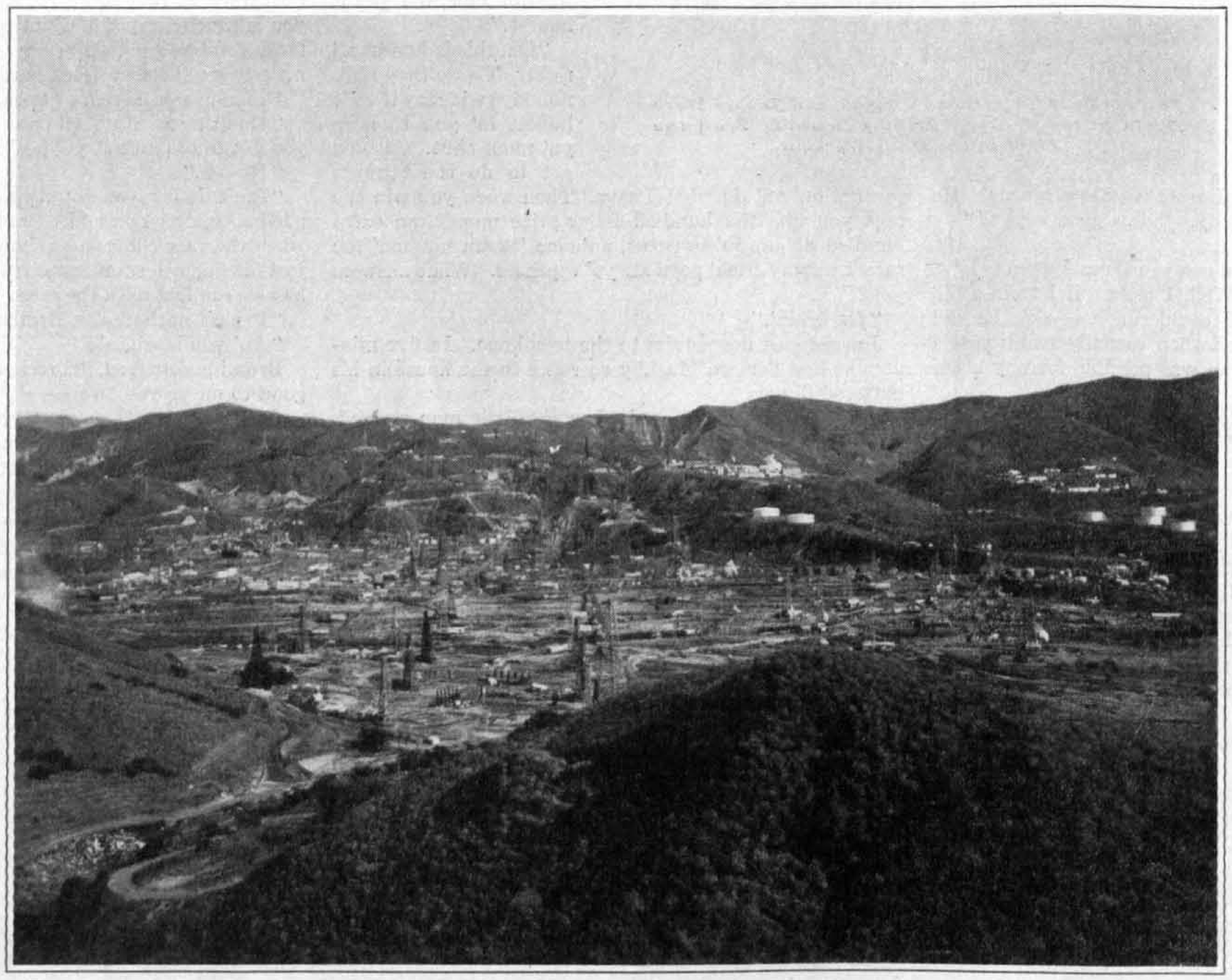
Assets With the Wanderlust

SINCE Colonel Drake put down his first well in 1859, the United States has produced nearly 10,500,000,000 barrels of petroleum. The annual output has grown from 209,557,000 barrels in 1910 to 900,000,000, which was the record of last year. We supply 70 per cent of the entire world yield. There are many men in the business who believe that if our present prodigality continues, this percentage will be exactly reversed and we shall be holding the short end.

With increased production has come a big advance in use. We consume, with exports, 1,000,000 barrels of gasoline a day. In 1927 the per capita absorption in the United States was 93.9 gallons, while for the rest of the world the rate was 3.3 gallons.

Each year has witnessed some new inroad upon oil. Its growing employment in the home is only one of many instances. The manufacture and sale of oil burners to warm the American household has increased more than 6000 per cent in the last three years. They warm every class, from cottage dweller to lodger in skyscraper hotel and apartment house.

Behind all this is the expanding maw of the American motor car. The high-powered vehicle is the demand of the public, let gasoline consumption be what it may. In 1913 we had just passed the 1,000,000 mark with automobiles. Today we have 23,225,000. Optimists in the business predict that we shall double this number in ten years. Whether the prediction comes true or not, the fact remains that for motor transport, as for nearly every other major line of human activity, we must have more and more oil to keep the wheels turning.



The New Ventura Avenue Field in California

If we had an inexhaustible reserve of oil underground, there would be no commentary on this expanding consumption. The reverse is true, because the store is highly problematical. You cannot block out oil in the same way that our reserves of coal, iron and copper are surveyed. Furthermore, coal stays put and oil does not. A testator is never certain that his bequest of oil land will be productive at that distant time when it is drilled by his heirs. This results from the nature of crude. It has the wanderlust. Because of its roving disposition, it must be garnered, once the oil well begins to flow. Otherwise adjacent areas take toll.

Any analysis of the situation must start with an inquiry into how much oil is left in the ground for our future needs. Like every other feature of the business, this is uncertain. All predictions so far have been in error. For forty years dire forecasts of imminent exhaustion ruled.

As recently as 1921 statisticians maintained that our domestic output would be at its peak when 500,000,000 barrels were obtained. Yet last year, as you have just seen, we produced 900,000,000 barrels, and the figure would have been higher but for the curtailment program at Seminole and Yates.

The difficulty in making any estimate of the invisible supply of petroleum grows out of the fact that the discovery of crude is not yet an exact art, although oil science has made many great advances during the last five years. Oil is hidden and production therefore becomes a finding industry. Favorable-looking lands become oil fields when the drill has proved the area, and only then. It means that all estimates must necessarily be conjectural.

Following the constitution of the Federal Oil Conservation Board by President Coolidge at the end of 1924, the American Petroleum Institute named a committee of eleven, which made an exhaustive investigation of the petroleum resources of the United States. Their report forms the best basis for ascertaining just how much oil is still available. The committee estimated that the wells and fields then producing would yield a future production, by ordinary flowing and pumping methods, of 5,300,000,000 barrels of oil. These fields had already yielded a grand total of 8,000,000,000 barrels.

The Surplus

IT WAS further pointed out that for each barrel that had been produced, and for each barrel that would be obtained by the methods then in vogue, at least two barrels remained in the ground. Owing to the haste that marks the oil operation, a maximum of only 25 per cent of the crude in the well is recovered. Many experts feel that the ratio of two barrels recoverable for each barrel already produced is too small, and that three and possibly four will eventually be available.

Using the minimum recovery of two barrels for one means that according to the 1924 calculation 16,000,000,000 barrels are in the reserve. This is based on the 8,000,000,000 barrels produced up to that time in the proved areas. Add to this the crude recoverable by the same ratio from the known reserve of roughly 5,300,000,000 barrels and you have a total of 26,600,000,000 barrels. Not all this ocean of liquid gold can be salvaged economically, but the oil is there and is obtainable in some way.

The committee of eleven report naturally took no cognizance of the flush fields brought in after its work ended. Since then new areas with gush yields have combined to bring about the existing overproduction. At the same time they will leave a wider area for recovery through intensive effort.

Chief among these recent bonanzas is Seminole in Oklahoma, whose five pools produced 108,572,461 barrels in fourteen months. While this series is being written four big wildcat wells in the same area have been brought in, adding more pools to the field. Under the curtailment agreement they have been pinched to 100 barrels a day each, awaiting the time when the older pools in the district shall have had a considerable drop in output. Drilling will not be delayed long, however, and by early summer these prospective areas, unless drastically held in check, may repeat the 1927 overproduction.

There appears to be no end to new discoveries and production in the West Texas field. In the now famous Yates pool two 20,000-barrel wells and one 65,000-barrel well were discovered late in November. It is estimated that the potential daily output of Yates is more than 300,000 barrels. As at Seminole, it is curtailed through agreement among producers. The limit here is 30,000 barrels a day. The Winkler field, also in Texas, would have a daily output of 100,000 barrels if the wells, now shut down, were being operated.

California has come to the front with a fresh spurt. At Long Beach a prolific deep sand has been uncovered in the oil Signal Hill section. By December first more than 100 wells were being drilled. Signal Hill is a town-lot area where lease owners cannot delay operation.

To these fields must be added Ventura Avenue and Seal Beach, both in California, as well as the reborn Spindletop in Texas. They strengthen the reserve for future use. The wells drilled during the last three years have already yielded considerably more than 1,000,000,000 barrels of oil and their productive life is still largely in the future. This makes the total reserve from all actually proved sources nearly 30,000,000,000 barrels. At the 1927 rate of production, this would last thirty-three years.

Moreover, the oil store of the United States lies in 1,100,000,000 acres of land not fully explored in which geology indicates oil is possible. Here and elsewhere the geologist is on the job with instruments that are taking the mystery and elusiveness out of oil finding.

Three Miles Down to Oil

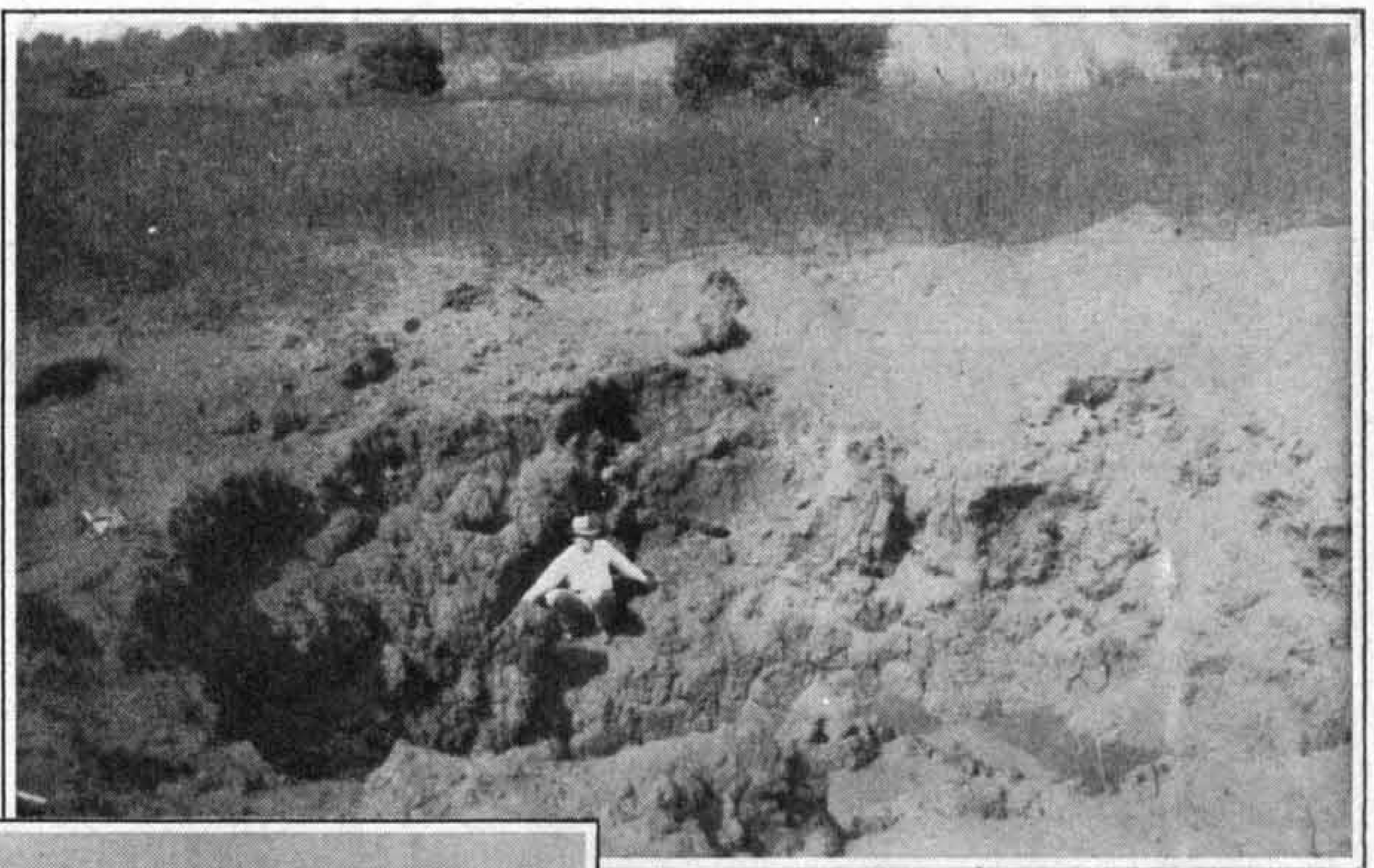
IT IS not until the finding of new fields lags that we shall concentrate on production in old areas. The period of prolific discovery in Pennsylvania, the mother state of petroleum, culminated in 1890. Production declined until 1915, when it was only 25 per cent of the peak reached in 1891. Today the output in Pennsylvania is actually greater than it was ten years ago. Efficient operation, once it became worth while, not only arrested the decline but enhanced the yield and held it for a decade, with the likelihood that it will continue for some time to come.

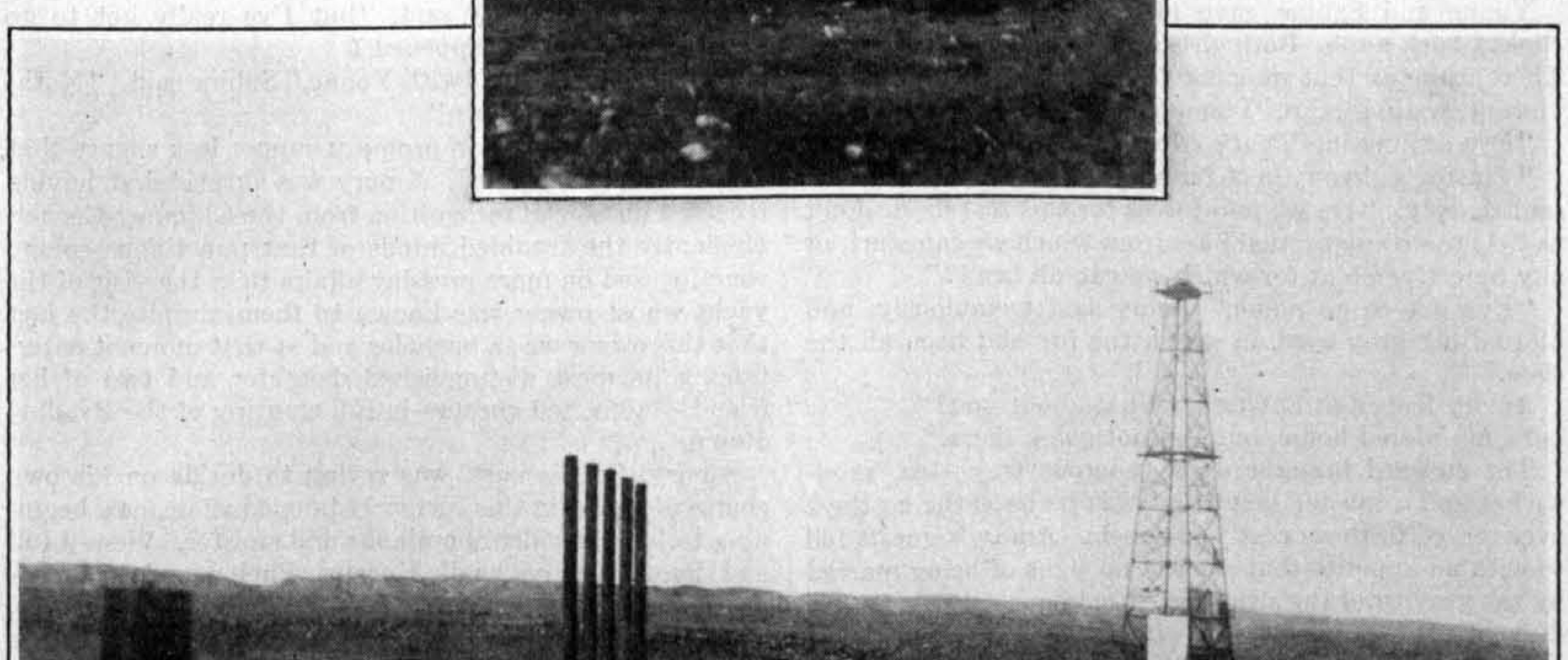
With this statement we come to what might be called the reclamation processes. They comprise one of the bulwarks of the future natural oil supply in the United States. There are four operations—namely, deeper drilling, water flooding, air and gas lift pressure, and mining. Each has demonstrated its ability either to restore old and abandoned areas or increase the output in active fields. We will take them in order.

Deeper drilling is just what the name implies. To understand it you must know that Col. E. L. Drake borrowed the idea for the pioneer oil well from salt drillers operating along the Kanawha River in West Virginia. Before that time oil wells had been dug by hand in Poland, Rumania and Russia. Even today wells are being bucketed—that is, actually dipped for oil—in these countries.

Colonel Drake used a drill and set casing in a hole. It was the first time that this had been done in oil finding. One afternoon in August, 1859, the well reached a depth of sixty-nine feet and the crew stopped work for the day. When they returned the next morning the well was nearly full of oil. The Drake discovery had been made and the American petroleum industry was born.

In the early days of the Appalachian development wells were seldom drilled deeper than a few hundred feet. As shallow sands—all oil is found in sands—became exhausted, the drill, in following the dip of the producing horizon, as it is called, or in searching for new horizons, had to go to greater depths. This penetration opened up new areas, with the result that drilling became increasingly deep.





A Dynamite Explosion to Create an Earthquake in Oil Finding

At Top—A Shell Hole Resulting From a Synthetic Earthquake

At Left—The Irak Well Just After it Blew in, Flooding the Countryside With Oil. It Now Flows 92,000 Barrels a Day

Below—The Irak Well Before it Blew In

It is interesting to contrast that first sixty-nine foot Drake well with the 8000-foot wells now to be found in California, where the operation is on a deeper scale than in any other state. The California fields provide the latest evidence that deep drilling can harvest two crops of oil. This is notably true in the Ventura Avenue field just outside the city of Ventura and sixty miles northwest of Los Angeles. In 1915 prospectors drilled to 2250 feet—a deep well for those days. It was not a paying producer and work stopped. Eleven years later commercial oil was brought in at 6000 feet. The field is now producing 60,000 barrels a day.

Another instance of the efficacy of deep drilling, this time with a romantic background, is furnished by the revived Spindletop. The wells in this spectacular field, which made oil history, never got below 1000 feet. It was long before the deep-drilling era. When they fizzled out the region was practically abandoned. In 1926, and within stone's throw of the original producing section, oil was discovered in big quantities at 5000 feet. It is estimated that 60,000,000 barrels of oil are now recoverable at Spindletop. Without deep drilling this might have remained forever locked in the sands. Seminole was not proved until the operators went down as far as the first prospectors.

Deep drilling therefore becomes a definite first aid to our future oil needs. It is altogether likely that the oil well of tomorrow may be from 10,000 to 15,000 feet in depth. The development of old areas through this improved method of production will be tantamount to the discovery of fresh fields.

The second method of recovering oil from old wells is by flooding them with water at high pressure. It has been successfully employed in the old Bradford field of Pennsylvania and elsewhere in that state. The cost is high and the system cannot be operated economically on low-priced oil on land giving a meager yield.

Scrubbing the Sands With Gas

MUCH more has been gained in a practical way from gas and air lift. Oil underground is heavily impregnated with natural gas, which helps to propel it to the surface once the hole is made. Unless the operator exercises care, much gas is wasted in the air. Hence the gas-conservancy movement now in full swing.

By the gas-lift principle the gas is returned into the well to aid and extend its flowing life. The sands are scrubbed with gas, as the phrase goes, and the gas permeates to adjacent areas, accelerating the oil movement. The process is called recycling, because the gas is literally recycled back to its original home. It brings about a restoration of pressure. The system has been so perfected that it is now widely employed. At Seminole, for example, it increased output by 150,000 barrels a day. It has been known to swell the daily production of a single well from 300 to 5000 barrels.

In connection with natural gas is a fact that few laymen appreciate. The utilization of natural gas for the making of gasoline constitutes one of the most important conservation efforts of the industry. Formerly

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most of the gas coming out of oil wells was permitted to escape unused. In recent years the building of natural gasoline plants to take care of the gas has become an integral part of operations throughout the country.

Natural gas is an increasingly important source of gasoline, supplementing the supply from petroleum. In 1926 the production of natural gasoline amounted to 32,000,000 barrels, as against 7,000,000 barrels in 1918. The development of this source of supply ranks second only to cracked gasoline, derived from fuel oil and gas oil, in its importance in supplying the voracious appetite of the motor car and forestalling a shortage.

The gas from petroleum and natural gas wells is treated by two principal methods—absorption and compression. The raw gasoline derived is a very volatile product. New methods of rectification have been developed which make it possible to produce natural gasoline suitable for high-compression airplane engines. The major portion of the natural gasoline is employed for blending with petroleum gasoline of low volatility. It thus makes available for motor use a quantity of fuel in excess of its production from crude.

Mining for Oil

The air lift uses compressed air instead of gas. It was originally devised to clear water out of flooded mines. The presence of so much gas in oil fields, however, makes its service preferable to air.

The mining process has been developed to restore semidepleted oil fields. It is considered operable in the majority of older areas in the United States and has been practically demonstrated in Texas. Engineers believe that it should recover two to three times the oil already obtained from the wells, and at much lower cost.

Because this operation is the latest innovation in oil recovery and is likely to have wide employment in the future, it is well worth explaining in some detail. A shaft is sunk as in metal mining to a point ten or fifteen feet below the oil sands. At this depth tunnels seven feet high are dug from the bottom of the shaft out under the sand. Cross tunnels are then excavated, so that an underground picture of the workings would resemble the streets of a city. Tunnels are never driven in the oil sand itself, so gas is not a serious fire hazard. Along these tunnels small wells are drilled upward into the bottom of the oil sand, one well every ten feet. A pipe is placed in the mouth of each mine well and connected to the main pipe line in each tunnel. More than 500 of these little mine wells are drilled for each forty acres. Oil flows from the bottom of the sand through the mine wells to a pump at the bottom of the shaft, whence it is lifted by pressure to the surface.

A different mining method is used at Pechelbronn in Alsace. There the tunnels are dug within the oil sand and the oil allowed to seep from the roof, walls and floor of the tunnels. The oil then collects in pools and is pumped to the surface. Approximately 350,000 barrels are recovered a year by this method. The Pechelbronn field was first drilled in the usual manner and 16 per cent of the oil obtained. Mining salvages approximately 50 per cent of the remaining crude. Gravity is the principal expulsive force of the Pechelbronn method.

This reference to mining projects a serious situation with regard to an essential raw material that is seldom discussed because it does not figure in the spotlight like oil. I refer to the depletion of the copper reserve. Amazing as it will seem to people not directly connected with the business, we have only a twenty-year supply remaining in the United States. At the present rate of exhaustion it is even doubtful if there is a store sufficient to cover this period. The reason is interesting.

The vast army of gold seekers attracted by the superficial gold deposits in the Far West during the thirty years succeeding the discovery of gold in California in 1849 became miners by occupation and prospectors by inclination. Never had such a pursuit been so favored. A great undeveloped country with temperate climatic conditions, abundance of water, ample timber, adequate lines of communication accessible to supply bases, combined to advance their adventurous explorations. What attracted them to ravine and canyon were the fabulously rich placer deposits containing gold that had been washed down by erosion from the mother lodes in the mountains.

When these superficial deposits became exhausted it was natural that the miner should turn his attention to the discovery and development of the sources of the mineralization that had yielded such profitable results. Silver, next to gold, was most eagerly sought. Except in a few cases, these ores were found associated with the baser metals. The development of our complex mines of gold, silver, copper, lead and zinc followed in natural sequence. Coincident with this intensive search for minerals was the rapid expansion of the country, offering an extraordinary market for all metal products. During this time the United States became the chief source of supply of the mineral wealth of the world. Oil vied with copper for premier place.

When the period of pioneering had passed and the mineral districts of the United States had been thoroughly surveyed, developed and finally coördinated into corporate ownership and management, it became necessary to prospect outside our confines. The modern copper developments in Mexico, Chile, Peru and other countries followed. Happily, we have a big share of these alien domains. Here you have another parallel with oil, as you will presently see. The Latin-American countries, however, were not so favorably conditioned for mine-prospecting enterprises as was the United States. Transport was difficult, progress slower and much more capital necessary.

It follows that the copper-ore reserves of the United States have been far more heavily drawn upon than the more recently developed stores of other countries. They will have an abundant supply when we shall be obliged to depend upon the imported commodity. Again you have a kinship with oil. Persia, Russia and South America will be flush when we are depending upon the synthetic product.

From Biblical Days

What a diminished supply of copper might mean to us, both from the industrial and political standpoint, is obvious. Copper is indispensable to civilization, forming an essential element in communication and electrical development. It is likewise a vital requisite to national defense. During the World War it was regarded by all governments involved as important as TNT. In the matter of substitution oil scores on copper. When the petroleum reserve is eventually finished, we shall be able to manufacture a substitute from coal, lignite or shale. Science so far has found no understudy for copper.

Resuming the oil narrative, we can proceed to the most fascinating phase of the subject. It is the new science of petroleum. Through what is known as geophysics—that is, the study of the physics of the earth—the search for crude is becoming easier and the results more certain. Applied geology has largely contributed to the existing disastrous overproduction.

Oil occupies a paradoxical position among minerals in that new researches and developments have tended to increase rather

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than decrease the possibilities of discovery. It is now known that petroleum occurs in sedimentary rocks of any age and in any structural position. The greater part of the earth's surface is composed of sedimentary rocks, but not all formations of this character contain oil. The aggregate acreage of all the producing areas in the United States is insignificant compared with the total area of sedimentary rock. There are numerous examples in the past history of the industry where regions, once drilled and abandoned, have been redrilled and found to contain valuable deposits. Hence the pursuit of oil has been a great adventure. Cold science is now taking the thrill out of it.

For ages oil finding was a haphazard proposition. There was no incentive for organized research, because petroleum figured only incidentally in daily life. No geologist, for example, was required to locate the pitch that tightened the seams of boats back in Biblical days. This material, by the way, was used to waterproof the historic little basket in which the infant Moses was found in those well-known bulrushes. Nor did a scientist discover the Indian oil springs in Northwestern New York which first introduced petroleum as a lubricant and liniment in the United States. The usual indication of a deposit such as this was through seepage.

The application of science to oil location was slow. This means that it barely covers two decades. The pioneers worked on a hunch, or used a divining rod made of the forked branches of a hazel tree. When the geologist first appeared he was placed in the same category as the oil witches or the oil smellers, who literally smelled out oil. The first scientists in the business were dubbed rock hounds, pebble pups and wrinkle chasers. The last-mentioned appellation developed from the fact that those early geologists based some of their estimates on earth wrinkles. Even after the geologist—or the geolog, as he is called—became a fixture, he was looked upon with scorn and skepticism by the old-timers.

Allied With Science

What practically amounted to a new science had to be developed. The accumulated geologic lore of a generation ago was a totally inadequate basis for an intelligent search for new oil fields. Many things had to be learned and as many unlearned. The old hunch gave way to definite formulas based on incessant probing into the bosom of the earth. Geology could not serve the petroleum industry with the greatest efficiency, however, until it literally became a part of the business.

In this respect an important advance has been registered. The original petroleum geologists were long-haired and highbrowed. They acted as consultants and sat apart, dispensing their academic lore in guarded and jealous fashion. They directed operations, but did not condescend to become part of the searching expedition. Moreover, they spoke a totally different language from that of the lowly driller. Neither understood the other. The big objective could not be gained until these two—the geologist and the driller—actually joined forces in a coöperative effort to locate oil.

Today this alliance has been effected. The geologist is an active oil finder and most oil producers have become geologists of parts. Geologists have invaded every branch of oil-search endeavor and become drillers, lease men, oil-field scouts and even production-department executives. Every company has a highly organized geological staff. In consequence the discovery rate has been accelerated tenfold since 1917, with only a 25 per cent increase in the number of wells drilled.

The first aspect of this new activity had to do with surface geology. More recently has come subsurface geology, carried on principally through the study of logs of wells. A complete record of every well drilled is made. The samples of rock taken out are analyzed in laboratories and producing areas charted. An oil bed is distinguished by the presence of fossils and sometimes by the general appearance of rock particles. A diamond core drill is used in research work. It is hollow and brings up samples, or cuttings, of the formations penetrated. This type of drill was responsible for the discovery of the famous Tonkawa field in Oklahoma.

With the growing demand on the geologist to find more and more oil, it became necessary to know in advance of drilling the general character of the rocks to a depth of several thousand feet. In consequence he has had to appropriate and adapt various devices which are almost uncanny in their operation. Chief among them is the seismograph, which deciphers the nature of deeply buried rocks.

Artificial Earthquakes

As most people are aware, the seismograph is commonly employed to detect and register earthquake tremors. It was made portable and adapted to determining rock character and geologic structure by the Germans during the World War, although its use for this purpose had long been anticipated and discussed.

Knowing the geology of the French battlefields and the general character of the rocks beneath the terrain, they were able to record the vibrations which artillery fire set up in the earth and in the air. From this they were frequently able to locate Allied batteries. The seismograph became a range finder.

Baron Mintrop, a German nobleman, is largely responsible for the development of the standard oil-field apparatus now in use. His war experiences equipped him to employ it in geological formation. He made the first survey in this country, with his own staff of operators and instruments. Thus indirectly the great conflict has made a valuable contribution to the petroleum industry.

The use of the seismograph in oil finding has created a picturesque activity. Earthquake waves are transmitted through various classes of rock at different speeds, depending upon the elasticity of the rocks encountered. One important type of oil field in America is always associated with a highly elastic rock—namely, rock salt. To find such an oil field it is necessary first to locate the buried mass of rock salt with which it is connected. If one could observe the passage of an earthquake wave through such a rock-salt mass, it would be possible to detect its presence by reason of the accelerated velocity through the highly elastic salt.

The geologist cannot sit down and wait for an obliging earthquake to come along to the particular area he is attempting to explore. Nature's ordinary quota of destructive shocks is fully adequate at all times. It is not sufficient, however, for the oil industry in its current hectic search for new areas. For this purpose earthquakes must be created artificially, at a zero hour, timed to the second and of a carefully calculated intensity.

The oil business therefore has become the focus and source of an earthquake epidemic of amazing proportions. It literally moves the earth in the frantic hunt for more oil. Synthetic earthquakes have become one of the most finished accomplishments of the scientific end of the game. These are produced by burying and exploding large charges of dynamite. The instant of each explosion and the arrival of the resulting wave, or shock, are recorded accurately by a number of portable seismographs distributed around the charge at known distances. The size of the dynamite charge varies from 50 to 500 pounds and the distance from charge to seismograph ranges from two to five miles.

There results from this work a dynamite barrage over prospective petroleum lands reminiscent of World War bombardments. The wildcatter has become one of the best and largest customers of our explosives industry. Thousands of tons of dynamite are detonated annually over the swamps and woods of the Gulf Coastal area. The explored terrain takes on the aspect of the shell-pitted No Man's Land of trench warfare.

So much for the technical explanation of a performance unique in practical investigation. Now for the results. Earthquake waves move through ordinary rocks at a speed of something like one mile a second, whereas through rock salt they hurry along at more than three miles a second. The rock-salt masses, with which salt-dome oil fields are associated, are usually a mile or more in horizontal dimensions. Therefore if a rock-salt mass occurs beneath the surface between the dynamite charge and any of the seismographs, its presence will be proclaimed by the velocity record which the apparatus makes.

The seismograph crew moves about over the country, sending out earthquake waves over a closely intersecting pattern so that no buried salt dome or any other mass of elastic rocks with which oil might be associated can escape it. Once a salt dome is found in this fashion, the drill is set to work to determine if there is any oil around it.

The seismograph is peculiarly useful in the search for salt domes on the Gulf Coast. Before geophysical methods were introduced, there were seventy-five known domes in the region, every one a possible oil field. Of this number a dozen were already prolific producers. By the use of the geophysical instruments six more have been discovered and the search has only started. Of the new domes already located, 85 per cent are credited to the seismograph.

The Gulf Coast region lends itself to seismographic investigation because of the elasticity of the rock. Elsewhere this elasticity is less differentiated, as the scientist expresses it. In such areas seismic work is more complex and difficult. For these regions the apparatus known to the physicist as the torsion balance is employed. This brings us to the second of the modern divining rods.

The Modern Divining Rod

A torsion balance is a precise instrument for measuring the strength of the ordinary force of gravity. It will be recalled that gravity is the form of attraction which every bit of matter in the universe exerts on every other. If an ordinary pendulum is set swinging, it will eventually come to rest at the central or lowest part of the path of its swing, because the force of gravity alone finally holds it as close as possible to the earth.

The torsion balance is a pendulum which swings in a horizontal plane instead of in a vertical plane. In its simplest form it is a metal rod or bar with weighted ends, suspended at the center by a wire from a fixed support. As the bar swings around, the wire is twisted until its resistance finally swings it in the other direction. It goes back and forth until it finally comes to rest.

The application to oil finding is made in this way: It has been observed that the rocks in which petroleum is found are often denser or more compact than the surrounding rocks at the same depth. By moving a torsion balance from point to point over the surface it is possible to detect the presence of very heavy rocks beneath and thus locate points at which it may be worth while to drill a well.

The third geophysical method involves measuring the strength of the earth's magnetic field from place to place with a delicately balanced magnetic needle. The earth's magnetism is often abnormal in oil fields. By magnetometric survey it is possible to locate an area of abnormal magnetic force, thus giving a possible clew to a buried pool.

A fourth rather widely used apparatus utilizes the property of petroleum which makes it impermeable to the flow of an electric or magnetic force. Oil is well known as an electric insulator and offers great resistance to the passage of electric currents. Recently developed portable generators permit the sending of small electrical currents, and the induced magnetic lines of force, to great depths in the earth and measuring or following their paths. If these paths encounter a body of oil-saturated sand, they will depart from their usual arrangement and so reveal the presence and position of the oil barrier.

These aids have not only proved their efficacy but their use and value are likely to be enhanced. An intensive scientific study of petroleum has just been inaugurated under the auspices of the Central Petroleum Committee of the National Research Council through the generosity of John D. Rockefeller and the Universal Oil Products Company. Each gave $250,000 for the purpose.

Twenty-one subjects for fundamental research have been outlined. Five are along geographical lines, seven deal with physics and the rest with chemical problems in the industry.

An Oil-Insurance Policy

The first phase will be a study of the generation of petroleum, seeking to discover the process by which and the source from which it accumulates in the earth. This embraces studies of fossil organic matter to determine what is really the mother substance of oil. Once this is learned, geologists will be better equipped to locate pools. You cannot wonder at the uncertainty of the oil business when you are told that its very origin is in doubt. One theory is that it is inorganic—that is, the development from chemical action on rocks forming part of the earth's crust. Another holds that oil is organic, resulting from the decay of animal and vegetable matter, both land and marine.

Another line of investigation covers oil structures. Sometimes when apparently promising structures are found, efforts to locate oil prove fruitless. With better knowledge of the mother substance, drilling of favorable formations which do not contain the proper source rocks, would be avoided.

More important to our future oil needs is a forthcoming survey of shale deposits, because out of shale may be distilled the motor fuel of tomorrow.

Science is being mobilized not only to increase the petroleum supply but to make it go farther. This is being done in two ways. One is by means of improved refining processes, principally cracking, which have steadily increased the yield of gasoline, now the major product of petroleum. Twenty years ago only 4.5 gallons of gasoline were derived from a forty-two-gallon barrel of crude. Now nearly fifteen gallons are obtained. It is possible that through further refining advance such complete use will be made of fuel oil that it will cease to compete with coal.

The other economy is being achieved through structural mechanical changes in the automobile so that more mileage will be gotten from gasoline than is obtained today. This saving in fuel comes from reduction in the size of the engine, less horse power and more flexibility of operation.

All this scientific advance has a distinct virtue. At the same time it embodies what might be construed as something of a defect. Geology makes oil discovery easier, to be sure, but it also accelerates the drain on the reserve. This store must find reënforcement if the age of substitutes is to be deferred.

Long before the present overproduction conjured up the vision of scarcity, the American oil industry began to write an insurance policy in the shape of producing lands abroad. We are now intrenched in practically every great petroleum domain overseas, notably Latin America, and are increasing our holdings every year. The sun never sets upon the Yankee driller operating on Yankee-owned properties.

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First let us visualize the world output, because it will show how we dominate the situation. In 1900 the entire production from all sources was less than 150,000,000 barrels. In sixteen years it had grown to only 457,500,000 barrels. The motor car had not become the factor in consumption that it is today. By 1926 it reached 1,095,934,000 barrels. To this the United States contributed 70 per cent. Mexico was second with 8.3 per cent, Russia third with 5.71 per cent, Venezuela fourth with 3.41 per cent and Persia fifth with 3.27 per cent. These were the big five. Last year the total world output expanded to 1,243,000,000 barrels and our share was again 70 per cent. Russia moved up to second place and Mexico dropped to third because of governmental interference with operation. Venezuela and Persia remained fourth and fifth respectively.

The fact that Russia now ranks second in output justifies comment for a variety of reasons. From the late 90's until 1901 she led the world in petroleum production, producing a little more than 50 per cent of the total. Her two great fields—Baku on the Caspian Sea, which is the oldest in the world, and Grozny in the Northern Caucasus—were regarded as the greatest of all reserves. The decline to less than 6 per cent of the world output shows how her oil prestige is dimmed. We supplanted her and have led for twenty-six years.

We have—or rather had—a definite stake in Russian oil and it unfolds a sad tale of expropriation and loss. When the Bolsheviks came into power they seized all private property and nationalized every industry, with disastrous results for the victims. In most cases the business also suffered. Oil furnishes perhaps the one exception, because during last October production was brought to the prewar level for the first time.

Before sovietism became confiscation, the Standard of New Jersey bought a half interest in the Nobel oil concern, which had extensive holdings in all the Russian areas. These included wells, pipe lines, refineries and marketing facilities. The total investment involved was not less than $50,000,000. These immense interests were commandeered by Moscow and placed in charge of what is called the Naphtha Syndicate. In Russia every industrial undertaking is operated through a syndicate which the government both owns and operates.

Trouble in Oil

The net result is that the Standard and the Nobels have lost their properties. Meanwhile the Bolsheviks are producing and selling the oil throughout the world and the rightful owners do not receive any compensation. It is just one more commentary on the economic injustice—I use the most amiable expression—of the Bolshevik business creed.

The recent experiences of American oil producers in Mexico show how complications pursue operation abroad as well as at home. We own 65 per cent of the Mexican oil fields, representing an investment of $600,000,000. American capital and initiative made the republic at one time the second most important productive area in the world. Tampico emerged from a small town into a thriving city as a direct result of the oil effort. More than 60 per cent of the national revenue was derived from the petroleum taxes.

There is no need of rehearsing the Mexican oil muddle save to say that the Supreme Court decision, ostensibly favorable to the American interests, handed down late in November, did not solve the fundamental problem involved. The alien landowner is still obliged to exchange his actual ownership rights for a concession. Thus the retroactive and confiscatory feature of the constitution of 1917 remains effective. It is likely to continue so long as Calles and his type of government persist.

The decline in Mexican output constitutes the strongest possible indictment of communistic meddling in big industry. In 1922 the yield was 182,278,000 barrels. In 1927 it had shrunk to 65,000,000 barrels. Though intrusion of salt water had depreciated some of the older fields, the output would have been much bigger if socialistic adventuring had not well-nigh paralyzed operation and begot uncertainty of actual ownership.

In still another Latin-American field the American oil man is booked for possible trouble. We own practically the entire productive area of Colombia, which last year added 15,000,000 barrels to the world supply. Legislation is now pending in the Colombian congress to nationalize the oil industry. The effect is not, however, so far-reaching or destructive as the Mexican program.

The American Group

A refreshing exception is Venezuela. Here American interests control nearly 40 per cent of the fields, where output in 1927 was 62,000,000 barrels. The oil offensive radiates from Maracaibo, once the haunt and rendezvous of pirates like Morgan and Lafitte, who infested the Spanish Main.

Political and legal conditions in Venezuela are much more favorable to industrial development than in Mexico. Dictator Gomez is a shrewd business man and has given every possible aid to alien enterprises. Oil has become the foremost meal ticket of the country. Moreover, it is changing the face of the country, because it means good highways, increased wages and a higher standard of living for the natives.

Conditions similar to those in Venezuela prevail in Peru. Here American companies own 81.16 per cent of the oil area. Like Gomez, the Peruvian president, who is the masterful little Leguia, encourages the foreigner. American-controlled development has redeemed the Talara region from the desert and given it an annual production of more than 10,000,000 barrels.

Our oil exploitation extends from Canada, where it affects 59.13 per cent of the business, by way of Rumania, with holdings of nearly 7 per cent, to Poland, with 6.58 per cent. It has a share in the Trinidad output and a small foothold in Argentina. The Dutch Indies, preëminently the home of the vast Royal Dutch combine, have also been invaded by the Yankee.

One American oil interest overseas is in a class by itself. It involves the participation of what is known as the American group in the Turkish Petroleum Company, which has begun an extensive development in Irak, the one-time Mesopotamia. The concession is more bound up with romance and political adventure than any similar modern undertaking. It has survived two empires—the German and the Turkish—and was originally linked with the departed Teutonic ambition to rule the East. I have already told the story of this enterprise in detail in these columns. A brief summary is necessary to bring it up to date.

In the early days of the twentieth century the Germans discovered oil in the Mosul area, which was then a part of Turkey. They wanted an economic foothold there, because the German-conceived Berlin-to-Bagdad Railway ran through the Sultan's domain and was part of the Hohenzollern spearhead aimed at British rule in India. The British and Dutch also aspired to control the area, with the result that in 1912 the late Sir Ernest Cassel, who owned

the National Bank of Turkey, a British institution, coördinated all the conflicting elements and organized the Turkish Petroleum Company. This same name had been used by the original German prospectors. The Anglo-Persian Oil Company got 50 per cent of the stock and the Dutch-Shell and the Deutsche Bank, which represented the Germans, 25 per cent each.

Because of the vagaries of Turkish rule the validity of the concession was more or less in doubt. The World War galvanized it into new life and integrity, but not without almost endless complications. For one thing the Turks lost a great deal of their territory, including Mosul. It became part of Mesopotamia, which, in turn, emerged as the independent country of Irak under British mandate.

It was not until the San Remo Conference in 1920 that the Turkish Petroleum concession once more became a live international issue. At this meeting of the Allied Supreme Council the oil spoils of war were distributed. The German interest of 25 per cent in the Turkish Petroleum Company was given to a French group in consideration of the right to build a pipe line across Syria, where France has a mandate, to the Mediterranean. This left the Anglo-Persian with 50 per cent and the Dutch with the remainder.

The United States suddenly woke up to the fact that it had been left out in the cold. After diplomatic representations by the State Department, the Anglo-Persian turned over half its share to what is known as the American group, composed of the Standard of New Jersey, the Standard of New York, the Gulf Refining Company, the Atlantic Refining Company and the Pan-American Petroleum Company. American entrance meant the open door in Irak on an equitable basis for everybody concerned. We performed the same operation, by the way, for trade in China.

The Turkish Petroleum Company was not able to drill until last year. Many obstacles intervened. First the Mosul territorial problem had to be settled by the League of Nations and Irak stabilized as a functioning country. A formal agreement between the Irak Government and the company was then necessary. It was signed in 1925. There was still a difficulty. A picturesque Armenian, C. S. Gulbenkian, who had been financial adviser to Abdul Hamid, last of the Turkish Sultans, owned a 5 per cent interest in the company. When his claim was adjudicated in 1926 with a royalty arrangement, the way was finally open to exploitation.

A Gusher Blows In

Late in September, 1926, it was decided to drill ten wells in an area including five districts. Four are in the wild country of the Kurds, which lies toward the eastern border of Irak, adjacent to the Persian frontier. It is a hilly region, merging gradually into the Kurdish mountains which overlook the ancient Tigris River. The Kurds are descendants of the Saracens, whose gallant and warlike leader, Saladin, was the implacable foe of Richard the Lion-Hearted in the days of the Crusades.

The remaining district to be developed is on the west bank of the Tigris, forty miles south of Nineveh, renowned in history as the scene of the great Assyrian battle raid. This section differs from Kurdistan in that it is flat desert and sand. The oil seepage is so rich that it can be smelled miles away.

The Kurdistan area has produced the first big strike. In October last a great gusher, which flows 92,000 barrels a day, was discovered. On the night of the fourteenth work was suspended at a depth of 1500 feet. The camp was in repose and no sound was heard save the challenges of the sentries. This land is still so primitive that armed guards must be maintained. At three o'clock in the morning the place was awakened by a crack followed by a terrific roar. The monster well had blown itself in. For six days it defied all efforts to shut it. In consequence the entire countryside was awash with oil. Two American drillers were fatally gassed. This spectacular discovery temporarily focused world oil attention on the Mosul area.

Irak is now added to the list of petroleum fields. Other wells have been brought in and there is promise of a huge production. The country is so isolated that expansion is invested with hardship as well as great expense. Among other things, a pipe line 700 miles in length will have to be built across Syria to link Irak with the Mediterranean. What has often been called the cradle of the world, where stalked the figures of an immortal age, will soon be harnessed up to modern industrial needs.

Oil has become a world issue of vital and increasing interest, because essential raw materials are the new incentives for governmental control everywhere. The association of the American group in the Turkish Petroleum venture therefore means much more than a quarter share in a new flush field. It signifies that we are part and parcel of a petroleum internationale, which can only make for political and economic amity between the four countries involved. With kindred interests, they will be disposed to keep the peace.

The Shortage Solution

At this point the question arises: How can the existing American machinery of oil transport be adapted to a foreign supply? Several years ago I put this query to the head of one of the greatest oil companies in the United States. His reply, as applicable today as then, was as follows:

"If the source of a considerable part of the American people's crude oil requirements be transferred from domestic to foreign fields, the American petroleum machine can go into reverse without much more effort than throwing out the clutch. It was built to do that.

"The trunk pipe lines from the interior to Atlantic and Gulf ports will carry crude as cheaply to the interior as away from it. Should the American producing field be changed into a consuming market, the problem of supplying the refineries dependent upon it would present no great difficulties, and the cost need not necessarily be much higher. Once afloat and in large bulk, crude oil can be transported in tankers at a surprisingly cheap rate as compared with any other method.

"The big tankers with which the industry has equipped itself, and which are now engaged in the movement of crude oil from California and Gulf ports to various seaboard refinery points, could be used for the movement of crude from, say, a Mediterranean port, which would be the terminus of a pipe line from Irak, at a lower cost than is now incurred in moving crude through the Panama Canal from California to a North Atlantic port. The longer the water route, the cheaper the cost per ton mile. It is as feasible to bring crude by water from foreign fields to be refined in the Atlantic, Gulf or Pacific Coast refineries, exporting the surplus, as to refine the crude at the point of origin and be under the necessity of exporting all the variety of finished products derived from it.

"Given access to foreign producing fields, the industry could protect American consumers of petroleum products against danger of shortages, and hold and increase its foreign trade. It would not matter in what remote corner of the globe the fields were situated if American tankers could tank them. Diminution of our native crude supply would not in the slightest degree mean the impairment of America's position as the greatest petroleum exporting country in the world."

Despite imports from foreign fields and the salvaging of old areas, it is obvious that some day our petroleum supply will be inadequate. How are we to meet the deficiency?

The answer is simple. Foreign nations, especially Germany, have already solved

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the problem on a commercial basis at existing prices for oil products. We can duplicate their effort and on a bigger scale. We will make our oil and gasoline when it becomes worth while out of carbon and hydrogen, the same ingredients that Nature uses in her laboratories.

We possess these elements in literally inexhaustible quantities. They are the two fundamental constituents—in fact, the only essentials of petroleum and petroleum derivatives. By heat and pressure we can combine them to form our various necessary oil and liquid fuels. They occur throughout the earth and over as much of the universe as it is possible to observe with any degree of precision. The ocean—that is, water itself—is hydrogen in large part. Every woody plant is essentially carbon. Our coal, lignite and shale are carbon and hydrogen susceptible of conversion into fuel and lubricants in such quantities as to furnish gasoline in adequate volume for centuries to come.

It is not surprising that the Germans should have been the first to find the formula for synthetic oil. Their research in substitutes leads the world. Self-sufficiency in raw materials dictated an intensive drive during the war, when the country was under rigid Allied blockade. They were not pushed for oil, because the Rumanian supply was available.

Their chief anxiety, after food and copper, was for rubber, which was artificially produced during the last two years of the conflict. The product was especially useful on truck tires so long as they remained in a temperate climate. Exposed to the rigors of Russia and Poland, they failed to stand the strain. Besides, the process was highly expensive.

It is interesting to interpolate that during November the Chemical Trust—the famous I. G.—which is the biggest industrial aggregation in Germany, announced that its chemists had finally manufactured synthetic rubber that could be commercialized. No explanation was made save that a new catalyzer had been found uniting the elements of rubber contained in coal tar. If this discovery is practical it will mark an era in industrial life. For decades the conquest of artificial rubber has been the dream of chemists the world over.

All From Coal

The I. G. controls the Bergius patent for synthetic oil now being used in Germany. Under it bituminous or subbituminous coal is milled, or pulverized, to a fine powder, to which 30 per cent coal tar or oil residue is added, forming a thick paste. This mixture is heated to a temperature of not less than 400 degrees centigrade while terrific pressure is applied. This carbon in its pasty state takes up the hydrogen to create the oil. The first-run oil is then distilled.

According to official reports made to the Department of Commerce, a ton of coal with 6 per cent ash content yields 1000 pounds of oil. This, in turn, is productive of 300 pounds of gasoline, 400 pounds of Diesel and impregnated oils, 120 pounds of lubricants and 160 pounds of fuel oil. The rest is lost.

By this process the cost of a ton of oil products is from \$20 to \$23. The price of the natural article in Germany, with import tax, varies from \$35 to \$47.50. During this year the I. G. expects to produce 100,000 tons of synthetic oil, which will be an important contribution to the country's requirements.

Not only are the I. G. oil processes available for the Standard of New Jersey through an arrangement for interchange of patents made last summer by Walter Teagle, president of the company, but the American rights to the original Bergius patents, seized during the war, now repose in the archives of our Chemical Foundation. It will be necessary only for an American concern to get a license to use them. Meanwhile our chemical research will undoubtedly devise some new operation.

What concerns us is the date when we shall be obliged to turn to synthetic oil. Contrary to popular belief, it will arrive considerably before the exhaustion of our native petroleum supply. The artificial product is likely to compete with the real thing.

The general opinion among American oil men is that when gasoline sells from twelve to fifteen cents a gallon at the refinery—at this rate the cost at the filling station would range from twenty-five to thirty cents—it will be time to turn to the manufacture of oil out of coal, lignite or shale. The Germans are now trying to demonstrate that they can sell gasoline made from brown coal at the equivalent of twenty-five cents a gallon.

A Look Into the Future

The important point is that whenever the era of substitutes arrives we shall not only be equipped with formulas but have vast supplies of available raw material. It so happens that our great coal fields are adjacent to oil-producing areas. This is notably true in Pennsylvania, West Virginia, Indiana, Illinois, Texas and Oklahoma. The value of this proximity is that the equipment for both transport and refining is near at hand. We possess immense deposits of shale in Colorado, Wyoming, Washington and elsewhere. Half the American states could easily become sources of oil.

This transition will work a tremendous change. For one thing, oil finding becomes a mining proposition. Coal, lignite and shale must be dug, requiring much more manual labor than the present drilling operation. It would mark the end of the landowner's hectic rush to have his holding exploited the moment oil is struck. Whatever the other economic consequences, the synthetic epoch will doom overproduction.

One final query remains. How can the existing refineries be adapted to an artificial product? This will offer no difficult problem. Since 1918 improvements in refining, notably to increase gasoline extraction, have been so constant that most of the big establishments are remade every few years. The conversion to coal or shale distilled oil would therefore be just another step in what has become a continuous evolution.

All this means that the motor car should be able to continue its triumphant march. The oil industry, which gave us a new world industrial supremacy, is equipping itself to meet the emergency of a depleted natural crude reserve and remain a dominant factor in our productive life.

Editor's Note—This is the fourth and last of a series of articles by Mr. Marcosson dealing with the oil situation.

The Reagan County Oil Field

IN ONE of Mr. Marcosson's articles in the present series he repeated a story about the location of the Big Lake Field in Reagan County which in some of its details is incorrect. According to Frank T. Pickerell, Vice President of the Texon Oil and Land Company, Dr. Hugh H. Tucker drove the stake at the present site of the Santa Rita, the discovery well of Reagan County, Texas, and it was upon his recommendation that this well was drilled.