G.W.R. Mechanics' Institution, Swindon.

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Librarian.

THE OIL CONQUEST OF THE WORLD

THE FIRST OIL-WELL.

Sunk by Colonel Drake, who, in silk hat, is seen talking to his chief engineer, at Oil Creek, Pennsylvania, in 1859. In the background are "Old Billy Smith" and his two sons who drilled the well.

From a photograph taken in 1859.

Frontispiece.

CONQUESTS OF SCIENCE

THE OIL CONQUEST OF THE WORLD

BY

FREDERICK A. TALBOT

ILLUSTRATED

LONDON
WILLIAM HEINEMANN

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PREFACE

PROBABLY few of the treasures of Nature are exercising such a vast transformation upon the complex social and industrial activity of the community as oil. Comparatively speaking, it is only within the past few years that the significance of this material has become realized, because it has effected its advance so silently and unostentatiously.

It is safe to assert that the average individual fails to recognize how dependent we have become upon this commodity. It enters into every phase of our existence. Elaborate, highly technical treatises have been written upon the subject, which is of exceptional fascination, but they are beyond the understanding of the average reader. This volume has been written with the express purpose of extending some enlightenment, in a popular manner, upon the issue; to narrate the romance of the huge industry which has been created; to relate the many ramifications of its applications; and to show the many conquests it has achieved. Technical details have been resolved into simple language.

I have received considerable and valuable assistance in the compilation of this work, for which I am greatly indebted. I owe my thanks particularly to Lord Cowdray and the officials of the companies in which he has an intimate interest; the Standard Oil Company; Mr. William F. Nye; the Oil-Well Supply Company; the Pumpherston Oil Company, Limited; Messrs. Otto Monsted, Limited; and many of those enterprising engineers who face the dangers of the unknown and the trials of the unexpected in the world-wide search for oil.

FREDERICK A. TALBOT.

October, 1914.

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CHAPTER I

THE COMING OF OIL

While the nineteenth century will be known to history as the Coal Age, the twentieth century certainly will go down to posterity as the Oil Era. Oil is becoming more and more indispensable to our complex social and industrial existence; in fact, it is almost impossible to mention a phase of human activity in which it does not play a more or less prominent part in one form or another.

At the same time, however, it must not be thought that oil and its uses constitute a modern discovery. Far from it. Oil was used for lighting and heating, if not for power, long before the fuel value of coal was recognized. The earliest civilizations employed it, in an asphaltic form, as a cement in their building operations. Two thousand years ago the citizens of Agrigentum, in Sicily, used oil as an illuminant, burning it in crudely fashioned lamps. And does not the Parable of the Virgins indicate that oil was an acknowledged source of light at the dawn of the Christian era ? In some countries, where it oozes from the ground in the form of natural springs, the aborigines have regarded it with reverential awe since times immemorial. Pilgrimages were made to the oil-fires of Baku for centuries. The Red Men, long before the white man's invasion of North America, placed implicit faith in the properties of " Seneca " oil. The tribes were wont to gather at the oil-springs, where the medicine-man ministered oil treatment for illness and disease, and the braves apparently entertained high opinions concerning the therapeutic properties of this substance. Under these circumstances the present movement may be characterized rather as a revival, forced upon civilization to-day by economic considerations.

In many of the big oil-fields to-day interesting and contrasting illustrations of the primitive and the modern working side by side are offered. In Roumania the pyramidal derrick of the modern oil-well and the elaborate tackle of the oil-borer, overshadow the crudely hand-dug native well. These latter are driven to a depth of 500 to 600 feet, and the facilities employed are of the most primitive description. Many are worked upon "syndicate" lines, a number of native toilers participating in the sinking of the well and the raising of the product to the surface, expenses and profits being shared. In this manner as many as 10 tons —3,000 gallons—of oil are raised daily. In the heart of the oil country of Farther India, the Burmese still "bail" oil from shallow open workings.

One may wonder how such primitive methods possibly can prevail when brought into violent competition with the scientific rival alongside. Nevertheless, these crude workings are financially successful. The world's demand for oil far exceeds the supply: the companies feeding the markets with this commodity are industrious in their efforts to collect every gallon available; consequently the slender contributions offered by the native toilers are thankfully received. The Burmese toils alone in the primitive because to him it is profitable and enables him to maintain a certain measure of independence; he is his own master. The modern worker forthwith encourages the native because profit is derived thereby. Open tanks are provided especially to receive the oil obtained in this rude manner. The natives come with their vessels filled with oil, the quantity is checked, it is turned into the tank, and the toiler receives a voucher to the value of the volume delivered, which he is able to convert into cash or kind whenever he feels so disposed.

In Roumania the oil is run into small earth reservoirs or ponds, the contents of which are purchased and drawn off periodically. The primitive processes are highly lucrative to the natives because they live cheaply, while, as they are contributing to a certain market, they are assured of a living.

The term "oil" is somewhat vague. It includes all the oleaginous fluids and solids derived from the animal, vegetable, and mineral kingdoms, although, generally speaking, it is admitted to apply essentially to that drawn from the last-named source. For distinctive and commercial purposes, oil extracted from the earth is generically known as "petroleum." This may be regarded as its technical nomenclature, because it is marketed under many colloquial descriptions, such as rock-oil, mineral-oil, coal-oil, and so on; but one and all are the same—petroleum.

Nature has been unusually lavish and indiscriminate in her distribution of this product, because it is found in nearly every country from Alaska to the Antipodes, if not in one, then in another guise. In the crude, or raw, condition it differs considerably, being found in fluid, plastic, and solid forms. The bulk comes under the first category; natural pitch may be said to represent the plastic; while the solid representation is illustrated by ozokerite, which is mined in the manner of coal. It is also found in combination with other materials, such as shale or tar sands, and then the recovery of the essential article involves a somewhat elaborate process.

Possibly one of the most novel and interesting forms in which it is found is revealed in Burmah and Java, although similar conditions formerly prevailed in the Baku region. This is what is familiarly known as the "mud volcano," which is virtually a geyser, similar to those found in New Zealand and the Yellowstone Park, only in this instance salt water and finely divided detritus associated with oil are erupted. They are not volcanoes in the strict sense of the word, being in reality oil-gas springs, and are encountered for the most part in the jungle. Here and there the dense bush will be found to be relieved by a large patch of absolutely sterile barren soil, in the centre of which spasmodic agitation is observable. Suddenly a mound or dome of earth is forced a few feet into the air, to burst with a report. The explosion shivers the mound, from the cracks and crevices of which clouds of steam issue. The earth subsides, and all is quiet for a few seconds, when another outbreak occurs. The collapse of the mound is always attended with the dispersion of fumes reeking of petroleum, which plainly indicates the agitation to be due to the subterranean pressure of petroleum gases.

The explanation of this phenomenon is simple. The stratum of limestone covering and sealing the oil deposits has become broken and disrupted at places. The natural gas finds a means of escape through these fissures, and draws the oil with it. The oil, moving slowly, mixes with the soft soil immediately above the limestone seal, and forms a kind of slime. The gas pressure below increases, until finally it attains a sufficient degree to force this slime to the surface, the emission being in the form of a big bubble. When these volcanoes first burst into activity eruptions take place at intervals of a few seconds, but as the volume of escaping oil increases, and forms a thicker skin of slime upon the limestone formation, the escaping gases are confronted with a more difficult task, especially as the oil-saturated detritus ejected to the surface oxidizes from exposure to the air and becomes harder. Consequently the periods between successive discharges steadily lengthen, until at last the gas pressure becomes insufficient to effect an escape. The oxidized oil-mud on the surface and the slime below form a seal over the fissures in the limestone, effectively bottling the oil and gas below.

At times the natural gas, finding a suitable outlet through the rock near the geyser, comes to the surface, becomes ignited, and burns continuously. This is the "eternal fire of Demak," which is regarded by the natives with superstitious awe. The territory in which this eruptive phenomenon occurs is at the heart of the famous Javanese oil-fields. In fact, it was observation of the action of the mud-volcanoes and of the strong odour of the petroleum accompanying the eruptions, which prompted the first borings for oil, and served to reveal one of the richest deposits of high-grade petroleum in the world.

The fluid oil, being the most abundant, has attracted the greatest measure of attention and capital. Petroleum is found in plenty among rugged mountains, dense forests, sterile deserts, under the sea, and, if the "wild catter" is to be believed, is even obtainable from the ocean and the air above. New sources of supply are being revealed every day in response to the world's one insistent cry—oil, oil, oil! This plea is so penetrating that the uttermost parts of the earth are being ransacked and probed diligently for oil-beds.

Some countries, however, have been better favoured by Nature than others. Investigations in the British Isles have proved abortive. Although these islands possess immense beds of coal, oil is conspicuous by its absence. Small quantities have been discovered here and there when hewing coal and sinking water-wells, but the probable extent and volume of the oil-bearing strata are so insignificant as to render comprehensive boring operations wildly speculative, and certainly void of any attractive financial results. Natural gas—that is, gas composed of the volatile constituents of petroleum—has been tapped here and there, and in Sussex is turned to commercial account upon a limited scale. The existence of this gas instantly provoked the contention that oil must exist in South-Eastern England, but so far it has not been found. I have seen one sample of oil which was obtained in the North of England, and it looks promising. It was drawn from the sea-bed. This discovery created a wave of excitement, but expert opinion was so deadly opposed to further development that nothing has been done. The sample is merely a curiosity. Britain's oil resources are confined to the deposits of shale in Scotland, the exploitation of which is being conducted upon a comprehensive scale, but the yield is insignificant in comparison with the output of other countries.

The United States of America, and indeed the whole American continent, reeks with petroleum. The Appalachians and California constitute the richest producing centres at the moment; but the supremacy of these territories is being assailed seriously by the discoveries which have been made in Kansas, Texas, and Oklahoma. Canada, so far, has not proved a very remunerative field, although it is generally believed that the United States beds extend into that country. During the past few years Mexico has created a sensation as an oil-producing country, mainly through the endeavours of Lord Cowdray, while South America gives promising indications of swelling the markets with this commodity to a pronounced degree.

In Europe the oil-beds are probably richer and more extensive than in America. The territory fringing the Caspian Sea, more particularly upon its eastern side, is a colossal subterranean oil reservoir, rivalling even the richest stretches of the United States. Roumania and Galicia are two other immense petroleum fields. Russia, with the exception of the Caucasus, has not been submitted to searching investigation, but it is generally considered by competent authorities to possess petroleum resources, at present lying dormant, which exceed in value any other mineral wealth of that mighty empire. Italy, Spain, France, Germany, and Scandinavia, like Great Britain, appear to have been neglected by Nature when this commodity was bestowed, there being no known petroleum territories.

So far Africa has not entered the lists of oil-yielding countries to a serious degree, but this result is probably due to the difficulties of transport which handicap surveying and experimental borings. The west coast gives promising evidences of petroleum deposits, and one or two fields are in operation. South Africa has proved exceptionally disappointing. Hopes were raised from one or two slight indications that oil existed in abundance, but castles in the air have been rudely shattered by expert investigation. It is a moot point whether South Africa possesses so much oil as the British Isles! Some shales have been found in Natal, but at the moment it is doubtful whether they will pay to exploit. The most promising yields have been obtained in the most unexpected spot—beneath the Egyptian desert near the sweltering coast-line of the Red Sea. Should this discovery materialize, it will be of far-reaching import, inasmuch as Egypt and the Soudan at present

By courtesy of the Oil Well Supply Company.

WORSHIPPING THE ETERNAL FIRES.

Temple at Baku to which Mahommedans have made pilgrimages since times immemorial.

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OIL CREEK, PENNSYLVANIA, AS IT WAS IN 1859.

The white cross marks the spot where oil was struck by Colonel E. L. Drake.

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suffer from the absence of native fuel supplies. The country will be able to absorb every ounce of petroleum which it may produce for many years to come. Indeed, the availability of a first-class fuel on the spot will give an incentive to industrial development which at present is impossible.

Asia possesses enormous oil resources. Trial borings in Mesopotamia have proved promising, while troublous Persia contains untold oil wealth. The largest oil-fields known at the moment are those of Burmah and the Dutch Indies including Borneo. The Chinese Empire, which has been closed to development until recent years, is an unknown quantity in this connection. It is generally believed to possess immense oil-beds, but this is merely conjecture. The Standard Oil Company, having entrenched itself in the country and having received valuable concessions, has laid its plans with its characteristic enterprise and energy to satisfy itself upon the point, while British interests are equally active in a similar direction.

The Australasian continent has not been neglected, but the prospectors have failed to reap attractive fruits from their labours. Australia's oil resources, at all events so far as the settled and explored regions are concerned, appear to be concentrated in shales, although petroleum wells have been sunk and are being worked upon a limited scale in Tasmania and New Zealand. Wresting the oil content from shales is not a process to be undertaken lightly. The Scottish deposits are remunerative because they are worked scientifically and upon well-accepted commercial lines. The majority of other shale-fields have proved little else than financial sinks, owing to the lack of knowledge and absence of commercial acumen in their operation.

While petroleum is a natural product, it is not a definite chemical compound. It is a mixture of a series of hydrocarbons—combinations of hydrogen with carbon—the number of the members composing which, as well as their respective proportions, vary according to the district in which the substance is found. These variations cause the crude oil to differ very considerably in its general characteristics, and also affects the yield and number of various articles derived therefrom. Thus the petroleum obtained from California, Texas, Russia, and Mexico is dense, heavy, and viscous, while that obtained from Pennsylvania, Kansas, Roumania, Burmah, and the Dutch East Indies is lighter and far more fluid. In appearance and colour there is also great variety, according to the district of origin. One will be of the consistency of thick, sluggishly-flowing treacle, densely blackish in colour, and will emit a pungent aroma. Another will have a lightish grey, amber, or light greenish hue, will run almost as freely as water, and be practically odourless. Oil from one district will be eminently suited to illuminating purposes, while that from another will be rich in lubricating constituents. The Roumanian, Dutch East Indian, and Pennsylvanian petroleums under refining yield large quantities of naphthas, of which petrol or gasoline is probably the best known. But the Texas, Russian, and some of the Mexican petroleum is indifferently fitted for the yield of such a valuable product, but forms a first-class liquid fuel for firing locomotives, steamship boilers, and so on.

Under these circumstances it has been necessary in the interests of commerce to establish a system of grading petroleums. This was not a simple task, inasmuch as a scientific graduation would have fallen short of requirements and would have contributed to trading confusion. The urgency for simplification brought about quite a different method of grading the oil. Instead of regarding oil drawn from the earth as petroleum purely and simply, irrespective of district of origin, those from different localities are assumed to be individual products. Classification is carried out according to the predominating or characteristic basic constituent, and these comprise two broad groups. For instance, the light oils, such as come from Pennsylvania, Roumania, and so on, which are rich in paraffins, are said to have a paraffin base, and are known as paraffin oils. On the other hand, Mexican, Californian, and Russian oils have an asphalt base, and in the same way are described as asphaltic oils. But it happens sometimes that a particular petroleum has some other predominating characteristic, such as sulphur. Then it is described as a sulphur oil. The characteristic constituent provides the index for gradation or classification.

Petroleum is found at varying depths. In some places it will be struck in large quantities comparatively near the surface of the earth; in others it is necessary to bore to 3,000 and 4,000 feet or more. The popular impression is that oil occupies immense cavities in the crust of the earth, forming huge lakes resembling the subterranean stretches of water about which one reads occasionally. This is a mistaken impression. Oil is found associated with sand, the latter acting somewhat in the manner of a sponge. The sand fills the cavity, and is saturated with the oil. Perhaps a better idea of the composition of the oil layer in the earth's crust may be gathered by taking a tumbler and filling it with small shot; then, after the glass has been so charged, to pour in water until it rises to the brim. One will be astonished at the quantity of water which a glass apparently occupied entirely by the shot will contain, the reason being that the water occupies all the interstices between the beads of lead. If one withdraws the water, leaving the shot behind, the glass apparently is still full. In the oil strata the grains of sand do not occupy the entire cavity: the oil occupies the spaces between them.

The construction of the earth's crust for the most part follows well-defined lines. The strata are distinct, but they do not extend in a perfectly horizontal direction. Instead they have an undulating formation, the lower parts of depressions being known as "anticlines," and the humps, or elevated portions, as "synclines." Now, one would naturally think that the oil, being a fluid, would collect in the depressions. But, for the most part, this is not so. It gathers upon the crests of the humps, or synclines. A little reflection will reveal why this is so. Oil is a comparatively light fluid; it will float on water. The latter, gravitating, finds its way to the depressions, and occupies all the available spaces. Consequently, the oil is forced to the upper levels; hence its position upon the humps.

Unfortunately, however, the formation of the earth's crust is not regular. The rhythmic undulations have been upset by volcanic action. Consequently, the geological character of the country in which oil is being sought must be borne in mind. For instance, in California, the movement of the earth's system, which brought about the formation of the towering Sierras, disturbed the oil-beds very seriously. The wavy layers running horizontally suffered disruption and upheaval. In places the strata have been set actually on end, with the result that the oil occupies a vertical cavity. In the Caucasus, where volcanic energy has been exceedingly violent, the disturbance has had a different effect. The strata containing the oil appear to have been pushed to one side and superimposed, with the result that there are successive layers of oil-yielding sands.

Generally speaking, oil never is found in districts where there has been excessive volcanic disturbance. This is due to the fact that at these points the upheaval of the crust has been so terrific, and such enormous pressures have been exerted, that the oil-sands have been expelled or else have been burned up. For this reason oil has not yet been found among the Swiss Alps, nor among the Rockies. Likewise it is not apparent in the British Isles, which owe their existence primarily to volcanic activity. This action has produced some very curious results. As is well known, the Andes range thrusts itself towards the clouds near the western shore of South America. The mountain flanks are exceedingly abrupt. No oil has been discovered in the range itself, but upon the level shore it is found in abundance, and is being profitably worked. The same phenomenon occurs in California, where the Sierras have produced a similar effect. One or two trial wells were put down above high-water mark. Oil was tapped, and flowed forth in copious streams. A survey of the situation was then made. Did the deposits run out to sea? Everything pointed towards such a conclusion. Accordingly, derricks were erected in the water, where drilling met with complete success, the oil being more abundant than on shore. The inevitable boom set in, and to-day clusters of derricks protrude above the water, connected by plank gangways with the shore, and winning oil from the sea-bed flourishes. Depth of water alone will restrict the enterprise proceeding seawards, but there is every indication that the deposits extend some distance beneath the Pacific. Fortunately this coast is free from attack by tempest, otherwise wind and wave would make short work of the timber oil structures. In the Caspian territory there are similar evidences that the oil strata extend beneath the Caspian Sea, but no effort has been made to tap them upon lines similar to those practised in the United States. In Russia the proposal is to reclaim sections of the foreshore beneath which oil is known to exist, and then to tap the oil from a dry position. Coal and tin are mined from the sea-bed, but the Californian undertaking represents the solitary effort that has been made to make the sea give up the oil wealth which it covers.

The mammoth oil industry of to-day owes its existence primarily to a British chemist, Mr. James Young, who was the first man to produce illuminating oil from crude petroleum. Young was apprenticed to his father, a humble cabinet-maker in Glasgow, but the boy devoted his evenings and spare time to the mastery of chemistry. In this he proved so brilliantly successful that he was appointed assistant to Professor Graham, and subsequently abandoned working in wood for the position of industrial chemist in Manchester. While there Lord Playfair drew his attention to a thick, viscous, liquid matter which was oozing into a coal-mine at Alfreton in Derbyshire. Investigating the material, Young found that it was crude petroleum, and, succeeding in distilling paraffin therefrom, he left Manchester, erected a small refinery near the mine, and devoted his energies to the production of the illuminating oil, which in those days was regarded as the solitary useful product of mineral oil. When Young commenced operations the spring was giving about 300 gallons of oil per day, but the yield diminished steadily, until at the end of two years it gave out completely. Young had anticipated such a contingency, and had made arrangements accordingly. This period of activity had proved sufficient to enable him to perfect his great idea. In 1850 he took out his famous patent for the production of paraffin by distillation, which has proved to be one of the most historic and momentous developments associated with the oil industry.

Young's success had not escaped the attention of certain interests in the United States of America. The remains of the ancient oil-workings and natural oil-springs were accepted as conclusive evidence that oil existed in plenty in the earth. Its extraction could be converted into an attractive commercial proposition. The patent taken out by Young represented a triumph in refining, and as there was great scope for an illuminating oil to supersede the rush light, the Pennsylvania Rock-Oil Company came into being in 1854, to sink wells for oil and to refine the product. For two or three years the proposal languished, but in 1859 operations were commenced in grim earnest under Colonel Drake.

He selected a spot on Oil Creek, Pennsylvania, which in those days was a picturesque sylvan dale, through which the stream wound its tortuous way. The hills rising gradually from the depression were densely clothed with scrub and forest, relieved here and there by patches of pasture-land, where the grasses grew luxuriantly. Drake drove his well in the floor of the vale, and essayed to tap the oil upon the lines generally practised in sinking an open water-well. He commenced operations on May 20, 1859. He had not descended more than a few feet, when an inrush of water and mud, filling his excavation, brought about a sudden cessation of work.

A pretty problem for those days was presented. Drake strove might and main to overcome the visitation, but in vain; thereupon he decided to drive a pipe into the ground until he touched solid rock. The actual drilling operations were carried out by William, familiarly known as "Old Billy" Smith, who was assisted by his sons. Drake supervised the task, bringing his knowledge to bear upon the solution of the troubles as they developed, and successfully breaking them down one after the other. It was pioneer work from beginning to end, and in the manner of such operations the troubles at times were of no mean description, while the tools, primitive in comparison with those used to-day, had to be contrived specially to meet the situation.

But perseverance brought its due reward. On August 27, 1859, when the drill-pipe had been carried to a depth of 69½ feet, petroleum was observed to be welling to the mouth of the bore-hole; the flow increased slowly as the bit shattered the remaining thickness of rock. Drake and his diligent toilers realized that the goal of their ambitions had been reached. Oil had been struck! The yield was not imposing, judging from modern standards, being only twenty barrels—840 gallons—per day, which output was maintained for a year.

The news of Drake's success spread rapidly, and there was a tremendous wave of excitement. Curiously enough, Colonel Drake appears to have underrated the significance of his discovery and its importance to the world at large. He was completely satisfied with what he had accomplished. He had undertaken a certain task and had completed it. Forthwith his interest in petroleum appears to have disappeared; he never became an oil-king, nor a millionaire. Just when Fortune was within his grasp he retired from the new world which he had opened up, to devote his attention and interests to more congenial occupation. In his later days, while he never regretted the loss of the wealth which should have been his, he was sometimes in sore need of the bare necessaries of life. Illness overtook him, and he died practically unknown, with few to sound his praises for creating a new industry.

Within a few months of Drake's momentous discovery a mad rush set in to the spot where he had found oil. Prospectors, adventurers, ne'er-do-wells, and financiers, flocked to Oil Creek as frenziedly as if a gold-mine had been revealed. The placidity of the Pennsylvania countryside was rudely disturbed; its picturesque sylvan beauty was destroyed ruthlessly. The country for miles around was overrun in all directions, and the land, which had hitherto been deemed of little value except for the quiet humdrum of agricultural pursuits, resounded with the staccato clank of axes felling trees, the resounding crashes of hammers striking nails, the raucous shouts of the uncouth who had contracted the get-rich-quickly fever, and the wild screech of steam.

The vale fringing the stream beside which oil had been found was promptly christened Oil Creek; towns of curious and fantastic names, suggested by some incident associated with the oil rush, came into existence. There were Petroleum Centre, Bonanza Flats, Church Run, Funkville, Red Hot, Pithole, Cow Run, Wild Cat Hollow, to name only a few of the places which sprang into bustling activity. To-day many of these spots are but a memory of the strenuous oil days of '59.

Such was the beginning of the oil boom which prevails to this day. Drake's discovery, combined with Young's invention for distilling paraffin from crude oil, changed the whole outlook of the world; then followed another important improvement, though it was a mere detail. The paraffin of the early days was burned in open lamps and naturally only gave an indifferent light under such conditions, while it emitted considerable smoke. This defect prompted an inventor, Samuel Kier, a merchant of Pittsburg, who was interested in the disposal of the product, to search for some means to improve the light. He devised a burner to which a movable glass chimney could be attached. The paraffin lamp was changed instantly and completely. Instead of giving a faint glimmer accompanied by nauseating black smoke, a brilliant, smokeless, and steady light was produced. The doom of the rush light as an illuminating agent was sealed, and a tremendous fillip was imparted to the young paraffin-oil industry.

There is one place which, born of the '59 rush, has survived the successive oil boom and vicissitudes of the Pennsylvania oil industry; this is Titusville, which stands near

TOOLS USED BY COLONEL E. L. DRAKE IN SINKING THE FIRST PETROLEUM WELL.

TO THE MEMORY OF THE MAN WHO MADE THE PETROLEUM INDUSTRY.

Drake's monument in Woodlawn Cemetery, Titusville, Pa. Erected by H. H. Rogers at a cost of $95,000 (£19,000).

COLONEL E. L. DRAKE.

The father of the petroleum industry.

"OLD BILLY SMITH."

Who drilled the first oil-well.

the spot where Drake drove his well. Titusville is the Mecca of the oil world, because many of the greatest developments connected with the earliest days, happened in this district. The first big flowing well was tapped near by. It gave a yield of 200 barrels per twenty-four hours—ten times the output of the Drake well—which for those times was considered a sensation. Subsequently another equally startling discovery was made. Petroleum, or, as it is called, "natural," gas, was struck in the Newton well, and thus another commodity was brought within the reach of an expectant world.

Drake's momentous discovery is perpetuated to-day by a Drake Museum, which is one of the "sights" of Titusville, and by the magnificent monument which has been erected to his memory in the Woodlawn Cemetery. It is fitting that this memorial, which cost $95,000 (£19,000), should have been erected by one who made millions out of petroleum, and who was always an admirer of Drake and his work. This was H. H. Rogers, a colleague of the Rockefeller brothers, and one of the creators of the Standard Oil Company, the richest and most powerful commercial organization in the world.

The epitaph is terse. Upon the six panels are inscribed the following:

> COL. E. L. DRAKE : BORN AT GREENVILLE, N.Y., MARCH 29, MDCCCIX.; DIED AT BETHLEHEM, PA., NOV. 8, MDCCCLXXX. FOUNDER OF THE PETROLEUM INDUSTRY. THE FRIEND OF MAN.
>
> CALLED BY CIRCUMSTANCES TO THE SOLUTION OF A GREAT MINING PROBLEM, HE TRIUMPHANTLY VINDICATED AMERICAN SKILL, AND NEAR THIS SPOT LAID THE FOUNDATION OF AN INDUSTRY.
>
> THAT HAS ENRICHED THE STATE, BENEFITED MANKIND, STIMULATED MECHANIC ARTS, ENLARGED THE PHARMACOPŒIA, AND HAS ATTAINED WORLD-WIDE PROPORTIONS.
>
> HE SOUGHT FOR HIMSELF NOT WEALTH, NOT SOCIAL DISTINCTION; CONTENT TO LET OTHERS FOLLOW WHERE HE LED. AT THE THRESHOLD OF HIS FAME HE RETIRED, TO END HIS DAYS IN QUIETER PURSUITS.

It is a somewhat curious circumstance that, although Great Britain is deficient in native oil resources, British endeavour has played, and still is playing, an exceedingly prominent part in the revelation of new and unexpected sources of supply. British engineers are in universal demand for prospecting and proving oil deposits in new countries. The reason may seem somewhat obscure, because one would naturally imagine that the men with the greatest command of practical or field experience, such as those who have developed the oil-producing territories of the United States, would be in most request. The explanation is simple. American and British interests follow widely divergent lines. The former bores for oil, like a farmer cultivating potatoes. He reasons that such and such a district should produce oil, and without more ado sets to work to tap it, as sure of results as a farmer is certain that potatoes will grow where the seed is planted.

This attitude is due to the conditions prevailing in the American homeland. The United States reek with petroleum: the chances of success are so overwhelming. The American, speaking generally, is not an oil-prospector; he is skilled, rather, in the art of drawing it from the earth once the deposit has been located. In his own country he has made so many hits—he never says a word about his misses—owing to fortune being on his side, that, when he is transplanted to another country and is urged to look for oil, he is nonplussed. His one idea is to bore, bore, bore. If he strikes oil he is satisfied; if his efforts prove futile he expresses the confident opinion that the country does not possess enough oil to float upon a glass of water.

On the other hand, the British oil-seeker sets about his task diligently and methodically. First of all he knows exactly what geological conditions should prevail to insure oil being present; consequently, a knowledge of geology plays an important part in his system. He first makes himself acquainted with the geological construction of the country in which he is working; then, primed with this information, he relates whether oil is likely to be found, and if so, why.

The average American oil-worker has a certain contempt for geological deduction; he prefers to rely upon close observation and a peculiar instinct which has been cultivated by long association with the subject. This attitude is explicable. The geologist has been confounded and proved to be in error so many times, not only in connection with oil but with other minerals, that his statements are received with scepticism by many practical men. The latter argue that a geologist is not possessed of more penetrating eyesight than they; that the geologist cannot peer into the earth and see what is beneath, or how the strata of earth are disposed, their kinks and twists, their regularity or interruptions. In one or two instances, when a geologist has pronounced his opinion that a certain district is oil-less, the practical worker, animated by feelings of sheer antagonism, has set to work boring upon the barren spot, and has made a strike, which he has not failed to blazon to the world at large as an example of practice being superior to scientific theory; in fact, had it not been for the latter, and his spirit of wild speculation, some of the richest fields in the States might have been lying dormant to this day.

However, it must not be thought that the British worker depends essentially upon geological theory. This assistance is utilized merely as a tentative guide, because the expression of scientific opinion may avoid considerable useless work. It is more economical to learn something about the prevailing geological formation than to carry out a number of trial borings blindly; this is particularly the case in connection with distant countries which are somewhat inaccessible. Questions of transport, commissariat, and maintenance of communications, are of great significance under such circumstances.

Nowadays prospecting for oil is carried out upon a scale comparable with scouting for a railway route, or even exploration. The party not only has to find oil, but has to determine the exact geographical situation of the field, how the necessary machinery is to be brought in, and how the oil raised is to be transported economically to a point of shipment, since, obviously, it is of no avail to discover oil if it cannot be turned to commercial account; consequently, the oil-prospector must be an engineer and an explorer as well as a geologist. When a new country is to be scoured for oil deposits the oil-prospector skilfully organizes his expedition, and prosecutes his task with as much care as if he were bent upon the preparation of a survey map. Distances, altitudes, and other data have to be collected. Depots or caches must be established to contain reserves of supplies, so that the expedition may not be threatened with disaster, while probing the unknown hinterland. A force of porters or a pack-train must be provided to carry the immediate necessities of the travelling party. The search for oil may appear a somewhat simple operation, but, as a matter of fact, it has its particular spice of adventure, excitement, and encounter with the unexpected.

As a rule when a new country is to be investigated, a reconnaissance is first made. The oil-prospector, or, as he should be called, the oil-surveyor, moves as swiftly as circumstances will permit through the territory, making general notes of the prevailing conditions, the indications of oil, proximity of water-supplies—a vital point—and suggested lines of communication, together with an approximate estimate of the cost of establishing lines for transportation. The report in due course is submitted to the concessionaires, or holders of the rights to exploit the oil, together with any suggestions which the engineer may deem worthy of consideration.

The outlook proving attractive, a second expedition is sent to the country to carry out more detailed plans. In this instance the party may comprise four or five men, or, if a large territory is to be surveyed, its numbers may reach thirty or more. The party is subdivided, each being allotted a certain area to cover, but all working under a single chief. The party will include one or two assistant engineers, geologists, surveyors, topographers, and possibly one or two practical sinkers to carry out trial borings. If the expedition is large, an imposing pack-train will be required, or, should the country be trackless and trailless, porters will have to be hired to carry the requirements of the party, while another force will have to be rallied to move to and fro through the hinterland, stocking the caches with supplies.

The work in the field is of varied character. The material gathered from the reconnaissance must be resolved into more minute detail. Often, when penetrating a new country, no reliable maps will be in existence; accordingly, the party must prepare its own maps. Distances, which were paced and roughly calculated upon the preliminary survey, will be measured accurately; altitudes will be taken with precision; suggestions concerning transport, which the reconnoitring engineer indicated briefly and roughly, will be amplified and corrected. While surveyors are driving their lines for the preparation of the topographical maps, the geologists are making close investigations of the construction of the earth's crust and committing to paper the contour of the strata. The drillers are set to work making trial borings, and if these substantiate the deductions of the geologists, the engineers set to work aligning the roads, and, if necessary, the route for railway communications.

Owing to the mass of detail which has to be committed to paper the task necessarily takes considerable time, especially if trails and tracks have to be driven to facilitate movement. In one case in the East more than thirty months were spent in the field before the controlling interests were furnished with the requisite data to enable them to commence actual operations. Nothing can be done until the surveyors return, as they alone have the information upon which subsequent developments can be conducted.

Occasionally the oil-prospecting surveyors are forced into a tight corner. A few years ago surface indications of oil in the Peace River country of North-West Canada aroused considerable interest. The first accounts, disseminated by inexperienced men, intimated that the discovery was worth following up. A small party, numbering five or six men, was organized, including one prospector, who had gained considerable experience of the oil question in California and

Mexico, and an engineer. I spent some days with the latter in a survey camp, and he told the story of the oil expedition, which he described as an "unholy nightmare." The information about the exact location of the "find," as narrated by one of the wanderers of the West, was extremely hazy. "On the Peace River" was approximately the sum of his statement, and seeing that the waterway is a few hundred miles in length, it was not very illuminating; but by persistent close questioning they narrowed the issue down until they obtained a tolerably intelligent clue to the approximate whereabouts of what was optimistically stated to be "the biggest oil-field in the world."

The party set out, and, gaining the banks of the Peace River, took to Indian dug-outs. The equipment and supplies were stowed aboard very carefully, and although the load brought the free-board perilously low, the boats were pushed off. Paddling was comparatively easy, although at times the vicious current made a sudden demand upon navigation prowess. One morning, while camp was being broken, one of the party who had been roving afoot, returned with the information that in his opinion the oil-field must be within reach. The journey was resumed about 7 a.m., and the men were paddling along comfortably when the leading dug-out gave a wicked lurch. Before those aboard realized the situation, they were struggling desperately in the water; the dug-out had capsized. The second boat, following closely, rammed the leader, and the inevitable happened: it split from end to end. The water poured in, submerging the craft within a few seconds. The whole party contrived to scramble ashore, and a sorry spectacle they made when they stood on the bank. All equipment was lost; they had nothing but the dollar bills in the purses of their belts. Money in such a country is almost useless; but it was of no avail to warble "Hard luck," so they plodded through the bush, hoping to meet fortune in some unexpected quarter.

After trudging for some nine hours, and when nearly exhausted, they caught sight of smoke from a camp fire

HAND-DUG WELLS IN ROUMANIA.

By courtesy of the Oil Well Supply Company.

BURMESE WINNING OIL FROM THE EARTH.

The natives still practise their crude methods in the shadows of the modern derricks.

INSTRUMENT SET UP FOR PROSPECTING.

DIAL OF INSTRUMENT SHOWING NEEDLE WHICH IS DEFLECTED BY THE HIDDEN OIL.

THE MANSFIELD "OIL" DIVINER.

Devised to discover subterranean water-supplies, this instrument has proved highly successful in locating oil deposits.

They hurried up as well as their expended energies would allow, and reached the spot. Luck was in their favour; it was a railway survey camp, where they were made extremely welcome. After a hearty meal and while drying their clothes on their backs around the blazing camp fire, they related their mission. The chief of the camp dashed their hopes to the ground. There was no oil in that territory, or he would have heard about it, because nothing of that nature had been communicated to his headquarters by the reconnoitring surveyor, who knew every mile of the country. But he had heard that oil had been seen about 300 miles in the opposite direction! The face of the leader of the oil-prospecting party was a study; he consigned those north-western wanderers, who have no idea of distance or location, to oblivion. With the assistance of the railway pathfinders, who were camped on the river-bank, a raft was fashioned, the prospectors were re-equipped with supplies, and were given a hearty farewell.

Oil was not found on that journey: not sufficient to make a chipmunk intoxicated, as the surveyor quaintly related. By the time the party returned to the States and made their report, some £8,000, or $40,000, had been expended, and all to no purpose. But there is oil in the Peace River country, as subsequent investigations, carried out under more congenial conditions, have revealed; the foregoing party merely missed the district, that was all, which goes to indicate the gambling character of the task of looking for oil.

Another expedition—which at one time, it was feared, had met with disaster—was despatched from London to the interior of Bolivia. The party comprised nearly thirty British engineers and geologists, who were mapping out and proving some 3,000 square miles of territory. Roads and even trails were conspicuous by their absence; consequently, the expedition had to drive its own paths through the forest, which was found to be exceptionally dense. Fortunately the extreme elevation of the Bolivian plateau robbed toiling in a tropical country of many of its most fearsome plagues. Mosquitoes and miasma were comparatively absent. The expedition had been planned with extreme care. A fully equipped commissariat train maintained the depots in the bush with provisions, although the absence of communication facilities proved a serious drawback. The headquarters in London only received intelligence from the front at fitful intervals, when the expedition happened to meet the supply train, or was able to despatch letters through passing traders.

Some weeks had passed without any sort of intelligence being received; then, one morning, the newspapers came out with telegrams announcing that a party in the wilds of Bolivia had been surprised by some truculent natives and had been massacred. It was feared that the oil-survey party had come to grief, as the men were working in the inaccessible dangerous territory indicated. The newspaper information was meagre; only the bare details were vouchsafed. Inquiries were cabled out immediately, but no definite response was received. Anxiety was giving way to practical certainty, when the chief engineer-in-the-field cabled home that his work was completed, and that the whole party, safe and sound, was preparing to return to the coast. Subsequently it was ascertained that it was another expedition, labouring in a different corner of the country, which had fallen foul of the natives and had been overwhelmed.

Even in civilized areas the task of the oil-prospector is not always agreeable. The Nobel Company, which virtually controls the petroleum industry of the Caucasus, was anxious to extend its operations. An island in the Caspian Sea attracted attention. Would it yield oil? The question could only be answered satisfactorily by making investigations upon the spot. A young Englishman was deputed to undertake the unattractive task. The islet was almost out of sight of land, uninhabited, uninviting, and lonely. The party pushed off, and the toilers made themselves as comfortable as conditions upon the barren outpost would allow. Geological indications were favourable, and wells were sunk. Six months elapsed before the underlying oil was tapped, and then the Englishman was permitted to return to the mainland, his work completed; but he admits that it was the dreariest half-year in his life. Only on rare occasions was he able to return to the shore, and then but for brief periods. Many of his men chafed under the restraint and refused to stay. Under trying conditions he had to keep his forces going day and night. It was as lonely as being marooned upon a penal settlement, and Baku, though by no means alluring under the happiest of conditions, was positively inviting when he returned, for the last time, from that lonely island in the Caspian Sea.

The British oil-prospecting surveyor is like the material for which he searches—he is found in all parts of the world. To his energies and activity are due the opening up of many of the new sources of supply, and he is labouring diligently to extend this field of productivity. It is a task which appeals to the British instinct; it involves the penetration and settlement of the unknown, wrestling with the unexpected, an incessant struggle with abnormal difficulties. It is also a valuable school of experience; but for the knowledge thus gained, many of the oil-fields which now are pouring forth their wealth of liquid fuel by thousands of tons daily the whole year round, would be unknown. Through perseverance and activity Burmah, Borneo, South America, Africa, Roumania, and even Russia and Siberia, have been compelled to reveal their dormant resources of oil.

In some instances primitive native effort in the extraction of oil has induced methodical development upon a comprehensive scale. If the local inhabitants can draw paying quantities from shallow wells, it is only natural to surmise that modern drilling must tap the deposits in abundance; this is only a logical conclusion. Certainly it was the case in Java. An enterprising Dutch engineer followed the operations of the natives, and their success induced him to undertake a scientific exploitation. So, in 1888, he founded a small company, with a capital of less than £30,000, or $150,000, to carry out drilling and to erect a refinery. He plunged boldly into the dense jungle, and at the promising spots made small clearings in which rude derricks were run up. Before drilling for oil, he had to find adequate water-supplies to flush out the oil-borings. In some instances he was forced to draw the necessary water from a distance, and in such cases it was conveyed to the oil-well through pipes and stored in tanks. His plant was extremely primitive. The derrick was a skeleton pyramid structure, fashioned from bamboo poles, while the buildings for housing the natives and machinery were equally rough—bamboo shacks roofed with palm-leaves. The oil-wells were bored by hand, because the cost of taking mechanical plant through a country possessing no roads would have been prohibitive.

The wells were gushers, and were generally brought into action at a comparatively shallow depth. The crude oil was caught in ponds, or tanks, where it was allowed to settle, after which it was pumped through pipe-lines to the refinery. Despite the disadvantageous conditions under which this pioneer laboured, he found that he was drawing more oil than he could refine; accordingly, another refinery was built, and the company thus was able to turn out about 1,000,000 gallons of illuminating oil per month. The refined oil found a ready sale among the 25,000,000 inhabitants of Java, among whom it was distributed by railway tank cars. It was the success of this initial undertaking which attracted world-wide attention to the oil resources of Java, and eventually resulted in the formation of what is to-day one of the most powerful oil companies in the world.

But probably the opening of the Mexican oil-field is the most romantic story in the history of the oil industry. Although the oil deposits of Mexico were known during the time of the Spanish occupation, nothing was done until 1868, when Dr. Autray, of Angostura Bitters fame, found the oil-springs of Cugas, and from this surface yield refined illuminating oil by means of a small still. Unfortunately, his initial effort ended in disaster, probably owing to the limited scale upon which operations were conducted and the paucity of the local demand. The scheme was abandoned, the necessary financial support being withdrawn.

In the early eighties of the last century British interests decided to make another attempt to develop the Mexican oil reserves. They co-operated with American engineers and financiers, and started drilling upon a small scale; but the American engineers were somewhat ill-disposed towards British activity. It is stated that they intentionally drilled upon barren spots, with the idea of exhausting the funds available, and inducing disgust among the British capitalists. Then, by accretion of fresh American capital, they intended to resume operations upon the proved areas, where oil would be struck, and thus bring the fields under American control. It was an ingenious plan, but fortunately it went agley. The British capitalists certainly became disgusted at the small fruits attending their enterprise, and, as anticipated, they withdrew from the project. The engineers, exulting at the success of their move, quietly went to the American interests which had co-operated with British effort, revealed their proposal, and sought further support; but the American financiers construed the suggestions as an excuse for wasting additional good money, and to the sheer disappointment of the drillers they refused to advance another cent, maintaining that, as their British colleagues had not received the slightest return upon their outlay, there was no evidence that the American financiers ever would be any better off. Thus came to an untimely end the first attempt to exploit Mexico's oil reserves.

During the nineties the well-known engineering organization presided over by Sir Weetman Pearson, now Lord Cowdray, was engaged in the reconstruction of the Isthmian, or Tehuantepec, Railway. During one of his periodical visits, the head of the firm observed evidences of oil near the line. Attracted by the discovery, he gave instructions for borings to be driven, and, as he anticipated, oil was struck. A refinery was erected capable of handling 1,400 tons of crude oil per day. A promising field was opened up in this manner, although, as events proved, it was insignificant compared with the areas subsequently revealed in other parts of the country.

The success of this first move prompted Lord Cowdray to carry out his operations upon a more extensive scale. He despatched his prospectors and engineers to other corners of the country along the Atlantic seaboard, and in this way brought to light the immense reserves of oil lying in Northern Vera Cruz. A huge sensation was created by bringing in the celebrated "dos Bocas" well, which probably ranks as the largest gusher ever struck, and subsequently the great Potrero de Llano No. 4. Before Lord Cowdray, who is now known as the Mexican Oil King, commenced operations, Mexico was considered a doubtful oil-field. The organization in possession was the Waters-Pierce Company, a subsidiary of the Standard Oil Company, which imported all high-grade oils, and sold the local crude product to the railways for fuel. Under energetic British enterprise all doubts were swept aside, and in the course of a few years Mexico came to be regarded as a serious competitor to the United States. To-day more oil is drawn from this country in the course of twenty-four hours than was obtained in a whole year twenty years ago.

Perhaps one of the most interesting and romantic instances of the difficulties, trials, and tribulations, as well as uncertainties, pertaining to the task of the oil-prospector, at least during recent times, is associated with Persia. Some years ago an enterprising Britisher, Mr. D'Arcy, decided to search the dreary wastes of this bygone Empire for reserves of oil, and, in the event of their existence being revealed upon a sufficiently promising scale, to develop a local industry. The project was characterized as one of the most fantastic ever contemplated, but there was method in the Britisher's madness. Rumours and native stories of natural yields of oil had reached his ears; he investigated them, and concluded that rich oil deposits existed, but the puzzle was to find them. This question could be settled only by embarking upon methodical investigation of the country. To insure his position, Mr. D'Arcy approached the Shah and succeeded in securing the sole concession for prospecting and exploiting throughout the vast territory known as Western and South-

Western Persia, where the conditions seemed most favourable.

Armed with this authority, the work was commenced upon a systematic basis. One or two expert Canadian oil-drillers were engaged, and the little party plunged into the heart of the forbidding sterile and roasting country to hunt for oil. Borings appear to have been concentrated upon the most inaccessible and deadly depressing stretches of the country, but the quest proved a heart-breaking and maddening string of failures. Borings were driven one after the other, here, there, and everywhere; but the oil-sands, if they were present, completely baffled search. The outlook was distinctly depressing. A round £200,000, or $1,000,000, had been sunk in, and apparently had been absorbed by, the blistering sands, and all to no purpose. Even some of the most enthusiastic believers in Mr. D'Arcy's courageous enterprise commenced to entertain misgivings. The sands of Persia evidently possessed no more oil than the ice-floes of the Polar seas.

While toiling among the silent wastes, striving to " suck juice from Hades," Mr. D'Arcy met a fellow-worker who was labouring diligently in another field of activity in the same country. The latter had penetrated a corner which the mad Britisher so far had not gained. The conversation naturally centred upon one another's objects and labours. The stranger, when he learned that oil was D'Arcy's objective, directed the latter's attention to some natural tar-springs, which were being worked upon a limited scale and in a primitive manner between Mal-Amir and Shustar. Curiously enough, the spot was known among the resident tribe by a name which interpreted runs " The Field of Oil."

This was news indeed, and Mr. D'Arcy hurried his little party to the spot. Here he found a natural oil-spring trickling from the ground, and investigation showed it to be rich in naphthas. But his indomitable optimism and energy received a shock. The natives had been exploiting this oil upon a slender scale since time immemorial. The oil, as it issued from the ground, was collected in small ponds, formed by the erection of rude dams, where a simple process of natural fractional distillation took place. The fierce solar heat evaporated the more volatile constituents, while the oxidizing action of the atmosphere made the oil take a thick, viscous form, which in the course of time was withdrawn by the natives and sold for various purposes, such as a plaster and unguent for wounds, and also for caulking boats. When Mr. D'Arcy intimated his intention to start boring operations upon this spot, his move met with unveiled antagonism. He was encroaching upon vested interests. Before he could be permitted to put a drill into the ground he would have to compensate those in possession. The canny natives anticipated that if the Britisher, with his scientific methods, tapped the wondrous material below, their spring would dry up. To avoid any conflict, Mr. D'Arcy offered to buy out the natives' rights; but the latter at first showed no disposition to dispose of their riches. The oil-springs which had been so indifferently worked suddenly assumed an enormous value in the eyes of the local inhabitants. Haggling and bickering ensued, and at last, fretting and fuming at the turn things had taken, and the delay caused by the dilatory tactics of the tribesmen, the Britisher agreed to their terms. The rights were purchased and the natives departed, no doubt laughing up their sleeves at the way they had tricked the mad Britisher.

The drills were set to work, and descended steadily to a depth of 1,000 feet. But up to this point the evidences of oil had been disappointing. However, the drill was kept going, and then, when another 100 feet had been driven, the tools crunched through the overlying crust of rock into the oil-sands. The strike was revealed in no uncertain manner. The confined oil, directly a vent was offered, surged up the bore-hole with mad velocity, and rushed forth from the earth to a height of 70 feet, carrying the derrick away with it. The oil flowed in such volume that the persevering toilers were amazed at their success. Every penny poured into the ground was being returned a thousandfold.

Hurriedly they fashioned earthen dams to collect the oil until the flow could be controlled.

The point then arose, How could the oil be transported to a convenient shipping point? "The Field of Oil" is situate in most forbidding country, far removed from sea or other means of cheap conveyance. The situation was discussed, and it was finally decided to tackle the question boldly, and to lay a pipe-line from the oil district to tide-water upon the Persian Gulf. This was a daring undertaking in itself, inasmuch as it involved the construction of 170 miles of pipe-line through barren, roadless country. Powerful Gainsborough tractors were ordered hurriedly from London, while trailing vehicles were purchased to carry the pipes required for the work across the pitiless desert. At the tide-water end a refinery was erected, where the liquid mineral, as it comes down from the hinterland, is submitted to the involved process of distillation. Once this transportation connection was established, further drilling was undertaken, and well after well was brought into activity. To-day Persia is generally accepted as being rich in petroleum, and is destined to become one of the largest and most prosperous oil-fields in the world, more particularly since the British Government acquired the controlling interest in the company exploiting the proved field by the investment of £2,200,000 ($11,000,000) to meet the national demands for liquid fuel, and to remedy, to a certain degree, the deficiency in home supplies.

The success of the operations in Persia has prompted further investigation in Mesopotamia, inasmuch as the proved Persian fields abut on the international frontier. It is only natural to assume, therefore, that the oil-beds extend westwards into the Asian reaches of the Turkish Empire. This territory is now being prospected, and news of further sensational strikes are anticipated. Irrigation engineering is endeavouring to restore the agricultural value of the country, but if present indications offer any criterion, it is only natural to surmise that the Garden of Eden is destined to become a Garden of Oil.

While the Persian and other fields have been brought into activity as a result of persevering and systematic search, other districts have been brought to the notice of the world by accident. He was a closely observant, astute man who first pointed to the fact that oil was likely to be found in Egypt. The story runs that a passenger on board one of the liners bound for the East noticed oil floating upon the water around the vessel as she drove her way out of the Gulf of Suez. Whence came the oil? The question set the traveller thinking. He argued that it must issue from the earth somewhere in the vicinity. He kept his own counsel until he returned home. Then he revealed his observations and theories to interested colleagues, whom he urged to undertake prospecting upon the Egyptian banks of the Red Sea. It was a circumstantial clue upon which he based his arguments, but the suggestion was accepted. A syndicate was formed, and, as is well known, natural oil-springs were found. Borings were driven to a depth of 2,000 feet, at which level the paying sands were penetrated, and oil poured forth in a copious stream. The probability is that the Persian fields extend through Arabia, underlie the Red Sea, and reach far into the interior of sterile Africa, possibly below the roasting Sahara itself.

During the past few years many ingenious efforts have been made towards the perfection of mechanical instruments for determining the existence of oil. These are meant to supersede the scientific theories of the geologist. One might almost term it "oil-divining." The most striking success in this direction has been won by the instrument devised by a British inventor, which is known as the Mansfield automatic oil-finder. Curiously enough, this apparatus was not devised for application to this service, but was intended for indicating the existence of subterranean supplies of water. Its success in this direction was so sensational that the Indian Government went so far as to issue a Blue Book narrating official experiments therewith, and recommended its adoption in that Empire, since success was far more likely to be achieved by its aid than by the usual scientific methods then in vogue.

This instrument works upon the principle of indicating the presence of electric currents flowing between the earth and the atmosphere. Naturally, these currents seek the paths of greatest conductivity, and, accordingly, are always strongest in the vicinity of subterranean watercourses, the waters of which are charged with electricity to a certain degree. The instrument is provided with a needle, similar to that of the mariner's compass, and the presence of the electrical current induces its deflection to varying degrees, according to the strength of the electrical vibrations. The general procedure is to space wooden pegs over an area which is thought possible of yielding water, and to space them twenty paces apart in a direction usually south-east to north-west. The instrument is successively placed over these pegs, and as the needle moves the extent of its deflection is recorded. The point where the needle shows the maximum movement is the spot where the greatest supply of water exists, and where the borings should be carried out. If the needle does not move, there is no water present. Curiously enough, the instrument indicates the presence of water which is flowing in a natural state only. Water flowing through pipes, or sources that have sprung up to daylight, have no effect whatever upon the needle.

Upon one occasion, while experiments were being conducted for the discovery of water, the needle was observed to behave in a new and peculiar manner. This erratic action prompted the driving of a trial boring to elucidate the problem, if at all possible. To the amazement of those concerned, not only was water tapped, but oil as well. The reason for the unusual action of the needle was revealed. Oil-beds are always covered with what may be described as a water-blanket, in the form of clays, shales, slates, and so on. These water-impregnated strata act as a vehicle for the currents flowing in the earth, and between the earth and the atmosphere; but the non-conducting oil beneath acts so powerfully and strangely upon the needle that its presence is recognized at once.

This discovery was of the utmost importance, and to test its reliability the apparatus was subjected to searching tests upon several oil-fields. In every instance the correct spots for boring were quickly revealed, and when drills were sunk, the accuracy of the indication was proved. The success of these confirmatory experiments now enables oil-prospectors to determine exactly where the well should be sunk. There is no further need to run trial borings upon the haphazard principle, with the possibility of missing the oil. By making a detailed survey of the ground with this instrument, uncertainty is converted into a certainty. It is not surprising to learn that the instrument has been adopted by several of the leading oil-producing companies in various parts of the world, since it has been the means of avoiding appreciable financial waste in the sinking of wells in sterile places.

CHAPTER III

THE WELL-DRILLER AND HIS TOOLS

Boring for oil sounds a simple, straightforward operation. So it is, more or less; but several circumstances materially affect the cost of the work. Under certain conditions a well may be sunk for quite an insignificant sum, but more often than not the oil-sands are not penetrated until a heavy expenditure has been incurred.

To sink a well in an exploited, well-known oil-field is not so costly, as a rule, as to pioneer in a new country. In the former case transportation facilities are available, while labour is generally plentiful. In such cases the cost is affected by the depth to which the well has to be sunk before the oil is tapped. On the other hand, when a new country is to be opened up, the preliminaries which have to be completed before the drill can be set going may exceed many times the actual task of boring.

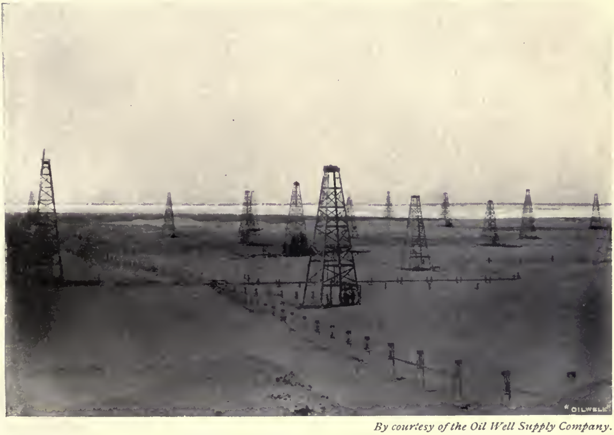
A new oil territory is always void of means of transportation; often there is not a friendly bush-road or even trail available. Accordingly, before the necessary plant can be taken to the site, heavy and costly preparatory work is imperative. The ground has to be cleared, a road with negotiable gradients has to be fashioned, while sometimes à railway has to be laid. The labour question is almost certain to be acute. Experienced labour has to be taken into the new field, even in civilized countries, to carry out the skilled part of the work, assisted by common or native labour. But even the latter is often impossible to recruit in the immediate vicinity, and consequently has to be taken in from distant points. This force has to be housed and fed, and although the requirements in this direction may not be exacting, the question is not free from its peculiar anxieties.

Water is another vital factor. Not only is it essential for the labourers, but drilling is impossible without it. The engineer has to make doubly sure that ample supplies of water are within easy reach. In this connection considerable ingenuity often is displayed. The opening up of the Peruvian oil-fields is an interesting case in point. The deposits here are beneath the flat, arid stretches fringing the seashore—the field probably extends beneath the ocean. The adjacent country does not yield a drop of fresh water, owing to the absence of rainfall for many years past; there is no friendly river, stream, or even spring.

To meet this difficult situation, an elaborate plant had to be installed for the distillation of fresh from sea water. This circuitous process unavoidably enhances the cost of winning the precious petroleum, and so the water-supply has to be husbanded most carefully. After the field had been proved, and had been firmly established, the water question grew more acute, because larger and larger volumes were demanded for the pumping plant. Messrs. Thompson and Hunter, the well-known British petroleum engineers, conceived a novel idea. This was the condensation of the steam, after it had completed its work in the engines, instead of permitting it to escape into the air. The conventional condensing apparatus was out of the question, because of its expense. At this particular point strong cooling winds are prevalent, and the engineers accordingly decided to harness this force, and to compel it to perform the condensing operation. A huge radiator was erected, designed upon lines identical with those followed in modern motor-car practice. The exhaust steam from the engines is passed into this large honeycomb, and, being exposed to the full blast of the wind playing upon the radiator's surface, is chilled and reconverted into water. The plant works upon the well-known thermo-siphon principle, and this unusual application has proved highly satisfactory, as well as economical.

The fuel question is often perplexing. In the Bush timber is generally available for firing the boilers, but in

NATIVE SURF-BOATS LANDING SUPPLIES FOR PERUVIAN OIL-FIELDS.



By courtesy of the Oil Well Supply Company.

PUMPING-WELLS ON THE SEASHORE OF PERU.

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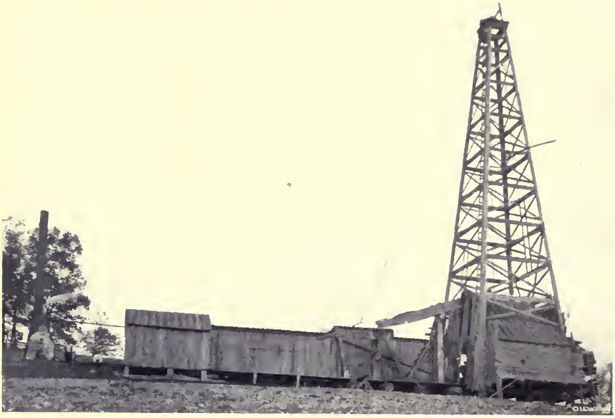

A MODERN WELL-DRILLING PLANT.

The above is known as the "Pennsylvania" Standard Cable Outfit.

By courtesy of the Oil Well Supply Company.

INSIDE THE DERRICK: INSERTING THE PIPE CASING.

Showing the Californian tongs employed to screw a new length of pipe into that already sunk into the ground.

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sterile countries the outlook assumes quite a different complexion. In the Soudan, for instance, coal, which has to be imported, costs upwards of £3 ($15) per ton; while at many points upon the American and Canadian prairies it exceeds this figure. Of course, once petroleum gas or oil is obtained, the fuel difficulty vanishes. The gas escaping from the well can be turned to useful account under the boilers, while the oil itself is utilized for steam-raising purposes. The steam-engine, however, is undergoing partial displacement, although a few years ago it was employed exclusively. Upon a new field it prevails at least for the initial stages, but when the well is brought into productivity it is generally superseded by the gas-engine. The advantages of the latter are so pronounced that they cannot be ignored. It occupies less space; the water question is overcome; less labour and attention are necessary; and the cost of operation is considerably lower. The gas flowing from the well is piped to the engine, and thus the well pumps itself.

The conveyance of the plant is often beset with difficulties and worries innumerable. If no railway is available, then everything has to be conveyed overland by the best methods obtainable. It may be by bullock teams, pack-ponies, or even the heads of native porters. Seeing that some of the component parts of the machinery, particularly the boilers, are bulky and weighty, their movement over even a few miles places a heavy tax upon animal effort. In the case of the Peruvian fields, owing to the lack of harbour accommodation and the exposed character of the coast-line, the vessels were forced to lie some distance off the shore, in the open roadstead, and to discharge their loads into native boats, which were compelled to run the gauntlet of the heavy surf. If possible, a small jetty or pier is erected, to enable supplies to be landed safely; but this practice is not always possible, especially upon such coasts as that of the Pacific seaboard of South America. When the field of operations is thousands of miles from the nearest markets, extreme care is essential to avoid losses of material, since an accident causes serious delays while replacements are being effected.

It is a moot point whether tapping the oil is carried out so cheaply as at Petrolia, Ontario, Canada. As the name implies, this is a petroleum-yielding district; but the harvest is so meagre, the wells yielding only a few barrels per day, and having such fleeting lives, as to compel the deposits to be exploited upon the very cheapest lines possible, so as to render the industry, such as it is, commercially profitable. The oil is found at a depth of some 400 feet, and the average cost of drilling a well is about £20 ($100). It is no uncommon circumstance for a well to last only a week, the owner commencing to draw oil on the Monday morning, and abandoning the well, because it has run dry, on the following Saturday evening. In Central America a well has been sunk for as small a sum as £30 ($150), and a rich yield of oil struck; but such successes are very few and far between, and certainly contrast vividly with the expense attached to well-sinking in other parts of the world. In the Baku oil-fields the average cost is about £5,000 ($25,000); while in Galicia, where the drills have to be carried to a depth of 3,000 and 4,000 feet, the expenditure under this heading ranges from £6,000 to £8,000 ($30,000 to $40,000).

As mentioned elsewhere, the earliest method of drawing oil from the earth was to dig a well by hand labour, upon precisely similar lines to those followed to-day in digging a shallow well for water in rural districts. Such a practice has its limitations. While sufficiently remunerative to the syndicates of natives in Roumania, Burmah, and elsewhere, the present needs of commerce never could be fulfilled by such methods. In the eleventh century a new system of boring for water was tried in the French province of Artois. Instead of sinking a well, two feet or more in diameter, by manual excavation, the principle of driving a bore of small diameter—say eight inches—was attempted. The idea was not original, because the broad principle had been practised in China for centuries previously. A suitable heavy tool was attached to the end of a cable. The latter was passed over an elevated roller. The tool was raised to its maximum height by hauling on to the cable passing over the roller, and then was permitted to drop. The force of the impact shattered the soil, even hard rock, immediately beneath, and this débris being removed by water, a hole was gradually sunk. The experiment in Artois proving completely successful, this method of boring for water came into general use, wells sunk in this manner being known as "artesian," from Artois, where the method was first tried and proved in Europe.

This combination of ancient Chinese and French ingenuity prevails to this day, as is well known, and its feasible application to drilling for oil was practised first by Colonel E. L. Drake, near Titusville, in 1859, as narrated in a previous chapter. Drake's success inaugurated the application of artesian boring to oil-drilling, and is followed to this day. The one notable improvement upon the Chino-French idea has been the utilization of steam for elevating the drilling tool, instead of relying upon manual or animal effort. Of course, in consonance with the advance of science and mechanics, many improvements in details—the fruits of experience—have been incorporated, but the fundamental principle remains.

The design, manufacture, and supply of appliances devoted to oil-well drilling has developed into a highly specialized branch of industry. In this particular field the United States, in which the oil industry originated, is considerably in advance of the other countries of the world, although British firms now are devoting more attention to the subject. But there is tremendous leeway to make up. The American plants, from their approved reliability and efficiency, are in use the whole world over, one firm in particular—the Oil Well Supply Company, of Pittsburgh, Pennsylvania—having penetrated to practically every oil-field in the world.

When the boom first set in, after Drake's sensational discovery, and the prospectors penetrated to States beyond Pennsylvania in search of oil, one fact was established readily. This was what might be described as the impracticability of standardizing the size and type of plant for oil-drilling. What was eminently adapted to one field was totally unfitted for another: the geological conditions influenced the question to an extreme degree. Consequently, in the course of time, the equipment became divided into distinctive grades, each of which is best adapted to certain conditions. Thus, there is the Pennsylvanian, the Canadian, the Californian, and the hydraulic rotary rigs respectively; while in Europe individual types also were created, such as the Russian and the Galician rigs. Both the latter, however, are essentially designed for deep drilling.

This sub-standardization has proved of far-reaching value to the petroleum engineer. In the determination of the plant best adapted to a particular field, he is guided by the prevailing geological conditions. For instance, the Californian rig is regarded as the most suitable for extremely difficult ground, owing to the peculiar disposition of the oil-sands in the State after which it is named. While the rock is hard and dense, the problem is affected more particularly by the troublesome caving nature of the sand and clays and bands of shale. The angle, or dip, of the strata also renders drilling additionally difficult. On the other hand, in Mexico the oil deposits are covered by strata of marl and shale, and consequently a lighter tool is able to meet the situation. Again, when the well has to be sunk through clay and quicksand, quite a different type of equipment is demanded. The first well or wells of a new country or district have to be drilled with extreme care, in order to produce a true geological record of the strata of earth traversed, as well as to ascertain the amount of water and gas that may have to be shut out or dealt with. It is this datum and other local information which guide the engineer in his decision of the system of drilling most favourably adapted to the field under review. Perhaps the most popular pioneer plant of the present day is the Californian rig.

The boring equipment comprises the rig, machinery, drilling and fishing tools, and casing or piping, which offers the channel through which the oil issues from the earth. The "rig" refers only to the structure, with its foundations of heavy timbers, and the wheels and reels on which are carried the lines or cables, to which are attached the drilling tools proper. A derrick and rig for foreign fields are frequently built of steel, because wood has a very short life in certain countries, particularly in the tropics, where the white ant is so troublesome. In such countries as Peru, where there is an absence of moisture, wood is imported for this purpose, and lasts for years.

The height of the tower or derrick varies according to the type of plant and the depth of boring. With the modern rotary equipment there is a tendency to have a derrick 100 feet or more in height when using either the combination or the hydraulic rotary system. This practice is followed with a view to extracting from the well a greater number of joints of drill-pipe in one length, so as to save labour in disconnecting and connecting when operating.

The machinery includes the boilers and engine for driving the tools. These vary in horse-power according to requirements, but both are designed especially for the work. Early experience speedily revealed the fact that certain additions to an ordinary engine were necessary to adapt it to the peculiar duty, owing to the unusual conditions which were encountered.

The drilling tools are many and various, being designed to work with the highest efficiency in different soils. While the percussion system is that generally adopted in oil-well sinking, the percussive action is carried out upon a principle widely divergent from that invariably associated with such tools in other cases. The drill, working on a cable or rope, is permitted to drop with the force of gravity, with sufficient fall to insure that a straight bore is driven, and that it shall strike the bottom of the hole fairly and squarely. The impact shatters and pulverizes the surface of the rock or other material into a slurry, which is brought quickly to the surface by a bailer, or what is called a "sand-pump." In oil-well sinking it has been found that unlimited rebound gives the most satisfactory results. The form of drill itself also varies. The cutting edge may be of circular section—the periphery forming the blade—and a hollow centre, or it may have a star-shaped head, and so on, this feature depending upon the character of the earth to be penetrated.

The bit itself, although it does the actual biting or chugging, is only one unit in the boring equipment. As a matter of fact, the "string of tools," to quote the driller's term—it is used with all cable systems, being attached to the free end of the cable, and thus accomplishing the actual drilling work—is somewhat formidable. The drilling bit, varying from 4½ to 6 feet in length, is at the extreme free end of the string. Above this comes the auger-stem, 16 to 48 feet long, into which the drill is screwed. Next come the drilling "jars," but these are not used as a rule until the hole has attained a depth of 150 feet. These resemble two great links of a chain. Following these come the sinker and rope-socket. The rope-socket is designed according to the style of the rope and the type of the drilling plant. Even this item varies widely in pattern. The total weight of the string of tools is from 1¾ to 2 tons, of which the bit or chisel alone represents more than a ton when large-sized bits are being used in holes of large diameter.

The "string" is not lifted to the top of the derrick for each stroke. Instead its elevation is fixed. The cable extends vertically from the borehole to the tower of the derrick, to pass over a pulley and to descend and be coiled round a reel. There is a seesawing or oscillating member, known as a "walking-beam," which recalls that used in the Newcomen beam-engine. The "string" is attached to the end of this member entering the derrick, the connection, of a grip nature, called a "temper screw," permitting the rope to be paid out as the well sinks deeper and deeper. When this end of the beam is elevated naturally, it lifts the string, and when it is depressed, it permits the latter to descend freely and quickly, enabling the chisel to strike the bottom of the bore with the maximum impact, and to rebound before the succeeding rising stroke takes place.

As may be supposed, the continuous smashing or pulver-

By courtesy of the Oil Well Supply Company.

A HUGE CHISEL FOR A RUSSIAN OIL-WELL.

The tool, weighing 3,125 lbs., was forged to bore a hole 25 inches in diameter.

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By courtesy of the Oil Well Supply Company.

DRILLING AN OIL-WELL BY THE ROTARY SYSTEM.

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izing action of the drill dulls the cutting edge of the tool, especially when the formation is hard, although the drill is made of the finest and specially-made steel. Periodically the whole string of tools has to be withdrawn from the hole to permit the bit to be removed for sharpening, another being substituted in the meantime. Consequently, the blacksmith's shop is a busy corner of the plant, because here is imparted that keen edge to the chisel which is essential to insure progress in "making hole," as it is termed. The life of the cutting edge varies considerably, naturally being shorter when driving against hard rock than when chugging its way through soft material.

As the drill strikes and pulverizes the earth at the bottom of the hole, the débris has to be removed. This is done with water and a sand-pump. In the hydraulic rotary system the method is somewhat different. The débris is removed automatically as the drilling proceeds, by continuous pumping or jetting of water. The detritus rises to the surface with the water, so that there is no accumulation in the bottom of the hole.

Under certain geological conditions the hydraulic rotary, instead of the percussive drilling, method has come into favour. This system, so called, is only practicable where water may be used satisfactorily, and may be obtained easily and cheaply. The principle is really what is known as "mud-flush," because in drilling through sand formations mud-laden fluid is used to seal the sides of the borehole temporarily, and thereby prevent the caving-in or collapse of the walls, prior to the insertion of the necessary permanent casing. This system is not recommended for drilling in a new area the exact geological conditions of which are not known, and where it is desired to obtain such data. The hydraulic rotary method is preferred by many engineers for the first part of the drilling, but usually the last sections —the penetration of the oil or gas sands—are completed with percussion tools. The hydraulic rotary system is frequently used as an auxiliary to the cable, and *vice versa*, and for this reason is generally known as a "combination rig."

As the bore is driven it requires to be lined. For this purpose iron and steel casing is used. The lining not only provides an easy passage for the movement of the oil, and prevents the wearing away of the walls of the borehole, as well as removing all possibility of its becoming choked, but at the same time it completely prevents the incursion of the oil-driller's worst enemy—water. As the bore descends, the chances are a thousand to one that a subterranean spring or pocket of water will be penetrated. If this be not held in check, subsequent difficulties and labour will be augmented considerably, because the oil will have to be separated from the water. In some instances a single lining is adequate to secure protection against this foe, but in others two or more pipes may be required, disposed in telescopic fashion—that is, one tube within the other—the annular spaces between the pipes being reduced to the minimum.

The tubes are inserted as the bore is driven, each additional unit being screwed to that already in the ground. The pipe is held vertically within the derrick by means of a cable or casing-line, to insure that the alignment is absolutely correct, because the bore must be quite plumb. Ponderous chain tongs—large editions of the chain grips used extensively by plumbers—are employed in the pipe-joining task. The upper end of the sunken section of the casing is held in position by means of a headpiece of large size and heavy weight, fitted with projections resembling horizontal arms. When sunk into the ground, these arms obviate any tendency of the casing already in position in the borehole to twist or turn while a new length is being added. When the section is screwed home, drilling is resumed, the tube sinking lower and lower as the drill cuts more deeply into the earth, until the casing has descended to such a depth as to necessitate another length being connected, when the cycle of operations is repeated, and so on, until the oil is reached.

Sometimes, instead of the tubular casing being inserted in the wake of the drill in the circular borehole provided, the column of pipe is driven. For this purpose what is known as a " drive-pipe " is used. This practice is adopted generally when a well is being sunk through strata the geological formation of which is not known with any degree of certainty, because it is safer. It is invariably practised when sinking the first well upon a new field. The experience gathered in driving the initial borehole is invaluable, because it enables succeeding wells upon the same oil-field to be driven with the most satisfactory tools and lined with suitable pipe, in order to complete the task with the minimum of time and expense.

Boring by freely falling tools, while highly satisfactory when sinking through hard formations, is useless when soft material, such as quicksand and clay, has to be penetrated. For the latter conditions the rotary hydraulic system is employed. The principle is the rotation of a column of pipe—drill-pipe—the lower end of which is provided with a cutting bit. Water mixed with mud is forced down inside the pipe by means of a pump, passes under the lower end of the drill-pipe, and then upwards between the outer surface of the pipe and the wall of the borehole. In so doing it tends to float the pipe, thereby preventing contact with the wall of the borehole. In this way the rotation of the pipe is facilitated, while at the same time the flush carries away the cuttings of the tool in the water and on the exposed wall of the bore, thereby preventing the latter from caving in. This process is used almost exclusively in the States of Texas and Louisiana, owing to the amount of sand and light clay, while it has an extensive use upon the oil-fields of Mexico, where similar conditions prevail.

When the oil-prospectors, in their desire to win oil from the earth, ventured to tap the deposits below the Pacific sea-bed off Summerland, California, they were faced with a pretty problem—the complete exclusion of the sea-water from the borehole. The venture was certainly fascinating but highly speculative. The first well was sunk in 1896, a low wharf being laid out from the shore over the surf, to a point beyond low-water mark. Although the conditions were somewhat unusual, the initial efforts revealed the fact that the task did not present any abnormal problems, owing to the even configuration of the sea-bed.

The first step is the provision of a light wharf, for communication between the well and the shore, and the passage of such materials as are required.

In sinking the well, what is known as a "conductor" is first placed. This comprises a length of oil-well casing, of larger diameter than what would be employed were the well being sunk on dry land. Inferior casing often is used for this purpose, and, if the preliminary borings have proved that no large boulders are likely to be encountered when driving through the sea-sand, the casing is not fitted with a shoe. The diameter of this casing varies according to the depth of water. When the latter ranges from 15 to 25 feet, $9\frac{5}{8}$-inch casing is used. Two lengths are joined together, giving a total length of casing ranging from 30 to 45 feet, the length being such that, when the bottom end of the casing is resting upon the sand, the upper end is brought near the roof of the derrick.

Setting this conductor is the most critical operation. It is held suspended by the sand-line in an upright position, with the lower end about one foot distant from the sea-bed. The driller waits until the agitation of the water is practically negligible. At the psychological moment the conductor is dropped suddenly. Upon touching the sand it is once more plumbed to see that it is vertical, and then stays are nailed upon the floor of the derrick around the conductor, to keep it in that position. The drilling-stem, fitted with a driving-head and clamps, is run into the conductor, and driven into the sand as far as it will proceed with safety. The clamps are removed, and the drill is set to work. As drilling proceeds, the conductor is sent downwards at frequent intervals, until it has worked through the sand and has penetrated the clay beneath. By this time the upper end of the conductor has been brought level with the floor of the derrick, and, there being no further need to hold it in position, the stays on the flooring of the derrick

GENERAL VIEW OF A ROTARY DRILLING PLANT.

By courtesy of the Oil Well Supply Company.

DIGGING A "SUMP" ON A TRINIDAD OIL-FIELD.

A pond is provided near the well to receive the oil directly it is struck.

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DRAWING OIL FROM THE BED OF THE SEA.

A glimpse of petroleum winning enterprise at Summerland, California.

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are knocked away. The conductor is then driven farther into the sea-bed, until the top is only a few inches above the water. By this time it will probably have entered well into the clay bed. The sea is now deprived of all opportunity to enter the borehole, unless there be subsequent carelessness or incompetence upon the part of the driller.

Directly the conductor has reached the "safe" position, the drilling bit is changed, the next smaller size being used. In driving the drill, it is imperative that the casing should follow immediately behind it. If it does not, the tools, securing an increased swing, are apt to cut a hole of greater diameter than is required to receive the casing. In this event there is the risk of a cavity being formed, which in time the sea-water above will find and take, thereby probably gaining entrance to the oil-sands below. Should this occur, not only the well, but the whole oil territory immediately in the vicinity, will be ruined. For this reason drilling into the sea-bed has to be carried out with care, but otherwise, after the setting of the conductor, the method of sinking does not differ widely from those practised upon dry land.

The successful driving of the first well into the Pacific sea-bed precipitated a scramble for water frontages, from which the necessary wharves could be run out into the water. Well-sinking went forward with remarkable zeal, some of the more adventurous pushing out to a point where there is about 25 feet of water at low tide. Four years after the first bore had been driven 305 wells had been sunk into the sea-bed, each of which was yielding up to sixty barrels of oil per day. The lives of some were extremely brief, the borehole being abandoned almost as soon as it had been completed, owing to the indifferent yield. In fact, within about forty months fifty-nine wells had been driven and abandoned.

The cost of a drilling plant for sinking an oil-well varies considerably. It depends upon the depth to which the borehole has to be taken, as well as the local conditions. The pipes or casing represent a very costly item, particularly in the case of a deep well, so that the expenditure may easily range from £500 to £10,000 ($2,500 to $50,000).

CHAPTER IV

THE "OIL-BOOMERS" AND OIL RUSHES

"More money has been put into the ground than ever was taken out of it." This is a trite saying, and one, reflecting upon the billions of tons of oil which have been extracted from Mother Earth and the enormous value thereof, might feel disposed to argue that here at least proverb is fallacious. But, as a matter of fact, never was the truth of the adage demonstrated so powerfully as in connection with oil. In this connection the snares and robberies of the "wild-catter" are not taken into consideration, since in the majority of these cases no attempt is made to put money into the ground; it runs into the pocket of the schemer.

Striking for oil, in the strictest sense of the word, is one of the biggest gambles in the world. The seeker is merely dipping his hand into a huge lucky-bag; he may draw a prize, but he probably will draw a blank. Often, if he does apparently shake hands with Fortune, he is just as likely to regret his luck, since the "strike" may prove more costly than utter failure.

It is the speculative character of the work which makes such an appeal to the American. He is a born gambler, delights in juggling with Fortune; with him speculation is second nature. In the quest for oil he has unlimited capacity to gratify his desires to become rich quickly. This is the main reason why to-day the United States occupies the foremost position among the oil-producing countries of the world. Had similar men been found in other countries possessed of rich deposits of this mineral, and been given scope to work upon the principle which has obtained in America, the oil output of the world would have been twice or thrice what it is at the moment. The oil industry was born in the United States, was developed there, and is represented in its highest degree of perfection in that country.

When Colonel Drake struck oil on Oil Creek in 1859, he precipitated one of the wildest rushes for wealth on record. The countryside was a dense forest, cleared here and there to permit tiny humdrum communities to exist when he launched his enterprise. While the country throbbed and swayed with the news, the boomers rushed to the spot. Within a few months the virgin country around Drake's well, which scarcely had known the imprint of human feet, was overrun like an ant-hill. Claims were staked off in mad haste. The timber which was brought down in clearing was lopped up to provide material for derricks, which rose like magic. The oil-boomers did not confine their efforts to Oil Creek. They perforated the banks on either side of French Creek and the Allegheny River as well. A tract of virgin forest to-day was a humming town of tents to-morrow. There was no staying the stampede. Drillers, investors, financiers, and land agents, were engaged in a wild mêlée. Poor men at the rising of the sun were millionaires before Old Sol set again, and again were penniless when the dawn broke once more. Discretion was thrown to the four winds. Fortune was in a benignant mood, was bestowing her favours on one and all promiscuously, and none pondered to reflect how long the goddess would show her open hand.

The ambitious, budding millionaires suffered from one serious disadvantage. They knew little or nothing about the difficulties and uncertainties of boring. It was the early adventurers without resources but able to maintain a cool head amid the tremendous excitement who made money. They refrained from well-sinking upon haphazard methods, but devoted their energies to mastering the intricacies of this peculiar art.. In a short time they became proficient drillers. As the boom increased, the services of these comparatively few men became keenly demanded, and they commanded very high wages. Financiers and capitalists provided them with constant employment, and being called upon to drill in all sorts and conditions of places, and encountering obstacles of infinite variety, they were able to measure the difficulties and uncertainties of the task, and incidentally amassed considerable and invaluable experience.

In time the driller tired of the everyday routine and the receipt of a certain wage for his brains and skill. He longed to become his own master, to have the opportunity of becoming numbered among the rich men in the oil world. He became thrifty. He reduced his living expenses to the minimum, denied himself various luxuries, toiled hard and long. Every cent he could spare he put into the bank. He became obsessed with one idea—to obtain a sufficiency of ready cash to purchase a drilling outfit and to sink a well upon his own responsibility.

This spirit prevails to this day. A workman only drills for somebody else at good wages until he has accumulated a little nest-egg. Then he sallies forth to tempt Fortune. This is the reason why, at the moment, American drillers are difficult to obtain, and why foreigners are being more widely employed for the work. The Hungarian, Roumanian, or Italian, is not so susceptible to the virus of the oil-speculation fever; he cherishes no ambition to become an oil-king. This type of labourer prosecutes his task diligently day by day until he has amassed enough to spend the evening of his life in comfort in his homeland.

The speculating American oil-driller is generally content to venture with a capital of $2,000 (£400). He makes a bargain with the manufacturers of the drilling plant. Should his capital be sufficient, he will purchase the installation outright. Otherwise he will undertake to pay for it by instalments as his prosperity increases; or, and this is sometimes the case, the manufacturing firm will share in the risk by giving the purchaser extended credit. In reality the latter incurs little risk. If the venture fails the driller is conscientious, and will spare no effort to wipe out the debt, knowing fully well that, unless he meets his obligations, he stands a very indifferent chance of securing another outfit with which to undertake his next plunge.

These preliminaries completed satisfactorily, the speculative individual casts around for a promising spot on which to drill. If he is in a proved oil-producing district, his prospects are distinctly rosy. Having made his selection, he approaches the farmer, or owner of the land, for permission to drill a well. The latter is just as anxious as the driller to make money quickly, and he listens attentively to the proposal, which is that, in return for permission to drill, the owner shall receive a certain share, virtually a royalty, per barrel upon the oil obtained. As a rule the proprietor readily agrees to the suggestion. He incurs no liability, and if the driller draws a blank no harm will have been inflicted upon the property. Sometimes, especially when the coveted spot is in a rich oil-yielding territory, the farmer demands more than a royalty. He himself has become inoculated with the speculating virus to a dangerous degree. The driller must pay a premium for rights to drill, in addition to the royalty upon the oil produced.

Often the farmer goes farther to improve the dazzling opportunity. After one driller has made a proposal, the farmer sedulously circulates stories of the oil wealth existing upon his property, accompanied with hints that he is willing to entertain offers to drill. This story generally succeeds in its avowed purpose. Other speculative drillers have their gambling instincts fired, and lively bidding ensues for prior drilling rights, the concession being extended ultimately to the one who offers the highest premium.

Speculative oil-drilling under such circumstances is rendered an additional gamble, and requires far more capital, the greater part of which probably is expended before a single piece of the plant is brought on the ground. The farmer is canny. He is fully aware that drilling may prove abortive, and consequently he demands the premium in cash in advance. This bargaining between the driller and the property owner has reached an acute degree. The humble gambler refrains from venturing upon such land, preferring to treat with one who is content to receive a royalty purely and simply in the event of success being attained.

The driller does not let the grass grow under his feet. His plant is brought up, and is in working order within a short time. The drills are kept going the livelong day, and often night as well. The situation is not without its excitement, comedy, and tragedy. Labour must be employed, and the man of little capital anxiously watches his drills sink deeper and deeper and his reserve of cash grow smaller and smaller. Finally he either strikes oil or reaches the end of his resources. He has sunk his tools to a certain depth, but has not touched any petroleum. Yet he is confident that it exists, such is his unquenchable optimism. But he cannot go another foot without money. He attempts to find it. He approaches kindred spirits who are keen on oil, possess the money, but will not drill. Possibly his mission is a failure, in which event he disposes of his outfit for what it will realize, and returns to his former occupation—toiling for someone else. Often, however, he will prove successful in his solicitations. A friend in need will finance him another two, three, or five hundred feet, but on terms. More bargaining ensues, and another slice in the speculator's possible fortune is cut. However, he is enabled to proceed, and to him that is everything.

Perseverance perhaps brings its reward. Oil is struck, and in paying quantities. Speculation is satisfied, although possibly the ardour becomes damped somewhat when the gambler realizes how much he has to pay out to his coadjutors before he is entitled to a penny. If the yield is a big one, he will regard his share with complacency; if not, he will sell out his share for what it will fetch, recouping his capital and a little extra. With this sum he will depart to pastures new to make another attempt, determined this time to dispense with outside financial assistance, unless, as before, necessity compels otherwise.

Some of these men go on from year to year, and wander from one part of the country to another, never making a big strike or materially adding to their fortunes, because of the heavy liabilities, in the form of shares, incurred with other interests. If a man is able to strike oil without enlisting additional financial aid, he has merely the royalty to pay, and stands in an advantageous position. The owner of the property not only will be willing to permit further boring, but, to secure a bigger return, will forego the royalty in order to receive a 50 per cent. share in the well, and will contribute one-half of the expenditure.

Many interesting stories pertaining to this speculation may be related. One gentleman, who is now engaged with the Standard Oil Company, was sitting in his office one morning when a dishevelled, dead-beat driller, his overalls saturated with mud, sought financial assistance. He was certain to make a strike within the next forty-eight hours if he only could get the money to restart his drill. It was his first speculation, and he appeared to feel acutely his unremunerative investment. He had approached other possible sources, but his entreaties had been in vain. My friend, ever ready to indulge in a gamble, offered the money necessary to keep the drill going for a week, accepting the speculator's own terms. The man went off delighted. Within forty-eight hours he tapped the oil. It was not a big yield as flows go nowadays in connection with the oil-wells, but the speculator was satisfied. The two shareholders finally sold out their holdings, and the driller went off to another district, where he was far more fortunate. In the oil-yielding districts of the United States there are hundreds of men who have won their fortunes by backing the speculative driller in this manner.

In another instance a small speculator met with fortune in his first attempt. His well was a paying one, but the speculating fever had eaten so deeply into his soul that he dreamed greater conquests. Fortune was on his side, he reasoned, because of his success at the first attempt. So he sold out his well for $50,000 (£10,000), and commenced drilling in another district. This time he met misfortune. Within a few weeks the whole of his capital had vanished, and he was compelled to resume drilling at a weekly wage.

Nowadays owing to the greater expense attending drilling, and the heavier risks which are incurred, the speculator seldom plunges alone. The more popular tendency is to form small syndicates, so as to divide the responsibility and the expense. This method has an additional advantage. Instead of money being expended upon outside labour, the members divide the tasks among themselves, working, in fact, upon the co-operative principle, and dividing the profits in equal or other proportions, according to the extent of their financial contributions.

The average oil-field is a veritable speculation in another sense of the word. It suffers from the disability of a brief existence. It may yield continuously for years, and then suddenly give out. The result is that oil colonies rise, flourish, and die within a handful of years. Rarely does a town born of the oil-boomers have a permanent existence. Its prosperity depends upon oil; it is brought into being; it flourishes upon the mineral; and its passing coincides with the exhaustion of the oil deposits. One may search the maps of Pennsylvania to-day for Pithole City, but the quest will be in vain, because it is no more. But in 1865 Pithole City was the most famous spot in the newly-proved oil country. Its business was of such proportions as to demand a post-office second only in size in the State to that at Philadelphia. The oil in the vicinity gave out, and the residents, whose existence depended upon petroleum, moved elsewhere. The deserted buildings crumbled into decay or were demolished, grass once more grew in the streets, and finally agriculture claimed the deserted property. Pithole City of 1865 is a farm in 1914; not a vestige of the former community or frenzied activity remains.

When an oil-boom sets in, all discretion vanishes. The speculating fever secures such a firm hold that it completes its ravages as surely as an epidemic. Land soars to prohibitive prices; companies of the most doubtful character are created every minute, 99 per cent. of which would be stillborn if the public kept its head. During the Texan oil-boom land which failed to attract \$2, or 8s., an acre as ranching country assumed immense value because of its problematical oil content. One tract for which the owner would have accepted \$5, or a sovereign, per acre previously, changed hands for \$10,000, or £2,000, and doubled again in value in twelve hours. In another instance an acre appreciated \$30,000, or £6,000, in value within a week, and found a purchaser at this figure. The passage of years has not tempered an oil-boom with wisdom. During the Calgary rush, early in 1914, land supposed to be oil-bearing commanded from \$50,000 to \$60,000 (£10,000 to £12,000) per acre; while companies exceeding a total capital of \$60,000,000, or £12,000,000, were formed in forty-eight hours, notwithstanding that the oil-field at the time was a doubtful proposition, and had revealed petroleum only in an indifferent quantity at one well. Even the leading oil companies do not fail to make their presence felt upon such occasions. The world's cry for oil is so insistent that it behoves these organizations to make an early move, so as to be in a secure position should prospects materialize. Thus, when a Canadian oil-boom became manifest some years ago, the Standard Oil Company immediately set aside \$5,000,000, or £1,000,000, so as to be in a position to participate in the Canadian development directly it became established.

A similar state of affairs attended the proving of the Mexican oil-fields after they had been proved by Lord Cowdray. At the time he appeared upon the scene, only two other companies were working in the country, and their successes had been indifferent. But the striking of "Dos Bocas," with its mammoth yield, precipitated the inevitable rush. Speculators purchased leases and concessions cheaply, and offered them dearly. Some were able to realize; others still have them on their hands, and are searching anxiously for purchasers. Within twelve years the number of oil companies in Mexico increased from two to about 130, but only a round fifty of these concerns are working to-day; the remainder exist on paper, are dormant or moribund.

Seeing that the speculator confines his energies to tapping the oil, one may wonder how he disposes of his product. He makes practically no arrangements to this end. He may set up a small tank or dig a temporary pond in which to collect the oil. Then he notifies one of the large companies that he is able to dispose of so many barrels of oil per day—oil is computed by the barrel, which in the case of crude oil is equivalent to forty-two gallons. If a pipe-line is within reasonable distance of the property and the yield is attractive, the company operating the latter will extend its system to the well. If the pipe-line runs past the property, it will insert a branch and connect up. If there is neither, it will collect the oil by some other method, so long as it is not too expensive. No contribution of oil, no matter how insignificant it may appear, can be ignored, if there is any feasible way to gather and convey it to the tank farm. A pipe-line company will collect a mere bagatelle of twelve barrels a day just as readily as an output of 50,000 barrels. The conveyance of the crude from the field to the refinery is one of the wonders of the oil world, as narrated in another chapter.

The individual and syndicate gambler is to be found in every corner of the United States. His energies and speculative activity have opened up the deposits of territories which were generally considered to be barren. He takes long chances in the true gambling manner; does not hesitate to rush in where wealthy organizations fear to penetrate. He revealed the petroleum wealth of Texas, Kansas, Oklahoma, and is now toiling among the bad lands of Wyoming and the forbidding fastnesses of Alaska. In each instance the local producing industry has been set upon a solid foundation through his plunges and enterprise. The pioneer in a new field, far removed from exploited territory, labours under advantages and disadvantages. Being the first upon the scene, his well provides the pent-up oil with the outlet for which it is striving. The petroleum bursts out with terrific force and in huge volume. It is certain to be a big strike if the heart of the stratum be penetrated.

A GLIMPSE OF AN EARLY OIL-BOOM IN THE UNITED STATES.

General view of Pithole Wells and Ball Town in 1865.

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JOHN BENNINGHOFF FARM OIL CREEK, PENNSYLVANIA, U.S.A., DURING THE BOOM OF 1865.

There were eighty-seven wells and derricks. (A) is the first pumping-station whereby the crude oil was moved by pipe-line over the hill (2) to Shaffer Farm, three miles distant. The well (3) is the first in which $5\frac{5}{8}$-inch casing was used.

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News of the strike is flashed to all corners of the country, and other speculators, fired by the chance to make money quickly, stampede to the new field with their tackle and equipment. In a short time the whole of the territory for miles around the first strike is divided up into claims. Timber derricks housing the drilling plant spring up like magic.

The pioneer is literally overwhelmed with oil, and his troubles then are likely to commence. He strives might and main to save as much as he can, and probably succeeds in retrieving a small proportion of the yield. Immediately the strike is noised abroad, and even before the stampeding speculators have arrived, the representatives of the big companies are upon the scene, surveying the situation, and hurriedly debating the ways and means of collecting and storing the oil, as well as transporting it to the refineries. Earthen reservoirs probably are thrown up hurriedly, while simultaneously material for tanks is ordered by telegraph. The steel and labour is rushed to the spot, and, ere other drills have commenced to bore into the earth to tap the deposit, the tanks commence to assume their familiar form. Simultaneously the pipe-line is hurried forward, and pumping-stations taken in hand. The result is that, before many wells have been sunk, ample facilities are available to receive the oil, and the means of transporting to the refineries well advanced towards completion. The first few weeks in a new oil-field are times of extraordinary bustle and activity, there being no cessation of effort night or day to have things in working order by the time additional wells commence to flow. Nothing is permitted, and nothing, indeed, is able, to arrest progress once an oil-fever has broken out.

At times awkward situations develop, especially if the pioneer has penetrated into new country far from facilities for storing and collecting the oil. In fact, sometimes the adventurous, intrepid plunger is a doubtful blessing to the oil industry. For instance, when the Texan oil-fields were brought into productivity, so much oil was obtained as to precipitate a glut. There were no cheap facilities available for its transportation. The drillers had the mortification of seeing fortunes slipping through their hands. The pipe-lines were hundreds of miles away. Oil had to be sold for what it would fetch, and the price during the height of the boom sank to 10 cents, or 5d., per barrel. A similar state of affairs prevailed during the Kansas boom. The drillers, in their mad haste, never paused to consider upon the disposal of the petroleum. They simply sank well after well as rapidly as they could. The price of the crude oil, owing to the situation, sank as low as 17 and 14 cents (8½d. and 7d.) per barrel, which was a ruinous figure. No improvement took place until the pipe-lines were laid, when, communication with the refineries being established, the price rose to the normal figure.

The large producers and refineries, appreciating the value of the speculative oil-seeker, foster rather than discourage his activities. He absolves them from considerable preliminary expense in drilling and proving a new territory. Their work is reduced to purchasing and transporting the raw material when it has been tapped. It is a development which is peculiar to the United States. In other oil-producing countries such a tendency is not supported. Steady and scientific prospecting and development are preferred. Taxation, moreover, is an effective barrier against this form of speculation, especially when the tax assumes the form of so much per barrel or other volume yielded by the well.

On the other hand, the speculating driller does not always regard his successes with pleasure, especially upon a new field. The first well struck is generally prolific in its flow; so much so that it invariably gets beyond control. The oil then is lost if the more fearful calamity, fire, does not supervene. All the big strikes in the United States have been accompanied by a terrific waste of oil. In connection with the first strike in California, the oil rushed out in a terrific fountain, carved a bed for itself, and was lost completely by tumbling over the cliff, a miniature Niagara of petroleum, into the waters of the river below. The arrival of scores of other speculating spirits and the feverish zeal with which they drive their wells to tap the subterranean liquid wealth eases the situation somewhat, because, as the deposits are given additional vents, the energy expended in the first borehole diminishes, until at last complete control is secured. Then the oil can be kept in leash until the storage facilities are completed, when the oil either is permitted to rush into the tanks under its own volition, or, owing to the reduced pressure, has to be drawn by pumping.

One curious outcome of an oil-boom in a new territory, and one which often puzzles the stranger, may be noted. The claims are marked off, the territory of each man being well defined. Smith will sink his well, say, 20 feet east of his boundary, and taps the oil below. His neighbour Brown at once sets to work at a point 20 feet west of the above boundary—that is, 40 feet distant from, and in line with, Smith's well. This is known as an "offset well," and is driven by Brown essentially as a measure of self-protection. It is obvious that the oil underlies the two properties, so, if Smith alone sinks a well, he not only draws oil from his own land, but also saps Brown's property. By sinking the wells in this manner, Smith and Brown draw equally from the reserves below. If either should sink a second, third, or even more wells, a similar distance from the boundary, the other will follow suit instantly. Brown is not permitted to have one well in excess of Smith near the dividing-line. This practice is followed in all oil-producing territories where the land is divided up into comparatively small areas. In many cases the wells will be sunk so closely together that the buildings will almost touch one another. The appearance of two parallel rows of derricks on either side of a fence, with extensive open and untouched areas on either side, is certainly somewhat quaint. The uninitiated is apt to imagine from this set-out of the wells that the oil extends underground in the form of a perfectly straight river. The first wells always are sunk near the boundary-lines, leaving the centre of the property untouched, because if the flow continues and warrants such further development, the later wells can be sunk in the centre of the claim, where the oil is not likely to be drained away by the operators on the adjacent claims.

It is somewhat curious that the speculating oil-driller, notwithstanding his energy and enterprise, more often than not fails to amass a fortune. This is entirely due to his love for a gamble and his quaint delight in driving a well and proving his ground. He is a roving adventurer to the manner born. Sinking a well appears to be his one ambition in life. When he has brought it to the productive stage, and a comfortable fortune is likely to accrue if patience be observed to permit the revenues from his product to accumulate, he follows an unusual line of action. The gambling instinct refuses to be stifled. He knows only too well that his borehole may give out any day. Accordingly, he invariably sells his property outright, either to one of the large companies, or finds a purchaser who is content to follow the stay-at-home-and-wait-to-get-rich policy. Many productive wells have been sold for trifling sums—£2,000 to £20,000 ($10,000 to $100,000)—and have brought large fortunes to their new purchasers. The speculator, armed with the ready cash thus obtained, immediately hurries off to a new corner of the country to tempt fortune once more. His one great objective is to strike a gusher: to accomplish a feat which will set the whole country agog with excitement. It is a vanity, and, in endeavouring to satisfy this foible, disaster often is encountered. The gambler loses what money he has placed to his credit, and is forced to work for a weekly wage until he can save another sufficiency to enable him to start afresh upon his own initiative.

Although the oil-drilling speculation is fascinating, and the prizes to be won certainly are attractive, the failures far outnumber the successes. Hundreds of wells are sunk, but only scores are productive. A mere barrel a day is the reward in many instances, while a strike of water is often the solitary return for the expenditure of energy and capital. Consequently, in this peculiar calling, the truth of the time-worn adage is substantiated, and not disproved.

CHAPTER V

TAPPING AND DRAWING THE OIL

In sinking an oil-well a premium is placed upon practical skill, especially when it is supported by years of varied experience in the field. The wages of the men who reach down to release the accumulations of liquid mineral imprisoned in the earth range from £25 to £40 ($125 to $200) per month. Often an attractive bonus is offered as an incentive to greater effort to expedite the task.

The expert driller is of a class apart—self-reliant, enterprising, persevering, optimistic, and of uncanny resource. Geological data may be available to indicate the character of the strata which the drills may be called upon to penetrate, but absolute confidence cannot be placed upon such assistance. The driller rather depends upon his own observations and the "feel" of the tools as they are working, in precisely the same way as the expert hand controlling an engine, who is able to detect by sound and touch the slightest deviation from the normal rhythm of his charge.

Naturally, the drills, in driving their downward way, are disposed to follow the path of least resistance. This tendency must be frustrated. It is absolutely imperative that a borehole shall be plumb, to facilitate the subsequent operation of drawing the oil, either by pumping, bailing, or whatever process is adopted. Should the borehole deviate from the vertical alignment, it must be corrected, and this can only be accomplished by redrilling. Again, it may so happen that a mishap befalls the tools chugging at the bottom of the hole. One or more members of the string perhaps come adrift and fall to the bottom of the hole, or some other misadventure may mar the steady round of toil. In any event the lost tools must be recovered or the accident remedied. When the borehole is only 6 inches in diameter, and the breakdown occurs at a depth of 1,000 feet or more, one may consider that the recovery of the lost tools is an extremely remote possibility.

But it is the unexpected for which provision must be made. Although 1,000 feet down, and imprisoned in a small circular space, the tools can be reclaimed. Special devices, known as "fishing" tools, are brought into service. These implements are of varying design for the work which has to be achieved. One will catch hold of a member of the string which has come adrift below the collar; another will seize a loose tool in the well; a third will loosen tools which have jambed in the borehole; a fourth will grip a piece of steel or any other small tool which has been dropped into the hole inadvertently; a fifth will cut the cable at any desired point and depth; while another will catch hold of the cable if it has broken; and so on. It is very rarely, if ever, that a borehole has to be abandoned nowadays because some tools have broken loose and are obstructing the passage.

Some extraordinary factor must supervene to cause a driller to relinquish the task which he has undertaken to complete. The odds must be overwhelmingly against him. The driller is ready for any emergency. A drilling bit becomes fixed in the material which it is penetrating, and snaps from the string. The uninitiated will regard the situation as hopeless, owing to the severity of the jamb and the extreme depth at which it has occurred. But the driller has no apprehensions. He merely withdraws the cable, attaches a suitable contrivance, which he introduces into the borehole, lowers it, and commences to fish for the missing member. He spuds round the seized bit, and gradually but surely releases it. Finally he sends down another tool, which grips the missing broken implement and brings it to the surface. Fishing operations may be wearisome and laborious. Often weeks, and even months, are occupied in patient, expensive work, making and adjusting the fishing tools to fit the fractured portion of the implements within the hole. But the driller pursues his arduous way unperturbed. Such misfortunes are inseparable from his peculiar task.

Sometimes the whole string of tools breaks away from the cable, and becomes jambed in the borehole. In this instance a length of 65 feet of tools connected together, and weighing some 3,000 pounds or more, demands recovery. It is of no avail to lower a device and to pull away at the derelict. Such action will assuredly fail to fulfil the desired end. The driller meets this awkward situation by attaching a special tool to the cable. This he lowers into the well, and starts to drill downwards beside the imprisoned string. In this way he opens out the borehole, and the increased space thus provided enables the jambed string to be freed. Once this has been accomplished, recovery is assured.

Occasionally, through severe external pressure, or owing to an inherent defect in the material, the casing collapses and completely obstructs the passage. But by means of a fluted swedge the driller surmounts this difficulty. With his special tool he drives a hole through the obstruction, providing a passage as clear and as good as that which existed before the mishap. Nowadays the driller is not dismayed by any accident to his borehole, no matter how serious it may appear: practically nothing, except a complete cave-in of the earth, will cause him to abandon a hole upon which he has once commenced drilling. Mishap may provoke a serious loss of time, but the driller is patient and dogged, so overcomes the set-back successfully.

But the well-driller has one relentless enemy. This is water. It is obvious, when driving downwards through the earth's crust, that pockets of imprisoned water must be encountered, and often the borehole provides a welcome vent for a lurking spring. Fighting water undoubtedly constitutes the driller's grimmest and most severe task, especially if the enemy makes its entrance by bursting the casing after the tools have advanced a considerable distance beyond the " bad " spot. The water, finding an outlet for which it has long been seeking, rushes forth with fury, and occasionally threatens to flood the workings. The driller may be surprised and balked, but he will not be beaten. He reconnoitres the situation, prepares his plans, puts them into execution, and in time he triumphs. It may be a stern and spirited tussle for supremacy, but the opposition of Nature has to assume extremely formidable proportions before the driller will admit defeat.

Water trouble is encountered in its most serious form when driving a borehole through quicksand and clay. In this instance it is not only the water which harasses the driller, but the treacherous earth which is set in motion by the water. It is incumbent upon the driller, working with the hydraulic rotary equipment, to keep a sharp eye upon the return flush, which he drives into the borehole to cool the cutting tool and to sweep the débris to the surface. The returning water offers an index to conditions prevailing in the well. Sometimes the flush does not come to the surface. It is only too evident that the tools are driving through a porous formation which is absorbing the water. If sand is troublesome, a thick mixture of water and clay is prepared, to prevent the running sand from closing the hole. The casing or drive-pipe is driven down with all speed to traverse and shut off or seal the absorbing formation. The water pumped into the borehole, being unable to escape in the previous direction, once more returns to the surface, and when the driller observes this return to be steady and of regular volume, he knows that he has dealt successfully with the fault below.

As the drills penetrate the lower formations lying immediately above the oil-bed, indications of this fact are betrayed. The volatile constituents of the petroleum, which have been given off in the form of gas, penetrate convenient fissures and cracks. The drill in its descent taps these pockets of gas, which naturally surge to the surface through the borehole. The driller maintains a vigilant lookout for such signs, because they guide him very reliably. If the volume of gas assumes substantial proportions, special precautions are urgent for its free conveyance into the air, or it may be sealed off. If the gas can be turned to useful account, it is led through piping to the furnaces of the boilers, or induced to drive the gas-engine which is being used for supplying the necessary energy to run the drilling plant.

When the oil or, "paying," sands, as the oil stratum is called, are entered, the fact that oil has been struck may be revealed by the petroleum immediately spurting from the borehole in a terrifying fountain. On the other hand, it may rise to the surface imperceptibly; the oil has commenced to flow, but the movement perhaps is sluggish. It must be hurried. To consummate this end, recourse is made to a powerful explosive, the operation of firing the charge to increase the oil-flow being known as "shooting" or "torpedoing" the well.

In order to insure the free movement of the petroleum through the borehole, it is essential that the lower end of the latter should terminate in a space or cavity into which the oil may gravitate and collect. As a rule the oil is impregnated heavily with sand, and if this material is permitted to gather at the bottom of the hole, naturally the latter becomes choked and the flow of the oil is impeded, if not completely arrested. By resorting to the stern persuasion of an explosive, this cavity is established and kept clear. It must be pointed out, however, that "shooting" is undertaken only when the limestone or sandstone is of such a nature that it restricts the flow of oil. For instance, while it is eminently satisfactory in the eastern and central oil-fields of the United States, it is not successful among the oil-sands of California. Similarly, it has a certain vogue upon the Caucasian oil-fields.

"Shooting" the well is perhaps the most delicate operation, and incidentally it reveals the supreme contempt, born of familiarity, with which man comes to regard a terrible devastating agent. In the early days powder was utilized, but to-day nitro-glycerine is used for this purpose As is well known, this is undoubtedly the most sensitive and destructive medium known; but the shooter handles it with no more compunction than if it were treacle, though he is fully cognizant of its annihilating powers.

The shot for a well comprises a cylindrical vessel, terminating at one end in a cone point, to the point of which is attached a small tin tube about 2 inches long. The type of torpedo varies somewhat, that generally used in the United States differing from that employed in the Caucasian oil-fields. In the former country the cylindrical vessel ranges from 6 to 7 feet in length, and as a rule is of sufficient capacity to receive 20 quarts of nitro-glycerine.

In shooting the well, every care has to be taken that the explosive charge is deposited the correct height in the sand-bed beneath the extremity of the borehole. When all is ready for shooting, the well is cleaned out thoroughly, a sand-bucket and what is known as a swab being employed for this duty. Then the depth of the borehole is ascertained with accuracy; a steel tape, to which a plumb or steel basket is attached, is lowered into the well, and the reading taken directly the plumb touches bottom.

The charge is now prepared. The tube is connected to a cord and pulley system, and is lowered into the mouth of the well to facilitate the loading of the charge. The nitro-glycerine, brought to the well in 2-gallon tins, is poured into the cylinder. The top of the tube is fitted with a metal lid and a cap of fulminate of mercury, this being the detonator employed, the arrangement being completed by means of a copper bale. The charge completed, the tube is lowered slowly into the borehole until it comes to rest finally in a vertical position in the sand-bed below. The slack in the paying-out cord releases the latter from the hook of the charge, and the rope is wound in rapidly.

The crucial moment for firing has arrived. The shooter takes a final look round. All boiler fires and other naked lights in the immediate vicinity of the well are extinguished; the workmen also are hurried to a safe distance. Satisfied that all precautions have been taken, the shooter, now in solitary possession of the well, fires the charge. The method of so doing may appear to be somewhat primitive, but, as a superior arrangement has not been evolved, it still is practised, and there is no gainsaying its efficiency. He uses what is known as a "go-devil." This is a compact and heavy cylindrical piece of solid cast-iron, fitted with wings to serve as a guide. He drops this into the borehole. The wings cause the "go-devil" to rotate during its downward flight, and at the same time causes it to follow a direct course, so that it strikes the detonator fairly and squarely, as well as with terrific force. Seeing that the tube of explosive is standing vertically in the oil-sands and immediately beneath the extremity of the borehole, it is obvious that the "go-devil" must strike the detonator.

The shooter stands by the borehole to ascertain the effects of his shot. In a second or two he knows that the "go-devil" has completed its work satisfactorily; he hears and feels the explosion; the tubular casing of the well confirms this intimation by vibrating violently. Immediately these evidences are detected, the shooter scampers to a safe distance to await events.

Seconds roll by, and the uninitiated spectators, who invariably gather to witness the spectacle, are cherishing the sanguine opinion that the shot has missed. Seeing that the borehole may be 1,000 feet in depth, and that the air within forms a cushion, which has to be expelled, the delay is not surprising. Presently there is a roar, gathering rapidly in intensity, accompanied by an indescribable clatter. The roar is the report of the explosion rolling up the restricted space of the tube; the clatter is the bombardment of the interior of the derrick with pieces of rock—some as large as the fist—and other débris, hurled violently from the well-hole amid a cloud of dust, gas, and oil. Often the derrick is blotted from sight by the outrushing wave. After the first gust, as a rule, the fountain of oil dies down to a mere bubble from the borehole, or issues in a lazy kind of over-running flow. But the shooter is satisfied; the shot has told that the well has been brought into productivity.

Occasionally the first shot fails to accomplish the desired end, in which event one or more explosions are necessary to induce the flow. Then the procedure has to be varied, for the simple reason that a large cavity has been produced at the bottom of the borehole by the preceding charge of nitro-glycerine; consequently successive tubes of the explosive will not stand upright, but will incline to the angle of the banks of the cavity. In this instance several tin tubes are requisitioned, each of which receives a charge of nitro-glycerine. These tubes are somewhat shorter than those employed in the first instance, being from 3 to 4 feet in length. They are fitted with conical bases, and the explosive is poured into the top of each vessel, which is then sealed with a cork. The tubes are connected in pairs, and in this manner are lowered into the well. At the bottom of the borehole the pairs of tubes assume varying positions and inclinations. This circumstance militates against the employment of a "go-devil" for firing purposes, so another device is employed; this is called a "squib," which in reality is a fuse. The squib is lighted, and then dropped into the well. Owing to its construction, it is certain to fall among the buried charges, and to fire at least one of them; the explosion of the one insures the successful detonation of the other charges, and thus the well is shot.

Often a well will yield steadily for several months, and then the flow will diminish or stop entirely for no apparent reason. These indications, however, point to the collection of sand around the bottom of the borehole, thus impeding the passage of the oil. To clear the obstruction, shooting is necessary, but in this instance a charge of some 40 quarts of nitro-glycerine is necessary, and it generally suffices to revive the activity of the well.

One might think that the detonation of such a charge as 20 or 40 quarts of such a powerful explosive as nitro-glycerine would inflict widespread damage upon the tubular casing of the well, but this is not the case. The explosive exerts its destructive force in downward and horizontal directions, leaving the casing unscathed, while the escaping gases drive the displaced débris and oil to the surface with terrific force. Occasionally the lower end of the casing will suffer disruption, but such damage is generally attributable to improper laying and firing of the charge rather than to any defects in the system.

Although the explosive is handled with apparent complacency by the shooter, as a matter of fact this useful servant is regarded with deep respect. A tin is never used twice for loading with nitro-glycerine, nor, indeed, for any other purpose; the risk is too great. No matter how carefully and apparently completely a tin may be emptied, tiny beads or a thin film of the liquid are certain to adhere to the interior surfaces of the cans; consequently, when the contents of the latter are removed, the empty tins are removed to a safe distance and piled in a heap. When the shooter has completed his task in connection with the well, he disposes of the empty cans summarily. He attaches a fuse to, and fires, the heap. Although the quantity of explosive lingering in each tin is insignificant, the terrific devastating forces of nitro-glycerine are brought home very vividly; the empty tins are blown to atoms, while a fairly respectable hole is torn in the ground where the pile stood.

As may be supposed, the shooter is highly skilled and expert in his peculiar craft; but the demand upon his services is somewhat uncertain and erratic. At times is he overwhelmed with orders; at others he is idle for weeks. Taking into consideration the risks incidental to his work, he is not overpaid. His remuneration averages about 4s. ($1) per quart of explosive used, so that a well which responds to the first persuasive effort he applies brings him in only about £4 ($20), while the revival of a well may return about twice that sum. If Fortune is kind, and he is required for several wells in close proximity to one another in a certain district, he may shoot several wells in one day, but such harvests are few and far between. As a rule he is on the road from early morn till the late hours of the evening, driving, riding, or walking among the wells in the oil country.

There are various methods of drawing oil from a well once it has been brought into productivity. When gushers predominate, as in Mexico, no pumping or other plant is required; the forces of Nature are quite sufficient to discharge the petroleum from the reservoirs below. But in the majority of instances resort has to be made to pumping. In the Caucasian territory the process known as "bailing" is followed. The bailer comprises a long cylindrical vessel measuring perhaps 30 feet in length; this is lowered into the well in the manner of a bucket, is filled with oil, is hauled to the surface, and is emptied. This method, even where conditions insure cheap labour, is more expensive than pumping, and for this reason is not practised extensively.

Compressed air has been pressed into service to draw oil from wells both in Russia and the United States. It has fallen out of favour among the foremost engineers, owing to the tendency, under certain conditions, of compressing or driving back the oil. The process is simple. An air-pipe is lowered into the borehole to such a depth as to insure ample submergence in the oil. Unless submergence is attained, the system is impracticable. Air is compressed by the ordinary type of air-compressor, and the pressure of air which is carried down the pipe, and finally released at its lower extremity among the oil, raises a certain proportion of air and oil to the surface. The flow of oil appears to be almost continuous.

Another ingenious method of raising oil is that devised by Herr Leinweber of Vienna, which has been used successfully upon the Galician oil-fields. This comprises an endless band of sufficient length to pass from a suitable machine placed at the mouth of the well to the bottom of the borehole, where it forms a loop, which is continually trailing through the oil. This band is covered with an absorbent material similar to the pile of a carpet. When the machine is set in motion, the band, continually passing through the oil in the cavity at the bottom of the well, becomes saturated with petroleum, which in due course is brought to the surface, where it is passed between rollers which squeeze out the oil. The yield of oil at the top of the borehole, of course, is continuous. In the tests which were carried out upon the Boryslaw and Maryampolski oil-fields, the results were

By courtesy of the Oil Well Supply Company.

THE "SHOOTER" POURING A CHARGE OF NITRO-GLYCERINE.

In order to bring a well into free activity the aid of explosives is often indispensable.

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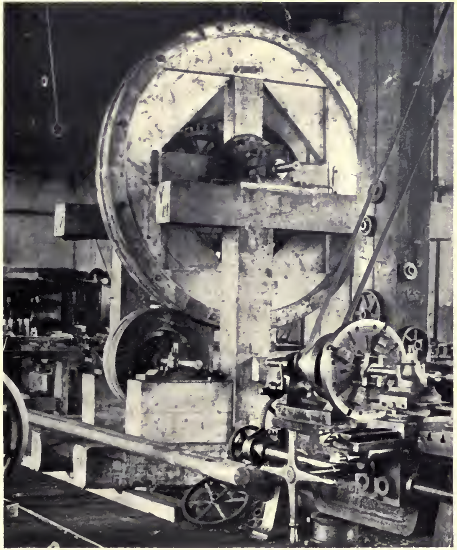

THE PLANT IN THE ERECTING SHOP.

Showing pressing-wheels, between which the endless band passes.

THE SYSTEM IN USE.

The endless band soaked with oil issuing from borehole.

THE LEINWEBER SYSTEM OF DRAWING OIL FROM THE WELL.

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found to be satisfactory, and compared favourably with the yield and cost of winning oil by the more conventional methods. Endless bands of this type were made, and lowered into wells 2,000 and more feet in depth. The system is not only simple, but the items of maintenance and repair are somewhat low. When signs of wear become manifest at certain points in the band, it is only necessary to cut out the worn portions and to introduce new lengths, attaching them to the existing fabric by ordinary carpet thread.

In some places the oil exists in several superimposed layers—that is to say, one stratum, lying at, say, 1,000 feet, is isolated from another at 1,200 feet by an intervening layer of rock or some other hard and dense impervious material; consequently, when the upper bed is exhausted, the well is driven deeper to enter the second deposit. In some instances three or four successive layers have been tapped consecutively in this manner, although, generally speaking, the yield diminishes as greater depths are attained, and, of course, the process cannot be continued indefinitely. In the Caucasus and Burmah the wells now have to be sunk to a much greater depth than in the early days of their existence, and a similar state of affairs prevails in other countries. It is becoming more and more costly to win the oil. The pioneers tapped the uppermost layer of oil-sands, and after this was exhausted abandoned the well, instead of driving the borehole deeper. Perhaps their action is to be excused, owing to the element of luck which enters into the question. Lower beds of oil-sands may exist; on the other hand, they may not. Satisfactory proof upon this point is forthcoming only by essaying the work; but the chances of failure are so overwhelmingly greater than the possibilities of success, that only those organizations possessed of ample financial resources can undertake the risk.

Well-drilling is essentially a gamble more or less. The well may be sunk upon the extreme edge of a field, and the consequent petroleum yield being sluggish, limited, and disappointing, an indifferent opinion concerning the productivity of the district may be entertained and expressed; yet other interests may drive their drills some distance away and make a rich strike. This is because the latter tap the oil-sands where they are richest, whereas in the former attempt the outermost and thinnest edge was struck. In many instances the first borings have missed the field entirely, sometimes by the proverbial inches; and the statement has been vouched that the country contains no oil, although, as a matter of fact, if the well had been put down 20 feet to one side of the spot actually drilled, the petroleum would have been struck in abundance.

In California, particularly, drilling is associated with considerable luck, because the deposits, while of comparatively limited area, often are of exceptional depth—they have been turned up edgewise by volcanic action. Many a well has been sunk in that country fruitlessly; it has just missed the paying sands. On the other hand, some of the largest gushers known to history have been brought to life in that State. The American is fully aware of this vagary of Nature, and consequently, if failure is courted in one spot, the whole district is not necessarily condemned, but other bores are put down in the vicinity. In one new American field, after oil was struck, wells were sunk right and left, but no less than 70 per cent. were abandoned; they failed to discover the oil-sands. Ultimately it was found that the so-called "oil country" was really a small bed which had become isolated from the main field by a wide ridge of rock, which had been forced upwards by seismic action, and which had split the field in twain. The main deposits were not struck until some months later, and then about twenty miles away from the spot where the first wells had been sunk.

Another factor contributes to the gambling character of drilling for oil, and incidentally tends to enhance the cost of this commodity. A well may be sunk and oil tapped, but the flow of petroleum may be so small, and the life of the well so brief, that sufficient oil is never brought to the surface to defray the cost of boring. Some wells will flow steadily for a few weeks and then dry up; shooting will fail to revive them, while deeper drilling is equally disappointing. The well is abandoned. Another well may not have a heavy flow, but it maintains its yield, with very little diminution, for months, and even for years. Unfortunately, the proportion of the former so overwhelms the latter that in the long-run the cost of winning the substance is inflated to an unreasonable figure. It is not surprising, therefore, when a large and rich oil territory is proved, and sustains the optimistic prophecies of its pioneers, that the ground immediately surrounding the fortunate initial borehole is honeycombed, and the derricks rise in such numbers as to convey the impression of a forest. Every ounce of oil that the field can yield at that point is certain to be extracted; the sands will be wrung to the last drop. Such a rich strike offers some compensation for the numerous failures which the petroleum-well sinkers encounter in the course of their operations. "Nothing is so uncertain as life," runs the time-worn adage, but among the drillers the modern proverb is that there is "Nothing so uncertain as oil!"

CHAPTER VI

SOME FAMOUS BIG STRIKES

MORE often than not the discovery of a new oil-producing territory is announced to the world at large by what is colloquially described as a "gusher." Although this phenomenon is by no means confined to new fields, such occurrences upon existing developed areas are neither so spectacular, impressive, nor of such volume, as those encountered upon virgin ground. The pioneer interests concerned in the exploitation of a new territory as a rule welcome the gusher, especially if it assumes huge proportions. It acts as an excellent advertisement, public attention is focussed upon the new district, and it proves the ground in no uncertain manner. In some instances, particularly in the American States, a big "gusher" has been allowed to have full and unrestricted play for several days, merely as a spectacle. Crowds of curiosity-provoked people will make long and tedious journeys just to see oil spouting from the earth in a huge fountain. Needless to say, such occurrences make impressive sights, but they are generally to be deplored. Enormous quantities of oil, representing huge sums, run to waste, to be lost irretrievably.

The "gusher" is a natural wonder. The oil is confined in the sands under tremendous pressure by the gas which it has emitted, and which has been unable to find a vent through which to escape to the outer air. The pressure of the earth above is too great to be overcome by the collection of gas, so that the oil-bed is practically a huge combined oil-tank and gasometer. The driller arrives upon the scene, and his drill, chugging merrily, bores a hole into the earth's crust. As it sinks deeper and deeper, the earth pressure upon the gas at this point steadily diminishes, until finally it becomes less than the upward thrust of the imprisoned gas below. Directly the balance of power is changed, the gas asserts itself and bursts its bonds. The remaining core of earth below the drill is shattered and pulverized, and the gas rushes forth with tremendous velocity and power, sweeping all before it. The gas, being combined with the oil, naturally drags the latter along with it. The oil gushes from the earth into the air; hence the name "gusher" or "spouter."

The pioneer driller bores his hole with caution. He knows fully well the chances are a thousand to one if oil exists below in any quantity, that it will come out with a mad rush long before his drill has completed its work; consequently he listens anxiously for the first peculiar signs of the coming oil. The moment he hears the characteristic music of the restless gas, he hurriedly abandons his position and races to a safe distance. If the strike proves a big one, he will witness a striking spectacle; the oil will shatter his derrick and drilling plant, reducing it to matchwood, sending the pieces sky-high, just as if a huge mine of dynamite placed beneath the plant had been fired. When the gas is in a terrific hurry, nothing will arrest its progress, and in its mad haste to escape it often will undo the driller's work entirely, by smashing up and expelling his sunken tools and pipe-casing in fantastic fragments.

During recent years several wonderful gushers have been struck. The opening of a new field in the Caucasian oil district generally has been attended by tremendous gushers. One of the most remarkable of these was upon the Bibi-Eibat field, in 1901. The well, 14 inches in diameter, was sunk to a depth of 1,813 feet, when the oil asserted itself in no uncertain manner. It came up the vent with terrific fury, and flew into the air in a straight column for 50 or 60 feet, when it opened out like the branches of a tree and fell in the form of spray. This was the biggest gusher which had been encountered up to this time, the volume of oil discharged into the air and lost being sufficient to represent many millionaires. As much of the oil as could be collected was gathered, and the depressions around the well in a short time were huge lakes of crude oil. Over 100,000 barrels of oil were taken from this spouter in the course of twenty-four hours. Oil actually rained upon the surrounding town and country, those who failed to secure shelter in time being drenched to the skin with pungent thick petroleum. The well continued gushing until 2,000,000 barrels of oil had been ejected in this summary manner, when it stopped suddenly. This was not the first spouter which had worried the oil interests of the Bibi-Eibat field, because some years previously a big spouter wrought widespread damage. On this occasion, owing to the wind which prevailed, a deluge of oil-drops fell upon the town of Baku, some two and a half miles distant, while the country lying between the two points was saturated with oil. In the Romani district another big well was struck in December, 1901. Its control harassed the engineers severely, since it spouted over 30,000 barrels a day. Some 1,000,000 barrels of oil were thrown out during the month, while it continued to yield 25,000 barrels a day steadily through the following January.

In the latter part of 1898, Captain A. F. Lucas, a geologist of Washington, D.C., who had long entertained opinions that oil existed in Texas, started off to make a thorough prospect of the "Lone Star State." After roving the territory which he considered to be oil-bearing for some two years, he finally decided to make a trial boring at Beaumont. The derrick was set up, and the drills commenced to drive downwards into the earth. On January 10, 1901, the drillers noticed a commotion in the well. Recognizing the import of the agitation and noise, they stampeded to safety. They had barely gained a safe distance, when there was a terrific hubbub. Looking towards the well, they were surprised to see 600 feet length of 4-inch iron pipe, which they had sunk into the ground, shot 200 feet into the air, as if from a gigantic cannon. The piping was followed by an ear-splitting hissing of the escaping gas, and a huge fountain of oil.

After establishing its outlet, the spouter settled down to

By courtesy of the Oil Well Supply Company

HOW OIL IS DRAWN FROM THE EARTH IN THE CAUCASUS.

The "baler" is a cylindrical vessel some 30 feet long, which is lowered into the well, and after being filled is drawn to the surface to be emptied.

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By courtesy of the Oil Well Supply Company.

"GASSING."

During the drilling operations large quantities of sand are often discharged into the air by the pressure of the escaping oil-gas.

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a steady, abundant flow, the oil flying skywards to a height of 150 feet in a solid column 6 inches in diameter, and then spraying. Estimates concerning the amount of oil poured forth varied from 20,000 to 50,000 barrels per twenty-four hours, and although there was no means of gauging the flow, probably the lesser figure was the more correct, though the former quantity undoubtedly was expelled during the first few hours of the spouter's activity. The enthusiasm aroused by this gusher was intense. It was given absolute freedom for six days, merely to entertain the crowds which flocked to the spot, and to indicate to the oil interests, whose representatives were soon upon the scene, that another gigantic oil district had been revealed. It was the biggest gusher that had been struck in the United States up to that time, and those responsible for the exploit did not mean to allow the fact to go unheeded. The oil tumbled to the earth in the form of a thick spray, and filled all the crevices, ditches, and depressions, in the vicinity, so that the country in the immediate proximity of the spouter was converted into an oil-marsh.

After the first feelings of frenzied excitement had died down, strenuous efforts were made to reduce the extent of the oil losses. Reservoirs were dug hurriedly, and open ditches were run from the well to these catchpools. Despite these precautions, however, the lakes and ponds overflowed, and more oil than ever was collected was lost for ever. One reservoir, the "Higgins," was a huge overflowing lake of oil covering several acres, and 20 feet deep at places; in fact, the overflow took to the natural watercourses, and finally escaped into the Gulf of Mexico. Six days after the strike the spouter was brought under control, but by that time it is estimated that over 1,000,000 barrels of oil had been lost.

This dramatic strike firmly established Texas as one of the great oil-producing States of the country. Subsequent geological prospecting ventured the opinion that the field was about 250 miles in length by 150 miles in width. Pioneering in other corners of the State was prosecuted energetically, and in a short while several other districts sprang into significance—Sour Lake, Saratoga, Prairie, and Humble.

California ranks as the largest producer of oil in the United States, and the industry in this territory received a further decisive fillip on March 15, 1910, when the Lake View gusher came into existence. Previous to this "strike" six other spouters in the Coalinga and Midway Maricopa field had come to life, and were yielding steadily. The Lake View gusher, however, was easily a record for the State, and the interest it aroused was remarkable. Its yield and financial value easily exceeded the historic Lucas Well of Texas, because in this instance only an insignificant percentage of the flow was lost.

This strike was entirely due to the confidence, persistency, and excusable defiance of a single man. The drills had been chugging away at this spot for some time, and the strike was anxiously awaited; but, though the drills bit deeper and deeper into the earth, no sign of oil was revealed. The directors of the company carrying out the operations haunted the well, anxiously awaiting the success that seemed loath to come. On March 12 the directors gathered at the board meeting and discussed the outlook lugubriously. After a prolonged and animated discussion upon the situation, they decided to stop drilling, and to prosecute their energies elsewhere. Accordingly, an order to abandon drilling at once was drawn up and despatched to the superintendent. The engineer received and appreciated the instructions, but, although faced with the penalty of instant dismissal for disobedience, he threw the order on one side and intentionally forgot it. He proceeded to the well and urged the men to greater effort. His call was answered; the men let themselves go, and within a short time drove the drills 47 feet deeper.

As the man who had flagrantly disobeyed official instructions expected, there came an ominous rumble in the well. The men scattered in all directions; the oil was coming. There was a terrible roar, violent hissing, and then the men saw the top of the derrick wrenched free and hurled into the air by a column of oil. As the well had been driven to a depth of 2,300 feet, the pressure of the gas was tremendous. The drillers were treated to a magnificent manifestation of Nature's pent-up forces. Pieces of rock were driven upwards through the pipe and hurled high into the air. The excited drillers took the precaution to get a respectable distance away from the gusher in order to escape these flying missiles, because the eruption was terrifying.

The population for a mile around was alarmed by the terrible roar. They hurried out of their homes and buildings, convinced that they were going to be overwhelmed by disaster, and their apprehensions were not readily quelled. The din was deafening. When in full blast, the column of oil rose to a height of 140 feet, and the spray, caught by the wind, was whirled two and a half miles away. The sage-brush for miles around was logged with oil, while the ground was saturated to a depth of several inches. The petroleum wrought havoc with ground life. Boys who hastened to the well to witness the unusual sight picked up dead rabbits—killed by the oil—by the score. Taxicabs and public service motor-cars in the adjacent towns plied a thriving business, carrying crowds of sightseers to the spot.

The greater part of the oil, forced into the air at the rate of 50,000 barrels per day, fell around the derrick, which in a short time was standing isolated in a lake of oil. Immediately the disintegrated pieces of rock ceased to be discharged, the drilling forces hurriedly strove to control the well, but the flow was so vicious that all attempts failed. Then labourers were crowded on to form additional pits and ponds to collect the flow. Three powerful pumps were brought up, and installed to lift the oil from the sump-hole, which was overflowing, into the huge tanks which had recently been completed near-by. This was the first oil to enter these receptacles, and it was fortunate that these facilities were available, otherwise heavy losses would have been incurred. The pumps had a combined capacity of 25,000 barrels a day, and by running them at full pressure they were able to keep the flow under control. As the tanks became charged, other pumps were set to work driving the oil on a journey of 150 miles from Maricopa to Port Harford, on the Pacific seaboard.

It was only by titanic labour that the oil losses were reduced to an insignificant degree. When the gusher first broke into activity, the flow was estimated to be over 60,000 barrels per day. The initial pressure becoming expended, the well settled down to a steady flow of about 42,000 to 45,000 barrels per day for six days. Then it ceased suddenly. It had "sanded up"—that is, the well-hole had become choked with sand and detritus. The engineers, realizing the import of this development, concluded that by pushing their arrangements forward at high speed they would be able to control the well. But they had miscalculated the enormous forces sleeping below. In a few days the pressure of the accumulation of gases became sufficiently powerful to remove the obstruction. With a deafening report the sand was blown out, and the well resumed spouting 42,000 barrels per day.

Owing to the precautions adopted and the reduction of the oil losses, the owners of the well netted over £60,000, or $300,000, during the first sixteen days after the gusher came into action, whilst during the first seven weeks over 2,000,000 barrels of petroleum were gathered. The quantity lost, owing to the arrangements completed in advance, was insignificant. The gusher did not maintain its yield continuously, but was somewhat intermittent in its action. After spouting to a height of 240 feet for some time, it would gradually subside until the oil rose only to a height of 170 feet. It would maintain this altitude for a considerable period, when without warning it would revive, and regain a height of 240 feet.

Owing to the tremendous force with which the oil is expelled from the earth, a gusher offers some pretty problems when its control is contemplated. The varying character of the oil, its velocity, and the local conditions, render it impossible to lay down any uniform methods for arresting

By courtesy of the Oil Well Supply Company.

THE "LUCAS" GUSHER IN FULL BLAST.

This strike of oil at Beaumont opened the Texas oil-fields. The oil flew 150 feet into the air at the rate of 20,000 to 50,000 barrels a day.

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THE FAMOUS POTRERO DE LLANO NO. 4 BLOWING THROUGH THE GATE VALVE.

This Mexican gusher was struck at 1,911 feet, and spouted 125,000 barrels a day. This photograph gives a striking impression of the diameter of the column of oil after the well was brought under control.

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the flow. Success depends essentially upon individual ingenuity and resource. Fortunately, there is no lack of either of these attributes among those engaged in winning petroleum from the earth. The unexpected lurks in so many and unfamiliar forms that the oil engineer never worries. He is always on the alert, ready for any emergency.

In the early days, when a spouter got out of hand, primitive methods were adopted, and, as may be imagined, proved abortive. The well-drillers, from lack of experience and knowledge, failed to realize the immense forces of Nature. They endeavoured to smother the fountain with sand and water. When this failed, a massive square shield was contrived from heavy balks of timber secured together by bolts and dogs. This was manœuvred into a convenient position near the well, raised on one edge, and then tipped or pulled over upon the fountain in the manner of a lid shutting a box. The surprise of the toilers, when they saw their cumbersome weighty device shot into the air like a blown egg upon a water-jet or wrenched to matchwood, may be imagined. But it brought home to them the enormous power that is present in a 4 or 6 inch solid column of oil when shot from the bowels of the earth.

In one instance a cap fashioned from cast-iron, and weighing some 10 tons, was given a cupola or bell shape. The light, flimsy derrick in this instance had been blown clean away from the borehole, leaving the column of oil quite free and accessible. The oil was spouting to a height of about 90 feet, and the heavy cap appeared to be quite adequate to smother it. The bell was manipulated to the edge of the well-hole, and laid upon its side. Wire cables, attached to shackles fitted to the bell, were passed to the opposite side of the well, and passed round windlasses. When all was ready, "Heave ho!" was sounded, and the ropes were hauled in gradually, pulling the bell over. Presently, after being sufficiently tilted, it tumbled over the well-hole, exactly as planned, but ere the workers had time to congratulate themselves it had been pushed bodily over in another direction, and the gusher was still free. Time after time the effort was repeated, until at last the bell was thrown bodily to one side in a contemptuous manner by the escaping oil. When examined, the massive cap presented a sorry sight. It had been cut and riven in a fantastic manner, while the solid crown was pitted and worn to half its original thickness. The gusher eventually was mastered, but not before it had expended the greater part of its energy.

In the Caspian fields the shield is the method extensively adopted to check the flow of a gusher. The shield is an elaborate piece of work built up of timbers and steel, and acts similarly to a lid, the oil being deflected as the shield is declined. Extreme skill and caution is demanded in the manipulation of the device, because, the oil being somewhat heavily impregnated with sand, the spouter acts very much in the same way as a sand-blast. Consequently, when the stream of oil comes into contact with the shield, violent erosion occurs. It is no uncommon circumstance for the shield to be worn to the thickness of a sheet of paper within a short time, and often it will be perforated like a sieve under the driving action of the sand. These measures, however, do not stifle the spouter so much as offering means to reduce the height of the fountain, so that the oil may be more easily collected.

The control of the Lakeview Gusher in California set a pretty tax upon ingenuity. The volition of the oil was revealed by the demolition of the derrick, and the fact that the heavy drilling tools were driven out by the mad rush of the petroleum into the air. As the flow was being caught effectively, no effort to cap the well was made for several weeks, the engineers hoping that it might expend the greater part of its force if given sufficient time. Finally, as there appeared to be no signs of the spouter dying down to enable simple means of controlling the flow to be adopted, a massive roof made of 16 by 16 inch timbers was built, and dropped lid-wise over the mouth of the borehole. Its demolition was instantaneous. The spouting oil wrenched the heavy members apart, completing destruction by tearing them to splinters and scattering them in all directions.

This abortive effort demonstrated that more ingenious means were requisite to achieve success. Capping was imperative, because tiny fountains had broken through the shattered earth's crust around the well, and were playing merrily. These subsidiary diminutive gushers were effectively smothered by the aid of successive bulwarks of brush, logs, and sand. A massive stockade 15 feet in height was built around the mouth of the well. Piles were driven, and thick balks bolted transversely thereon, forming a box-like compartment. The vertical piles were braced by supporting members set at an angle of about 30 degrees on the outer side of the wall, and secured to the upper ends of the former by notched saddles and bolts. The lower ends of the slanting pieces were anchored to similar thick members set at right angles to the latter, and driven deeply into the ground. The space between the vertical and slanting timbers was filled with rock and débris rammed well home, so that a solidly built, substantial embankment surrounded the mouth of the well.

On one side of the embankment a slanting runway was provided, and on this a massive raft was built, resting upon the runway in much the same manner as a vessel lies on the launching ways. This raft, measuring about 15 feet wide by 20 feet in length, was built of timber members, disposed in four layers set transversely to one another, and bolted solidly together. Heavy wire cables were then secured to each corner of the raft. Those at the two lower corners were anchored to iron pipes buried 10 feet in the ground. The two cables secured to the upper corners were passed over the top of the stockade, one on either side of the gusher. During one of the periodical lulls in the activity of the spouter, these upper cables were hauled taut, the raft was pulled down the runway, and dragged into position over the mouth of the stockade, though not completely occupying the space. The two cables which had served to haul the roof into position were then anchored similarly to buried pipes. In this manner the raft was virtually poised in mid-air, supported about 15 feet above the borehole by the force of the oil playing upon its underside, and prevented from moving sideways by the anchoring cables. The gushing oil, striking the raft, was deflected sidewise, escaped through the space between the edges of the raft and the wall of the stockade, and poured down the sloping banks of the latter into the sluices which were provided to carry it away to the sump.

Although this ingenious device did not completely smother the gusher, it effectively reduced its height from 240 to 15 feet. The raft stood up to its work, and the scheme proved financially successful, since the loss of oil which had previously occurred in the form of driving spray was overcome, thereby enabling the owners to derive more profit from the well than had been the case before the gusher was conquered.

Although the United States and the Caucasus have become far-famed for some big "gushers" which have been struck, the most sensational occurrences of this character are peculiar to Mexico. The interests controlled by Lord Cowdray revealed the wonderful oil reserves of the Central American Republic by striking the famous "Dos Bocas." Well, the story of which, as it was lost entirely by fire, is related in another chapter. In January, 1910, another gusher, known as the Potrero de Llano No. 4 awoke. Undoubtedly this is the greatest gusher which has yet been struck and brought under control, though owing to the immensity of the flow—it was practically an oil volcano or geyser—its conquest was attended with considerable anxiety and difficulty.

The proved gusher territory of Mexico lies between Tampico and Tuxpan, and the Potrero field lies in this area. The proving of this district was commenced in 1909, and encouraging indications of its wealth were contributed in January, 1910, when the first well was brought into bearing after the drills had been carried to a depth of 1,933 feet. As this well never got out of hand, it was shut down, for the simple reason that there were neither tankage facilities nor pipe-line connections to receive the product. Further drilling, however, was pushed forward actively, the engineers having no idea that they were destined to make a strike which would eclipse the never-to-be-forgotten "Dos Bocas."

The oil-sands in connection with No. 4 well were penetrated at a depth of 1,911 feet. Directly they were tapped, the fact that a heavy yield had been unlocked was revealed. The oil flew out in a tremendous column, and, although every effort was made to shut it down, it resisted control. It increased in intensity, and in a short time 125,000 barrels of oil were being belched into the air. The well ran wild for weeks, as it resisted every attempt to control it. The crude oil ran hither and thither over the surrounding country, forming pools and flooding extensive areas. Dos Bocas and the terrors of fire had not been forgotten. The serious possibility of the spouter becoming ignited was fully appreciated, and unceasing vigilance and elaborate measures were adopted to prevent such a contingency. The gravest dangers arose from incendiarism. In the district were numbers of dissatisfied Indians, and it was feared that some of their more irresponsible and militant members might deliberately fire the well. The Mexican rurales were despatched to the scene, and patrolled the country day and night. Despite this organization, several of the pools were fired surreptitiously, but, owing to the elaborate precautions and forces available, they were extinguished in the incipient stages.

As the possibility of shutting down the flow was entirely out of the question until the proper facilities arrived, the collection of the oil was taken in hand. The enormous yield demanded heroic measures. A huge force of 2,500 Indians and Mexicans—a motley crew—was recruited, and regulars were supplied by the Government to keep them under control. The engineers planned the hurried erection of an enormous temporary reservoir, or earth-tank—virtually a levelled stretch of land enclosed by a substantial retaining wall. Some 45 acres were railed off for this purpose, and a force of 1,500 natives kept continuously at work, in day and night shifts, piling up the earthen walls.

While this task was under way, other gangs were employed in laying the lead lines from the well to the reservoir. Two 8-inch lines were laid, and were connected with the casing-head of the well. An overflow or waste line was laid from the reservoir to the adjacent waterway, so that the surplus oil from the tank might effect a free and safe escape. As the well continued to discharge well over 100,000 barrels of oil per day, it was realized that the reservoir would soon become filled. Accordingly, arrangements for capping the well were pushed forward feverishly, so that it might be brought under control at the earliest possible moment.

The capacity of the reservoir was approximately 2,500,000 barrels (105,000,000 gallons). When filled, the lake was about 30 feet deep in the centre. The oil expelled was found to be remarkably clean, being absolutely free from sand and water. In ninety days the well yielded no less than 8,000,000 barrels of oil, and the noise of the gusher when in full blast was so terrific that it could be heard easily from a distance of eight miles. While the Potrero de Llano No. 4 ranks as one of the most prolific spouters which ever has been tapped in any part of the world, the engineers made another remarkable strike on July 11, 1912, at 2,000 feet, in the new Tiera Amarilla field, one and a half miles distant. At this depth a well yielding 25,000 barrels per day was brought in, and the engineers express the confident opinion that, if drilling had been continued a few feet deeper, a gusher equal to, if not rivalling, the famous No. 4 at Potrero would have been brought into activity.

This gusher was brought under control by the installation of a massive gate-valve. When the proportions of the

MEXICAN OIL-WELL COMMENCING TO FLOW.

BUILDING THE EARTH RESERVOIR TO RECEIVE THE FLOW FROM POTRERO DE LLANO NO. 4.

2,500 Indians and Mexicans were required to complete this great work.

A LAKE CONTAINING 2,500,000 BARRELS—105,000,000 GALLONS—OF CRUDE OIL.

It was built to receive the enormous initial flow of the Mexican gusher, Potrero de Llano No. 4. When full the reservoir was 30 feet deep in the centre.

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spouter had been realized, a valve was designed, and an American firm was urged to hasten its construction, since it was imperative to set it in position with all speed, so as to reduce the loss of oil. The valve was designed to withstand a pressure of over 600 pounds, which was the force exerted at the mouth of the well. The gate-valve was set in position, and bolted to the top of the pipe-casing, the valve being left open during the task, so as not to impede the escape of the oil. From the valve pipes extended to the sump or pumping-station. By the time the gate-valve had been set, the pipe-lines had been extended into the Potrero field, and the valve-gate was gradually closed, until at last it held a pressure of 300 pounds. When the transportation facilities were completed, the well was shut down to about 40,000 barrels per day, which represented the maximum capacity of the pipe-lines available to transport the oil to the coast.

To manipulate a gusher, even of comparatively small value, when it has been capped, is not so simple as it appears. A British engineer in the Mexican oil-fields instructed a native to shut down a well. The man went off entertaining quaint and certainly hazy ideas of the pressure exerted by a spouter. Instead of turning off the gate-valve slowly, he thought it could be shut off summarily like the domestic water-tap. But he was made to repent of his haste. The oil refused to submit to such ill-treatment. The man hurriedly closed the valve, and to his intense astonishment performed an unexpected aerial flight, followed by a series of unrehearsed backward somersaults, while he was drenched to the skin by petroleum in the bargain. The oil had burst the valve! Ever after that individual entertained an intense respect for a gusher, even when it was harnessed, and considered that a gate-valve was a far more dangerous contrivance, and demanding more delicate handling, than one would suppose.

Although the spouter makes a peculiar appeal to the driller, and is a fascinating spectacle for the curious public, it is viewed with mixed feelings by the interests to whom it belongs. This is especially the case when all attempts to control the well prove abortive, and no conveniences for receiving and storing the oil are available. The enormous losses upon the Beaumont field in Texas were entirely due to lack of enterprise born of surprise. Weeks elapsed before metal for the erection of tanks arrived upon the scene, while a year passed before pipe-line communication with the refineries was established. The men upon the spot were compelled to make shift with what they could contrive. Open lakes were built, and, as these proved insufficient, open ditches were dug.

While the spouter removes the necessity to pump or otherwise raise the oil, the quantity produced is far from always being a blessing. Often the well-owner would prefer it to flow more quietly, since then he would be spared many losses of a varied character. The Bibi-Eibat field, being on Government territory, which is leased under a fixed royalty of 5 kopeks per pood—approximately 1¼d., or 2·5 cents, per 36·1 pounds—the forced necessity to dispose of the abundant yield of a gusher at a low price, owing to the absence of sufficient storage or transportation facilities, does not leave an appreciable margin of profit, more particularly when the claims for damages have been liquidated. In the case of the 1901 spouter, the item of compensation was serious, inasmuch as property for over a mile on the lee side of the spouter was flooded. A village was overwhelmed by the visitation, and this had to be repainted by the oil-field lessees. This was not the first occasion upon which this particular village received refurbishing at the expense of the oil-wells. When the previous spouter sprang into existence, the colony, owing to the prevailing wind, suffered from a drenching oil-storm. The bill for damages on this occasion amounted to about £10,000, or $50,000. Every house in the village, as well as the local church, had to be given a new coat of paint, and the well-owner had to settle the account.

In Roumania, too, anxious times are experienced when a gusher comes to life. Here the spouters are not comparable in violence or magnitude with those of the Caucasus or Mexico, but they can wreak destruction unless elaborate and hasty safety measures are adopted. The rugged configuration of the country is an adverse factor. The villages are invariably in the valleys, and a gusher breaking loose upon a neighbouring hill may easily cause a terrible state of affairs. Huge dikes are thrown up on the hillside, and the cascades of oil thus are dammed back until means of connecting the impounded oil with the storage tanks are completed. The pressure upon the embankments, however, is enormous, subjecting the hastily-fashioned work to tremendous strains. Unceasing vigilance is required until the pressure can be relieved.

The life of a gusher varies considerably. It depends upon the quantity of oil and gas present below, and the number of points at which the latter is able to escape through additional wells. Obviously, if a field has only one outlet, the maximum quantity of oil will be expelled through that vent until the pressure below has been expended. On the other hand, each succeeding well tapping the same deposit serves to reduce the pressure upon the initial borehole. In Texas, owing to the frenzied haste with which other wells were sunk by the speculative drillers in close proximity to the first spouter, the pressure was relieved very speedily.

If the field is not tapped further, and the first gusher is left to itself, it may continue to yield for years, the force of the discharge gradually diminishing as the reserves of oil are depleted. At the same time, the expelling force is maintained more or less because the displaced oil is supplanted by salt water, which tends to maintain the pressure to a certain degree. The "Lucas" spouter came to an untimely end. Fire swept the field, ignited this well, and burnt it out, so that at the end it gushed only salt water. "Dos Bocas" shared a similar fate. Many of the small gushers die a natural death, or in time are abandoned because the daily yield is so small as to induce the owner to devote his energies elsewhere, although someone else fired with the money-from-oil fever may probably take it over, and hold it until the last remunerative gallon of petroleum has been given up. In the Caucasus the majority expend their force and become controlled in due course. Then " bailing " has to be undertaken to draw the quiescent oil from below.

CHAPTER VII

TAKING CARE OF THE "CRUDE"

"FIRST strike your oil, and then collect it!" This is the precept of the oil-producer, and although the initiated might feel disposed to cavil at the idea of drilling for oil without making even rough-and-ready arrangements for collecting the resultant product, the attitude of the gambling driller is perfectly explicable. He knows only too well that his calling is of the will-o'-the-wisp order; consequently, he regards the idea of making provision for the collection of the "crude," as the raw petroleum is called in the parlance of the oil world, before he has found it as somewhat fantastic. Although gushers are struck, it must be borne in mind that spouting wells are more the exception than the rule. For every gusher which is brought to life, hundreds of other wells are sunk from which oil cannot be withdrawn except by recourse to pumping.

Of course, the fallacy of the axiom is revealed at times, and in a somewhat disconcerting manner. The drill bites into the paying sands, and the oil bursts forth vigorously. The driller is caught unawares. Oil there is in plenty, but he cannot save and hold a drop, pending the arrangements of the refiner for its collection. If one be labouring with the drills in a proved territory, the anxieties of collection are small. The chances are a thousand to one that there are available tankage facilities in the immediate vicinity, and that the pipe-line system serves the field. But in a new country the problem assumes a very different guise. Once the oil is tapped, feverish haste must be manifested and ingenious measures extemporized to catch the precious liquid. Where the driller, producer, pipe-line, and refining interests are combined, the question is not so complex.

The trial borings reveal the existence of oil, so, while the first well is being drilled, arrangements for collecting the eventual flow with the minimum of waste are taken in hand. But when the drilling or producing interests are entirely distinct from the transportation and refining forces, quite a different situation prevails. The two issues work independently, and co-operation is resolved into the mere question that, if the producer strikes oil, the refiner will undertake to purchase it.

This is one point in which the Standard Oil Company emphasizes the efficiency of its organization. It spares no effort to secure all the oil possible. The more it can handle, the more powerful the position it can command among the world's markets. It is not a producer to any pronounced extent; it buys from the speculative element. The gambling driller knows fully well that he has only got to strike oil, and the above company will take care of it for him. He is not even forced to barter with the company concerning the price to be paid for his product. Contracts in this connection are foreign to its policy. The driller or producer is given a square deal; the open market is the solitary and automatic arbitrator. The price of crude oil fluctuates daily in all parts of the world in exactly the same manner as grain, coal, and other commodities.

The Standard Oil Company has reduced what is colloquially termed "taking care of the crude" to a fine art, and this is one explanation for the powerful sway it wields at present in the oil world. It makes no attempt to curtail output: that would be fatal to its welfare. At times it will do everything in its power to frustrate a mad rush to a new territory, because its unique experience has revealed the iniquities of such booms. Wells are sunk in frantic haste, oil is drawn from the earth in prolific rivers, and because there are no collecting facilities available it runs to waste or is sold at ruinous prices.

In one American rush a few years ago, where discretion among the drillers was thrown to the four winds, wells were sunk so rapidly and in such numbers that the country for miles around became saturated with oil. Its disposal was impossible at any price. One cent, or one halfpenny, per gallon was its market value, but that was purely a fictitious quotation, because there was no market. The railways were quite inadequate to handle the glut, tanks were lacking, and pipe-line communication was hundreds of miles away. Barely 1 per cent. of the petroleum drawn from the earth was sold. The producers assailed the Standard Oil Company for not displaying greater energy in supplying tankage and pipe-line facilities, but the refining company refused to crowd on further pressure.

In disgust the drillers turned to independent concerns, and sought similar assistance, but to their intense disappointment they received no warmer comfort. Neither one nor the other was prepared to rush in to save the frenzied oil-boomers. If they would wait until the facilities could be provided, then they could go ahead and drill with as much zeal as they felt disposed to display, because it would be possible to take care of every gallon of oil obtained. The producers declined to listen to words of wisdom, but went blindly forward, and some time elapsed before they came to their senses and appreciated the logical reasoning of the refiners. Then they ceased operations, and marked time until the tanks and pipe-lines were completed, when activity once more burst forth. The crisis, however, was past. The refiners could take care of every drop of oil extracted from Mother Earth, and had a respectable margin of safety also for unforeseen eventualities. In this particular boom more men were ruined, although they struck oil, than if their drills had missed the sands, merely because they were blind and deaf to sound commercial argument.

The tank represents the dividing-line between the producer and the refiner. It is the point where the latter assumes control of the product. Care must be taken by the producer to reduce the wastage of petroleum to the minimum. This is the one phase in which the American company excels, in which the organization and efficiency of its departments are most conspicuously revealed. It is not a producer in the strict sense of the term. Barely 15 per cent. of the total petroleum produced in the country issues from wells owned or leased by the Standard. It is essentially a purchaser, transporter, and refiner of crude oils. Incidentally, this is the most expensive issue of the problem. A well may cost only £250 ($1,250), but the collection, conveyance, and storage, of the yield from that well may involve an outlay of thousands. To maintain such a position demands enormous capital, highly trained officials, and well equipped departments.

The first move is the provision of tankage facilities for the storage of the oil as it issues from the well. These vary according to the yield of the field. If it is normal, the oil may be pumped into tanks of 400 barrels capacity; if heavy, the tanks may be of sufficient dimensions to receive 35,000 barrels or more. Standardization and organization are revealed very potently in this branch of the industry. The composition of the metal, the dimensions of the plates, and the methods of erection, are standardized rigidly. Consequently, the despatch of a consignment for a tank of any desired capacity may be completed within a few minutes of the receipt of telegraphic instructions. The methods of erection are simplified to a remarkable degree. In Great Britain elaborate scaffolding would be demanded to set the walls, and more time would be expended upon this preliminary than actual setting of the steel. In the United States the scaffolding is of the simplest character. It appears to be extremely flimsy and dangerous, but accidents to the men specializing in this work are rare. Scaffolding proceeds step by step with the growth of the tank walls. One does not impede the progress of the other, and when at last the tank is completed, the scaffolding can be demolished with amazing speed, and packed ready for removal to the next site. The resources and possibilities of the Standard Oil Company in this one direction were revealed very strikingly during the Kansas oil-boom. A tank of 35,000 barrels capacity was commenced every twenty-four hours, and each tank was completed in five days—that is to say, the storage units were brought into service at the rate of three every fortnight. In fact, the Kansas rush was so strenuous, and the demand for storage facilities so insistent, that directly the walls were completed pumps were set going driving the oil into the tank. Often before the roof was completed the tank had received its full charge of the crude.

This perfection of operation is not peculiar to any one concern. All the foremost companies are equally well equipped with such facilities, not only in the United States, but in other countries as well. In Mexico, for instance, although the labour problem there is somewhat more complex and harassing as compared with the United States, the interests controlled by Lord Cowdray have accomplished performances which vie in speed and smartness with the premier achievements of the Standard Oil Company. In California the Union Oil Company, and in the Dutch East Indies the Dutch interests, can point to equally noteworthy achievements in their respective spheres of influence.

The refining interests provide tank facilities at various strategical points. Here long rows of huge tanks are set up, forming what are known as "tank farms." Pipe-lines connect these farms with the small tanks receiving the oil from the wells. It is quite possible for one farm to hold 2,000,000 barrels or more of oil, and may represent the contributions, bought and paid for, from 200 to 300 producers, according to the yield of the adjacent fields and the daily flow of the individual oil-wells. In the Kansas field the Standard Oil Company has had as many as 21,000,000 barrels of oil in stock upon the farms, representing a value varying between $12,000,000 and $15,000,000 (from £2,400,000 to £3,000,000).

During the Californian oil-boom the enormous flow of petroleum overtaxed the facilities and equipments of even the foremost companies. The Kern River field, although covering a territory of barely five square miles, produced about 32,000,000 barrels from 876 wells during 1904. The yield doubled within a single twelvemonth. No fewer than 60,000 barrels were shipped from the fields daily; but the oil accumulated at such a rapid rate that a serious crisis appeared imminent.

The Standard Oil Company entered the market, and within a short time became the largest individual purchaser of the raw product. It laid down tanks having an aggregate capacity of 6,000,000 barrels, but these were soon charged to overflowing. The output of the wells gave no signs of diminishing. On the contrary, owing to the activity of the producers, there was the likelihood of its being increased considerably, despite the fact that the price of the crude sank as low as 20 and even 14 cents (10d. to 7d.) per barrel.

Although the Standard Oil Company concentrated its tank-erecting department upon the provision of further storage facilities, they could not keep pace with the supply. It was impossible to consummate this end with the standardized steel tubular tanks, even of the maximum capacity. Accordingly a new method was inaugurated. Instead of erecting circular steel structures above the level of the ground, it embarked upon sunken reservoirs, which were virtually immense holes in the earth. They are circular in form, and vary from 400 to 500 feet in diameter by 14 to 16 feet in depth. The inner face of the embankments and the floor of the first tanks of this type were given a coat of cement to obviate losses by seepage, but finally this precaution was abandoned, owing to delays and expense, in favour of ramming and tamping the earth thoroughly before the oil was admitted. A wooden roof of 1-inch boarding nailed upon the skeleton of joists is provided, and is carried upon heavy timber supports extending to the floor of the reservoir. The roof was finally covered with tarred paper to protect the contents from the elements. Not only were these tanks completed speedily, but were of far greater capacity than would have been possible with the orthodox steel plating, the largest tanks being able to receive 500,000 barrels of oil. In this manner the question of storing the enormous output of the wells was solved completely, and the necessity to shut down some of the wells, so as to bring

THE GATE VALVE WHEREWITH THE MEXICAN GUSHER POTRERO DE LLANO NO. 4 WAS BROUGHT UNDER CONTROL.

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By courtesy of the Oil Well Supply Company.

ERECTING A STORAGE TANK.

Showing type of scaffold employed in America. During the Kansas oil boom the Standard Company commenced one of these structures every twenty-four hours.

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the daily yield within the compass of existing tankage facilities was obviated. Moreover, the provision of these tanks enabled the market price of the oil to be increased to the normal and more remunerative figure.

When the San Joaquin Valley oil-fields came into activity, the overwhelming yield of oil caused a similar crisis to that which had been experienced at Kern River. It was idle to contemplate coping with the situation by means of the ordinary steel tanks, so the Union Oil Company evolved another ingenious idea. Designs were completed and contracts awarded for the construction of two reinforced concrete reservoirs, each capable of containing 1,000,000 barrels of oil. The speedy provision of these tanks was imperative in order to avoid financial disaster, so the builders were held up to a strict undertaking, which called for the completion of the work within four months from the date of the contract, with a penalty of £20, or $100, per day for every day exceeding the specified time.

This move represented the most important of its character ever attempted in the Californian oil-fields in connection with the storage of the crude, while the tanks rank among the largest oil-reservoirs ever constructed upon ferro-concrete lines. They were placed at San Luis Obispo, and were designed to receive the oil delivered through the pipe-line system which was undertaken at the same time. Each reservoir measures 601 feet in diameter by 20½ feet from floor to roof. Being a rush order, a small army was required to carry out the necessary excavation and the erection of the reinforced concrete walls. No fewer than 600 horses, 300 teamsters, and 300 additional men were required to remove 80,000 cubic yards of earth from the site. The spoil was dumped around the concrete wall, but a few feet distant from the latter, in the form of an outer rampart. This dyke was provided, not to strengthen the tank wall, but to act as a fire-break in the event of a conflagration eating its way towards the reservoirs. The tank wall itself measures 3 feet in thickness at the base by 6 inches at the top. Some 12,000 cubic yards of concrete and 250 tons of round steel were used for the walls, while the floor is covered with concrete 2½ inches thick reinforced with wire mesh. Some 2,500,000 feet of timber were utilized for the roofs of the two tanks.

The construction of these two tanks involved an outlay of £100,000, or $500,000. The main 8-inch pipe-line, wherewith the tanks are charged, is 200¼ miles in length, and carries the oil collected upon the fields, through which a tributary system of pipe-lines representing a further 200 miles extends, so that 400 miles of pipe-line were undertaken simultaneously with the construction of the reservoirs. This enterprise, which conveys some idea of the Herculean efforts and heavy financial outlay involved in connection with the provision of oil-storage facilities, comprised one item in the scheme projected by the independent producers of the San Joaquin Valley to increase their storage facilities by 15,000,000 barrels. A large pumping-station was also laid down to pump the oil from these reservoirs direct to the tank steamers at Port Harford, through an 8-inch pipe-line, capable of handling 25,000 barrels of oil during the twenty-four hours.

In many fields of the world the tank-farm in proximity to the wells is eliminated. This arrangement is possible when the company are producers as well as refiners. This is the case in Mexico, where the British company connect the gushers direct to the pipe-lines to lead the oil to the point of shipment. Tankage facilities are provided at the latter spot, as well as at the refineries. The gusher itself is shut down to the capacity of the pipe-line, or other desired output. This simplifies the problem to an appreciable degree, since, in the event of the district becoming exhausted of oil, losses are restricted to the capital expenditure upon the pipe-line, which eventually, if the well has a fairly long life and a good yield, is completely recouped. At the same time the tankage capacity upon the British operated Mexican oil-fields is considerable, being sufficient to contain 2,000,000 barrels of oil.

The refining forces constitute the backbone of the producer. Once he is in communication with them, he is relieved of further anxieties; his market is certain; he is assured of a fair price for his product. In fact, he works upon a basis identical with that prevailing in the grain industry. What the elevator is to the wheat-grower, the refinery is to the oil-producer.

When the producer has accumulated a tank of oil, he notifies the purchaser. The latter instantly answers the call by despatching an official equipped with a gauging-pole and "thief" to sample the crude and to measure the volume in the producer's tank. Accompanied by the producer, the gauger swarms the tank, and, removing the trap affording access to the interior of the latter, he lowers the "thief" to the bottom of the reservoir, so as to draw a sample of oil from the bottom. The "thief" is a small brass instrument, and the sample is drawn from the lowest depth of the tank, because, if the crude is associated with sediment and water, it will collect at this point. The gauger examines the contents of the thief, and, satisfied with the quality of the crude, inserts his pole to gauge the level of the oil within the tank. The figure is recorded on a blank form, which is handed to the producer, who, being present, satisfies himself that the work has been carried out correctly. The gauger then unlocks the valve connecting the tank with the collecting pipe-line, and the run of crude commences. From this moment the producer has no further interest in the contents of his tank: they are the property of the refining interests.

The oil is left running, the gauger calculating roughly how long it will have to flow before the tank is emptied. He returns in about an hour, once more lowers his gauge into the tank to observe how much oil is remaining, and gives a record of this reading to the producer. The connection with the pipe-line is shut off, and the valve locked.

A round of wells is handled in this manner every day, and upon his return to the office the gauger communicates with the refiner, giving the gauge readings before and after the runs. From this data the equivalent in barrels of crude is calculated, and a credit note or certificate for that amount is sent to the producer.

This certificate is as negotiable as a five-pound note or a dollar bill. The producer, if he has secured a lease of the farm for drilling purposes, or has concluded a royalty agreement with the land-owner, either arranges with the refiners to apportion the sum due—in the value of barrels of oil—to the latter in the form of a credit note, or the division is directly effected between the land-owner and producer. The Standard Oil Company favour the former plan, because it avoids friction between the two interests, and enables either to realize the certificate at any time independent of the other. But in any case a period of two months is extended for the realization of the certificate. All that the producer and owner have to do is to follow the market fluctuations and prices. Profiting by the conditions of the market, the certificate holders intimate to the refiners the desire to sell. The market price prevailing at the time of the post-mark is accepted by the refiners, and the certificate is redeemed thereat. Of course, if preferred, the certificate may be redeemed immediately it is received, or the recipient may take advantage of the market price any time within the succeeding sixty days. If at the end of two months the certificate has not been realized, the refining company remits the financial equivalent at the market price reigning on the first day of the third month after the oil was run.

The advantages of this procedure are obvious. The producer is given a thoroughly straightforward deal. He never can complain that he has been forced to sell at a ruinous figure. Even his gambling instincts are stimulated, because he is given the opportunity to speculate in the product for sixty days. He is absolved from all losses after the run of his crude has commenced. The risks from fire, tempest, and other causes are borne by the purchasers. There is only one deduction made—the freight-charges for transporting the oil from the well to the refinery or other centre through the pipe-line, but this tariff as a rule is nominal. In this way, even if one company holds a monopoly of the transporting of pipe-line facilities, and thus controls an oil-field, no "squeezing" of the producer is possible. The prevailing price of oil is not decided by any one company. It is set by the markets of the world every day, and the producer is able to satisfy himself by consulting the quotations which are listed on the exchanges and published in the Press of the most profitable opportunity within the stipulated time limit available to dispose of his product, or, rather, its equivalent, the certificate.

The price of oil fluctuates considerably. Thus in 1861 Pennsylvania oil realized a maximum of 52 cents, or 2s. 2d., per barrel. The oil era having dawned, and being appreciated, the price rose rapidly, high-water mark being reached in 1864, when the same grade of crude commanded $7.85, or 32s. 6d., per barrel. From that year the price declined steadily to 88 cents, or 3s. 8d., per barrel in 1879. With the exception of a spasmodic rise to $1.05, or 4s. 3½d., per barrel in 1883, Pennsylvania oil has hovered around the lower figure. The day when any one company could dictate the price which an independent producer should receive for his crude has gone for ever. In the early days attempts were made to profit from cornering the output, but these endeavours were speedily rendered impossible. Overtures to rival concerns, the building of competitive pipe-lines, or determined threats to carry out such projects, invariably brought the interests endeavouring to profit unduly from the situation to their senses. After all, the producer holds the dominating position. If he ceases operations, and diverts his supplies into other channels, the unduly grasping purchasing element courts disaster. It can only maintain its position by preserving good relations with the man who wins the oil from the earth, or embarks upon production upon its own initiative, the speculative character of which work is thoroughly appreciated.

CHAPTER VIII

PIPING THE PETROLEUM

ONE of the most extraordinary, and certainly one of the most impressive features of the oil-industry, is the transportation of the crude to the distillation plant. The refinery represents one of the most expensive phases of the industry. A modern plant, of large capacity, may easily involve an initial outlay of £800,000 to £1,000,000 ($4,000,000 to $5,000,000) or more.

This is essentially an age of centralization, and it was the early recognition of this circumstance and its manifold advantages which enabled the Standard Oil Company to become one of the most powerful industrial concerns in the world, and also enabled the American oil industry to be set upon a solid foundation. At the time this organization came into being haphazard methods prevailed for carrying out what might be termed the higher branches of the craft. Small refineries were set up here and there. Generally speaking, the proving of a new field was considered adequate reason for the establishment of a refinery in close proximity to the wells.

The creators of the American oil industry as it is known to-day completely revolutionized the practices in vogue. Instead of taking the refineries to the oil-fields, they inaugurated the policy of bringing the oil to the refineries. The latter plants were set up at the best strategical points, preferably near the waterside, to facilitate and cheapen the cost of shipping the crude and refined products. As a result, dozens of small refineries, upon acquisition, were abandoned and dismantled in favour of huge central plants. In several instances a single new refinery displaced a hundred or more small, isolated, and antiquated installations. The latter, being dependent upon the fields to which they were attached, were operated upon expensive lines. At times there was a glut of oil, and the establishment was hard pushed to keep pace with the situation. At others it suffered from a shortage, and was compelled to run upon short time. In the oil industry, such practice is not conducive to low costs and economy. It is the plant which is kept running at its full capacity the whole time which is commercially successful, because the manufacturing charges are thus reduced to the lowest figure.

But there was one powerful and obvious reason for the erection of these small refining plants. Crude oil is a bulky, awkward, and weighty article to transport, and the movement of the petroleum from the fields became one of the most acute problems of the early days. To a great extent dependence had to be placed upon animal haulage. The teamsters, being masters of the situation, levied extortionate rates for conveying the raw material. The general procedure was to barrel the oil, and to send it overland by horse teams. As roads were practically non-existent, movement was not only expensive, but slow. So far as possible, waterways were utilized. The barrels of oil were stacked on flat barges, which were floated or towed to the refineries, while, if railway facilities were available—and many short lines were laid down especially to handle oil—conical wooden tanks—huge weighty vats—conveyed the oil in bulk from the fields to the refineries.

The oil-well owners tolerated the exorbitant charges by road and water, and suffered the delays and inconveniences attending such methods with ill-grace. But extrication from the situation was entirely dependent upon their own exertions: they either had to work out their own salvation or suffer in silence. One day an enterprising spirit, Samuel Van Syckle, of Titusville, had a new idea. Water could be moved over long distances, up hills and down dales, across rivers and swamps, by being pumped through iron pipes. Why should not oil be handled in a similar manner? To him there was no justifiable argument against such a project.

He discussed the scheme with kindred minds, but while they were impressed by the proposal they were somewhat sceptical of its success. The cost of the piping and laying it would come to a heavy figure, so it was a question whether the cheaper movement by pumping, plus the interest on the capital expended, and the maintenance charges, would show any advantage over existing methods. The advocate of the new idea worked it out to the uttermost cent, producing figures based upon the market price of the piping delivered to site, the labour charges for laying the line, as well as the cost of the pumping-stations. Then he drew up an estimate of the cost of transporting oil by this means, together with the quantity which could be moved in a certain time. His figures were startling. He revealed the fact that the saving in the cost of moving the oil by pipe-line as if it were water would be sufficient to defray the initial outlay within so many months.

Forthwith a small private line five miles in length was laid down between Pithole City and Miller's Farm, and brought into service. Those who had doubted the ability to move crude oil in this manner were amazed. The theories and prophecies of the advocate of the system were substantiated to a remarkable degree. Meanwhile, those who were making fortunes from the conveyance of oil by animal transport laughed loud and long at the idea of pumping petroleum through pipes. Those interested in the new idea kept their own counsel, studied the whole problem diligently, and kept elaborate and comprehensive accounts of the working costs. The initial experiment proving so completely successful, other pipe-line schemes were projected and taken in hand.

Suddenly the teamsters and others received a rude shock. Contracts for the conveyance of the oil by animal traction were terminated. The dismay and rage of the teamsters may be conceived. Their livelihood was swept away in one stroke. Ruin stared them in the face. They had purchased and possessed extensive stables of animals, and other things necessary to maintain effective highroad transportation.

RECEIVING END OF THE FIRST SUCCESSFUL PIPE-LINE, BUILT IN 1865.

It belonged to Abbot and Harley, and was three miles in length. To the left are the old wooden tanks which were superseded by the steel tank shown at right. In the foreground is the Oil Creek Railroad and staging for loading oil into railroad cars.

LAYING A PIPE-LINE.

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These were now thrown upon their hands. There were no chances of turning these costly equipments to commercial profit in other directions, because there were no other available industries demanding services of this character. The fury of the teamsters was indescribable. Dire threats were uttered, and riots of a serious character appeared imminent. But intimidation proved futile: threats did not perturb the oil interests in the slightest. The latter were now masters of the situation, and they in turn laughed at and ridiculed the mortified teamsters, taunting them as being victims of their own avarice.

Owing to the success of the small private line, more ambitious piping projects were taken in hand. The first notable work of this character was a line eighty-seven miles in length extending from John Benninghoff Farm to Shaffer Farm on the Oil Creek Railroad. The first pumping-station was erected at the Benninghoff end, while the other terminal emptied into the tanks of Abbott and Harley, who were responsible for the enterprise. Shaffer was a strategical oil-shipping point, sidings laid to both broad and standard gauge, as well as pipe connections for loading the railway-cars being provided.

The teamsters were driven to exasperation. They expended their rage in an emphatic manner. The first Van Syckle pipe-line was ruthlessly torn up from end to end, and the piping smashed or carried away. Other lines which were in progress were menaced. The men engaged in the task of laying the pipes were ordered, virtually at the pistol-point, to throw down their tools, and to abandon the task of robbing a hard-working community. The truculent attitude and vengeful operations of the teamsters convinced the oil interests of the value of the new means of moving the oil, and they continued their operations undismayed.

Finally, the teamsters adopted a different plan of campaign. They decided to bring the pipe-line into disrepute, and spared no effort to consummate this end. Breakdowns and leaks became gallingly frequent in certain districts, which the teamsters noised far and wide as being due to the defects of the system, and which they maintained would always prevail. But only a cursory examination was necessary to determine that the mishaps were not due to inherent defects in the idea, but were due entirely to outside influences.

Such clumsy and nefarious tactics as were practised by the teamsters could not stay the force of progress. Even under such disadvantageous conditions the pipe-line proved its economic value conclusively. The puny destructive efforts of the offended interests exercised an effect diametrically opposite to what had been anticipated. In a way the teamsters hastened their own destruction. Breakdowns and interruptions due to maliciousness only served to advertise the innovation. Oil-producers and refiners hastened from far and near to investigate the new method of transporting oil, became convinced of its possibilities, and hurried homewards to instal similar facilities without delay in their respective districts.

Freed from the shackles of the teamsters, lines were laid in all directions with amazing rapidity. The success of the innovation in the United States prompted other countries to embrace the scheme, with the result that the movement of oil through pipe-lines is universally practised to-day. As an efficient and economic solution of a difficult and perplexing problem it is remarkable. It changed completely one important phase of the oil industry. By its means the world's output has been increased, because those districts which have so low a yield as to render conveyance of crude by ordinary methods unprofitable, are able to contribute to the world's supply at a remunerative figure. There is no other system of transportation upon land, no matter how cheap the labour factor may be, which can compete with piping. It is not surprising that the oil interests of America, after releasing themselves from the avaricious clutches of the teamsters, should have elaborated the idea, and introduced it as a competitor to the railways. In this instance, however, no attempt was made to supersede the steel lines of communication, but rather to supplement them, because, no matter how complete the arrangements for conveying oil in this manner may be, the railways never would be able to cope with the output, either between the fields and the refinery, or between the refineries and the markets of consumption or points of shipment.

Organizations, whose efforts are confined to the provision of pipe-line facilities in a manner reminiscent of the public supply of gas and water, were brought into existence, and their activities are boundless. Extensions are carried out with an enterprise which is probably unequalled in any other realm of human endeavour. The world cries so loudly for oil that even a few barrels per day cannot be ignored. Some of these organizations, which are independent of the oil-producing interests, control hundreds of miles of line. The largest individual owners are those enrolled under the banner of the Standard Oil Company. There are no less than 10,000 miles of trunk pipe-lines, which may be likened to the main tracks of a railway, and destined for through fast traffic; while there are over 80,000 miles of feeders or branches, extending in all directions, picking oil up here, there, and everywhere, and hurrying it to the refineries, and from the refineries to shipping points.

This huge network has been woven into a homogeneous whole by the pursuance of the policy of purchase, lease, and construction. It is the outcome of less than half a century's operations, which tends to offer one illustration of the stern, commercial, and energetic measures pursued by the Standard Oil Company, in accordance with its guiding maxim of "Reduce working expenses, eliminate waste."

The laying of a pipe-line differs from any other branch of transport engineering. When a highroad is moulded, or when a new railway is plotted, the engineers scour the country and resort to amazing ingenuity to keep down the grades, to facilitate the movement of traffic. The pipe-line engineer experiences no such worries. He follows the contour of the land. Acclivities and declivities, no matter how severe, do not materially affect the movement of the oil, which has the effort of powerful pumps to speed it onward.

All that is required is a reasonable stable foundation upon which to lay the pipes, and one where it is protected from Nature's destructive handiwork, such as washouts, avalanches, landslides, and so forth. The Burmese pipe-line, which brings the oil down from the distant hinterland to the seaboard, traverses country exposed to torrential rains, and in this instance the maintenance of the line is attended with considerable anxiety and difficulty, owing to the severity of the washouts and slides which are caused by the heavy rainfall. The diameter of the pipe varies according to the character of the oil and the volume to be handled, but the 4-inch, 6-inch, and 8-inch are those in general service.

The disposition of the pumping-stations also varies considerably, this factor being governed by the nature of the oil, the speed with which the producers desire it to be moved, and local conditions. Thus, on one Asiatic pipe-line, about 576 miles in length, only two stations are required. The oil is light, runs fairly easily and rapidly, there is no necessity for a very high travelling speed, while the country traversed, being sparsely populated, it is necessary to reduce the number of intermediate stations to the minimum. On the other hand, the oil which is obtained in Mexico is heavy, and so runs very slowly. On the fields controlled by Lord Cowdray's interests, owing to the enormous output of the wells, and the fact that the lines are taxed to their utmost capacity, the oil has to be moved quickly; consequently, in this instance the pumping-stations are spaced at intervals of about twelve miles.

Some thirty years ago, when oil was not appreciated so keenly as it is to-day, the wastage assumed enormous proportions, as related elsewhere. Wells were drilled by the speculators with the frenzy that a man pans the earth for the yellow fleece in a new gold-field. Never a thought was given to the problem, How is the oil to be despatched to the market ? The consequence was that, when a strike was made, the greater proportion of the yield ran loose, merely because there were no facilities available for its transportation. But now haphazard have given way to scientific methods. Of course, now and again a tremendous gusher will burst into activity, and its flow will exceed the most sanguine expectations to such a degree that much of the oil must be lost; but, taken on the whole, the losses in this direction have been reduced by quite 80 per cent., as compared with thirty years ago. This result is entirely due to the pipe-line.

A case in point may be cited. When the famous McDonald field was struck suddenly and unexpectedly in 1891, there was a complete absence of facilities for handling the product of 3,000 barrels a day. The Standard Oil Company received the earliest intimation of the strike, and, realizing the situation, immediately put its comprehensive and wonderful machinery into motion. Its pipe-line and tank erection nterests went to work with a will, being urged to spare no effort. The men toiled the round twenty-four hours at tip-top pressure. What was the result ? The steel plates for the tanks, together with crowds of labourers, were on their way to the new field while the telegraph was at work. In less than five months these forces completed storage facilities capable of receiving 3,000,000 barrels. Simultaneously, other gangs concentrated their energies upon the laying of the pipe-lines.

A territory some twelve square miles in area was being overrun by the prospectors and drillers, and new wells were coming into operation almost daily. A somewhat intricate network of pipes had to be laid. It was imperative that the main lines should be got through at all hazards to ease the situation, which was becoming critical. As rapidly as the storage-tanks were completed, they were charged to their utmost; in fact, the tank erectors could not keep pace with developments. It was a wild rush with the pipe-line, but in less than eight weeks sufficient pipage had been provided to take care of 26,000 barrels a day. Although this was less than the daily yield of the oil-field, it brought production under control. The various gangs continued their feverish haste, and within a further eight weeks all apprehensions disappeared. Over fifty miles of pipe-lines had been laid, and were able to carry away more than 80,000 barrels of petroleum during the twenty-four hours, which was in excess of the daily output of the field. Contrast this state of affairs with what prevailed in Texas upon the occasion of the coming of the Lucas gusher and the Beaumont oil-field! Here probably more oil was lost than ever was collected. More than a year elapsed before pipe-lines were connected to the wells.

It is no uncommon thing for the Standard Oil Company to authorize the extension of a pipe-line of twenty or more miles to a new well, in order to take away the owner's produce, and the latter does not contribute a penny towards the expense of the extension. That is borne entirely by the pipe-line concern. The producer merely pays the agreed tariff for the conveyance of his oil, and is generally thankful for the ability to dispose of it instead of watching it run to waste, or be compelled to dispose of it at a ruinous price.

While in the United States pipe-lines are laid, owned, and controlled by private enterprise, in certain other countries they are the property of the State. This is the case among the Russian oil-fields of the Caucasus. The urgency of a pipe-line was obvious, but private initiative manifested no desire to undertake the task, and, in fact, it received no encouragement from the Government. When one recalls the extremely mountainous character of the country, and the difficulties innumerable which the engineers experienced in building the Trans-Caucasian Railway, which still ranks as one of the wonders of the world, private hesitation may be understood.

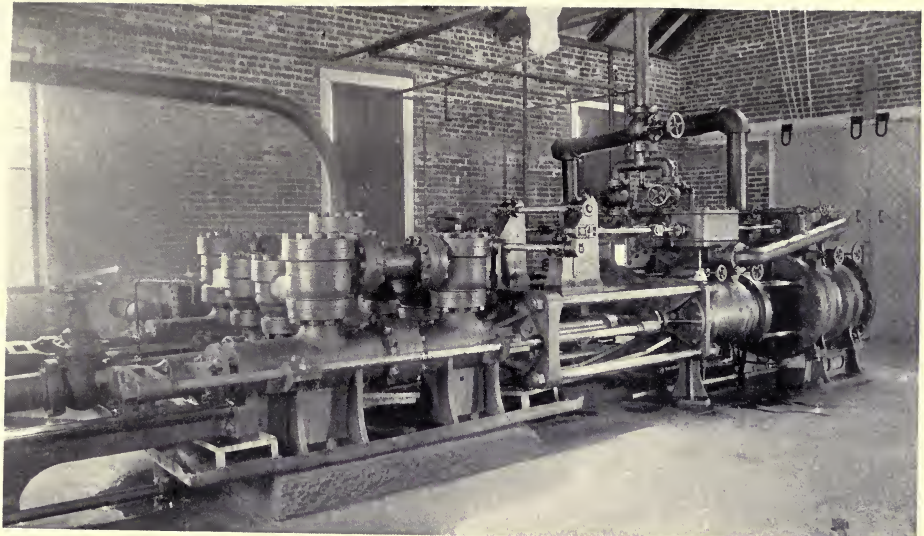
At last the prosperity of the Caucasian oil-fields, being dependent upon improved means for the movement of the oil between Baku, the centre of the district, and the shipping port of Batoum on the Black Sea, the Government was spurred to action. It decided to build and to operate a pipe-line as a national work. It was a gigantic undertaking in itself, owing to the severity of the climbs and the ruggedness of the route which had to be followed. Surveying revealed the fact that the easiest and most satisfactory alignment was alongside the State-owned Trans-Caucasian Railway. The first section, 145 miles in length, was taken in hand about sixteen years ago. A conduit of 8 inches internal diameter was selected. The receiving-point was established at the station of Mikhailovs on the State railway near the frontier of Kutain and Tiflis, and it was extended thence to Batoum. Owing to the heavy grades, three pumping-stations had to be provided. At the receiving-stations two huge underground reservoirs were built, into which the oil, collected in tank-waggons among the fields of Baku 400 miles away, and hauled by rail to this point, was despatched upon its long journey. Subsequently the pipe-line was extended to Baku, whereby its length was increased to about 550 miles. The line was designed to handle some 400,000,000 gallons per annum. This line ranks as one of the most remarkable in the world, inasmuch as it traverses the most difficult and broken country through which such a method of oil transportation ever has been attempted.

Curiously enough, in many of the large oil-producing countries the question of private against State-owned pipe-lines has developed into quite as acute a subject of discussion as the nationalization of railways. Government ownership certainly solves one question. It prevents discrimination and the setting up of a dominating monopoly, because if the vehicle of conveyance is open to one and all at an equitable rate, it is impossible for unfair advantages to be taken. Some years ago this factor was revealed in a striking manner. A foreign organization coveted the rich oil-fields of Roumania, and realized that if a pipe-line were laid from the fields to the strategical shipping port, a pronounced advantage over competitors could be obtained. It prepared its plans with great care, and having the capital at its disposal to construct the projected line, foresaw a complete control of the oil situation in the country, since competitors, deprived of a cheap method of conveying their product to the sea, would be at such a serious disadvantage that they would be forced to come to terms with the company owning the pipe-line. Unfortunately for the prospective monopolists, the scheme was scotched. The Government appreciated private enterprise in completing such a line of communication, and would do everything in its power to further its realization, but, upon completion, the line was to be handed over to the State, and was to be operated thereby for the benefit of one and all who had invested money in the oil-fields of the country! Needless to say, such an unexpected contretemps met with no favour among those casting envious eyes upon Naboth's oil-fields.

Heavy asphaltic oil taxes the pumping plant to a remarkable degree. The Kern River district of California yields a very dense petroleum, but, despite this fact, the producers resolved to attempt to pump it to a point of shipment upon San Francisco Bay. To this end a pipe-line 280 miles in length was laid. But its inauguration revealed an unexpected difficulty. The oil was so viscous and sticky that it moved at an imperceptible speed; in fact, five days were required to send it over the first thirty-seven miles. At such a pace, and with the prospect of the oil being five weeks in the pipe before it reached its destination, the interests decided to abandon the project.

A grave situation developed. Unless the oil could be driven through the piping, the capital sunk in the enterprise would have to be written off as a dead loss, while other and more expensive methods of transportation would have to be adopted which would react against the profitable exploitation of the fields. With a view to solving the problem, the expedient of heating the oil to about 120° F., thereby rendering it more fluid, was adopted, while at the same time the number of pumping-stations was increased. The latter move was the only logical method of overcoming the difficulty, as experience in Mexico has proved. Although the Mexican oil is far denser than the Californian product, no troubles are experienced in its movement through the pipes, owing to the number of pumping-stations installed.

The difficulty in piping the Californian oil was responsible for the perfection of an ingenious idea, which was tested upon a large scale. As is well known, oil and water refuse



A MODERN AMERICAN PIPE-LINE PUMPING PLANT.

These installations are disposed at varying distances according to the character of the oil to be moved.

PUMPING-STATION ON THE UNITED STATES PIPE-LINE.

This line, comprising two 4-inch mains, is 366 miles in length. It extends from Titusville to Marcus Hook, and is used for refined oil only. From 4,000 to 6,000 barrels are moved every twenty-four hours.

OPENING THE PERSIAN OIL-FIELD.

British tractor hauling load of pipes for the construction of a pipe-line across the Persian desert.

to mix, and this antagonism becomes more pronounced as the density of the oil increases. Accordingly, two American engineers conceived a pipe-line having a spirally grooved inner wall, similar to that of a gun-barrel, through which water and oil, in certain proportions, were to be pumped simultaneously. The inventors of the rifled pipe-line, as it was described, maintained that the antagonism between water and the heavy Californian oil would cause the former to take to the walls of the tube under the centrifugal action generated by swirling the contents round and round as they followed the path of the grooves. The result would be the production of a thin film of water moving along the surface of the pipe and with the oil, in the form of a compact core, travelling along the centre, the water, in fact, acting as a lubricant. Not only would the two articles move together in this way, but friction would be overcome, which, except for the water, otherwise would be so great as to arrest the movement of the oil. The promoters of the scheme also maintained that the pipe would have a longer length of life, owing to the reduction of friction.

The project appeared so feasible that it was adopted upon a comprehensive scale. A main pipe-line, 282 miles in length, was laid between Bakerfield and Porta Costa. Twelve months were occupied upon the task, which entailed an outlay of £900,000 ($4,500,000). It was designed to pump 17,000 to 20,000 barrels of thick heavy oil past a given point in twenty-four hours. Relay pumping-stations were disposed at intervals of twenty-three miles, and sixty men were detailed for duty along its entire length. At each pumping-station two oil-tanks of 55,000 barrels, and one water-tank of 10,000 barrels capacity, were erected. Each pumping installation had a set for driving the oil through the pipes, and one for pumping the water. The two substances were injected into the pipe-line simultaneously, the proportions being one part of water to nine parts of oil.

Unfortunately, the rifled pipe-line does not appear to have been the great success anticipated; at any rate, it has not been extensively adopted either in California or in any other countries where similar conditions prevail. The rifled pipe-line is regarded as an interesting engineering curiosity rather than a practical commercial proposition, and is condemned generally, owing to the cost of despatching the oil through the pipe being practically doubled. A greater number of pumping-stations, disposed at shorter intervals, was thought to be a far cheaper solution of the problem.

In Mexico, under the enterprise of the British interests controlled by Lord Cowdray, the pipe-line system has been brought to a high stage of perfection, possibly excelling that obtaining in the United States. The conditions in the Central American Republic are somewhat different, and attended with greater difficulties. The British organization has over 200 miles of pipe-lines in service, the majority being 8 inches in diameter. The whole network has to handle the heaviest classes of petroleum known; but in this instance, owing to the engineering knowledge available and displayed, the movement of the treacle-like asphaltic petroleum is attended with no more difficulty than the light paraffin oils found in the Appalachian fields.

At Tuxpan there is a pipe-line installation which is probably the most interesting in the world. This is the shipping point, but, owing to the shallow depth of water, the vessels are unable to come close in-shore. Instead of expending huge sums of money in the construction of a harbour and jetties, a novel alternative was adopted. On shore a large pumping-station and a farm of immense tanks were installed. From this pumping-station pipe-lines were laid upon the sea-bed to a point one and a half miles off-shore. At the ocean moorings, where there is sufficient depth of water to permit the largest tank steamers to ride at anchor, the pipe-lines are connected to lengths of flexible hose, which extend into the holds of the tankers. The arrangements enable three or four vessels to be loaded with oil at one and the same time. The practice of anchoring vessels in an open roadstead one and a half miles out, and thus loading them, may be open to criticism, but the practicability and success of the scheme are revealed by actual experience. During the year 1913 over 200 tank steamers were loaded at Tuxpan in this manner, and on the average a vessel was loaded and cleared within two and half days. By means of these interesting and unusual pumping and sea-line facilities, a ship can be loaded at the rate of 10,000 tons—75,000 barrels—in the course of twenty-four hours.

The pipe-line is used not only for the conveyance of the crude oil from the wells to the refineries, but also of the lighter products resulting from distillation to the seaboard for shipment in bulk, although it is in the carriage of crude oil, which has to be transported at such a low rate to show a profit, that its advantages are felt to the greatest degree. Crude varies in price. The factor is not based upon the law of supply and demand so much as the ability or inability to get it conveyed from the well to the refinery. A well may be producing 20,000 barrels a day, but if the owner cannot dispose of his product, he is in an unenviable position. Water is more valuable, for the simple reason that the crude oil may not only be useless, but it may become a nuisance. The existence of an organization such as the National Transit Company, with a capital of £6,000,000, or $30,000,000, available for pipe-line construction purely and simply, solves the transportation of oil as completely as other similar enterprises handle the shipment of grain or cattle for the stockyards. A pipe-line is an uncertain investment in itself. An oil-field is subject to a brief existence or severe depreciation, so that the project is speculative. Yet, taken on the whole, the pipe-line is a highly profitable investment, if worked upon a sufficiently comprehensive scale; in fact, under normal conditions it pays for itself in such a short space of time, that, when an oil-field becomes exhausted, it is more profitable to abandon the pipes than to tear them up for use elsewhere.

The Union Oil Company of California, in the course of its development, became intimately associated with the Texas oil-fields. But the properties were far distant from one another, and had no means of intercommunication.

There was only a long length of railway connecting the two territories, and this fact hampered economical operation. Moreover, the two fields were yielding immense quantities of the commodity which defied disposal, with the result that tankage capacity threatened to become overtaxed, in which event the glut of oil would lower prices. Accordingly, it was decided to link up the two fields, and incidentally to exploit new possible markets. The settlement of the isthmian territory contiguous to the Panama Canal prompted an investigation of the existing and prospective commercial conditions along its route, and, as these were deemed to be favourable, a bold move was decided—the laying of a pipe-line across the isthmus connecting the Pacific and Atlantic Oceans.

The requisite concession from the Republic of Panama was secured, and the United States Government, when approached, supported the movement on the understanding that the concession should terminate with the opening of the canal, and that the oil company should be a mere licensee, and not be entitled to any proprietary or other rights in the land upon which the line was laid. These terms were accepted, and within a short time large gangs of men were set to work running the line from both seaboards simultaneously, while additional gangs drove it eastwards and westwards from a strategical central point. By this method of building from three points at once, construction was accelerated.

The pipe has an internal diameter of 8 inches, and weighs 600 pounds per length. It follows the alignment of the railway practically throughout its length of fifty-one miles between La Boca, two and a half miles from Panama on the Pacific, and Colon on the Atlantic seaboards, respectively, cutting across loops and curves to reduce mileage. A surface line was laid, although in many places it has disappeared from sight, having sunk deeply into the tropical swamp. It attains a maximum altitude of only 210 feet above its terminal points. Construction was carried out rapidly, the conditions not presenting any serious engineer-

PONDS OF OIL.

In Roumania the oil often pours out heavily, necessitating the construction of dams upon the hillside to protect the villages below from inundation.

By courtesy of the Oil Well Supply Company.

SAND FROM OIL.

Mounds of sand shovelled from the settling tanks into which three oil-wells are baled. One man is retained to shovel continuously.

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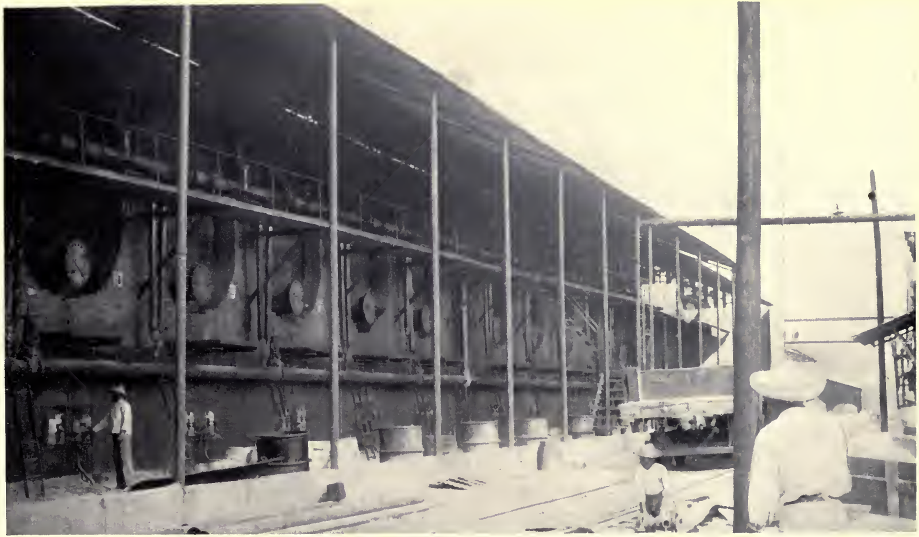

A ROW OF CONTINUOUS STILLS AT MINATITLAN.

This was one of the first plants laid down in Mexico for the refining of Mexican petroleum.

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ing difficulties, except, perhaps, in the crossing and recrossing of the creeks and other waterways. The pipe, however, is laid upon the beds of these obstacles, 111 such crossings having been made. Three pumping-stations are provided—one at either end, and one at an intermediate point. The pumping plant is able to handle 25,000 barrels a day, and the pressure within the pipe-line varies from 600 to 800 pounds per square inch.

A fleet of tank steamers operates upon either side of the continent in conjunction with the pipe-line. The tankers come down to La Boca laden with oil. They moor off the shore, and are connected to the tanks by means of flexible hoses or pipes supported upon floats. The oil is discharged direct into the tanks, drawn off by the pumps, and despatched across the isthmus to Colon, where it is emptied into other tanks, and thence loaded directly into the Atlantic tankers.

The conquest of the Isthmus of Panama by railway, canal, and oil pipe-line is most remarkable. To the territory contiguous to the canal, and to the United States, the provision of such facilities is of far-reaching import. Ample supplies of fuel are immediately available. At the same time the pipe-line is of incalculable value to the owners. It eliminates the necessity for laden vessels to pass through the canal from ocean to ocean, because trans-shipment and pumping constitute a more rapid and cheaper means of conveying the oil from one side of the continent to the other.

Owing to the rapid extension of the pipe-line systems in the United States, the possibility of driving the oil across the breadth of the continent has been mooted. Should economic considerations indicate the advisability of such a system, it will be consummated. The outlay would not be exceptionally costly, inasmuch as the gaps between existing fields and their pipe-line connections are being reduced rapidly, owing to the discovery of new oil-bearing districts. Probably, before another forty years have passed, the transcontinental pipe-line, reaching from New York to

San Francisco, will become a reality. It will enable the oil-fields in the Middle States to despatch their product either to the Atlantic or Pacific seaboards as desired. At the same time it will serve territories *en route*, which, being deficient in local coal resources, will be able to obtain fuel at a lower price than is possible at present.

CHAPTER IX

THE OIL REFINERY AND ITS EQUIPMENT

As a rule the oil, as it issues from the earth, is mixed with many foreign bodies, sand and water predominating. In some instances this percentage of deleterious matter, more particularly when the petroleum is drawn from loose sand, will be as much as 50 per cent. of the bulk raised. On the other hand, it may be present in very small quantities. This is particularly the case in Mexico, where the enormous gushers yield a strikingly pure crude oil. Contamination is wellnigh inevitable, because petroleum is always found combined with sand and water, and, as previously mentioned, when the oil has been exhausted, its place is taken by salt water. When a new well is sunk, and a rich strike is made, the proportion of impurities may be very low, but it increases as the sands below become depleted of their petroleum content, until invariably in the later stages the well becomes unprofitable, more water and sand than oil being brought to the surface.

When heavily impregnated with these useless substances, the oil, after issuing from the well, is allowed to stand for a time, to permit the sandy content to settle, and the water to isolate itself from the oil. In the Kern River country the sand and water trouble is particularly acute, and, indeed, prevails to a greater or lesser degree throughout the California oil region. In other countries a similar state of affairs prevails, particularly in Java, where, owing to the activity of the oil geysers or mud volcanoes, the three articles are somewhat intimately associated, owing to the constant state of agitation which is maintained by the forces of Nature.

The oil is pumped, or flows, from the wells into small ponds immediately adjacent to the borehole. These pits, known as "sumps," are designed in the first place to hold from 500 to 2,000 barrels or more of oil, but this capacity is reduced within a short time owing to the suspended detritus settling in a thick layer of sediment. Consequently the sump has to undergo periodical cleaning.

From this pond the crude oil flows by gravity, or is discharged through sluices to the storage reservoirs. Here further settlement takes place, to permit the sand and water to dissociate themselves entirely from the oil, the time required to bring about this requirement varying according to the nature of the petroleum. During the summer, when the oil becomes heated naturally, and is consequently rendered more fluid, the natural cleaning process is completed readily and speedily, but in winter the lower temperature causes the oil to become more viscid, so that the settlement of the sand is retarded. In this instance purification is assisted and accelerated by passing the oil through tanks in which steam-pipes are coiled.

This method of preliminary purification may seem primitive, but experience has proved it to be extremely effective. Oil, which upon emergence from the well may have a content of impurities bulking to 50 per cent., when drawn from the settling storage reservoirs will be found to contain only 2 per cent. of deleterious matter, no less than 48 per cent. having been removed merely by permitting it to remain stagnant for a few hours. This settlement also achieves another desired end. The oil, as it comes from the well, is associated with large quantities of gas in a finely divided or dissolved form. While the settling is taking place, this gas effects its escape. In intensely hot tropical climates, when the shallow tanks containing the heavy oils are exposed to the full action of solar heat and light, oxidation takes place. If left for a sufficiently long time, the oil will become converted into an extremely thick, viscid mass, approaching molten tar in consistency. But if the oil is protected from the effects of the sun, oxidation does not take place to a perceptible extent, although the gases are given a free escape. Consequently the oil may be stored for prolonged periods in such excavations, so long as adequate roofing facilities are provided.

When the impurities have been reduced to an insignificant bulk by passage through these preliminary settling tanks, the crude petroleum is ready for the refineries. This is the most important and intricate, as well as the most interesting and fascinating, stage in the whole industry, because it is here that crude petroleum is induced to resolve itself into a variety of commercial products for a wide range of operations and applications, from a spirit for automobiles to a wax for candles, or an oleaginous preparation for dressing wounds; from an illuminating oil for the table lamp to a product for the dye industry, or a material for the making of roads, and so on. Different petroleums yield varying substances, and for this reason, owing to the fundamental constitution of the crude oils, the processes vary somewhat, because paraffin oils yield some articles impossible of derivation from asphaltic petroleum, and *vice versa*.

The equipment of the refinery is extensive and intricate in character. It represents an enormous investment of capital, and it is for this reason that small refineries to-day cannot compete with the huge concerns bidding for the world's markets. It costs more to run an establishment representing an outlay of £100,000, or $500,000, than one which has involved a capital expenditure ten times as heavy. The latter and larger organization is in a position to reduce the manufacturing costs, by virtue of its equipment, organization, and highly trained technical skill, to a figure which the former never can hope to approach. The extensive character of its plant places it in a unique position. It can compel the petroleum to yield every commercial particle it possesses, and to turn the products into their marketable channels, merely because it owns the facilities for achieving this end. The small refinery, on the other hand, is able to concentrate its energies only upon what may be described as the staple articles. It is forced to ignore many possible sources of revenue merely because it is not in a position to derive them economically. This fact is revealed very strikingly in connection with the operation of the Standard Oil Company. By means of its complete and elaborate plants, and its command of the foremost chemists in the industry, it is able to take a gallon of crude oil, and, by submission to a comprehensive array of intricate processes, can force it to give up every trace of financial value which it contains.

The various commodities are resolved from the crude oil by the process of distillation. The stills used for this purpose follow one of two general designs—the horizontal cylindrical, and vertical or "cheese-box," respectively. No hard and fast rule concerning the design of the still, capacity, or method of heating them prevails. These factors are governed by the character of the oil to be handled, and the products which are to be derived. The subject of stills is one of considerable complexity and of interest essentially to the technical mind. It is an extremely highly specialized branch of chemistry, physics, and engineering. But from the elementary standpoint the process turns upon the application of heat in some form or another, which vaporizes the oil, and which subsequently is condensed and divided into its various classifications, each of which coincides with a marketable group. Thus, for instance, there are the explosive, the illuminating, and the lubricating oils respectively. Each class in itself can be further subdivided, and the subdivisions split up still further, and so on.

The horizontal cylindrical still resembles a huge steel boiler, and is built of boiler-plate. It may range from 30 to 40 feet or more in length, and from 12½ to 14 feet or more in diameter. It is built into a brick foundation, the brickwork being continued halfway up the sides, so that the upper half of the still is exposed to the air. As a rule these stills are disposed in rows or batteries, ranging from two or three to ten or more in number, for the sake of convenience in operation. Each still is sufficiently large

A TYPICAL REFINERY FOR DEALING WITH PARAFFIN PRODUCTS.

By courtesy of the Oil Well Supply Company.

A HORIZONTAL CRUDE OIL-STILL.

This photograph conveys a graphic idea of the immense proportions of the modern oil-still.

GENERAL VIEW OF AN AMERICAN PETROLEUM REFINERY.

Bulk cars used for transporting oil by railroad are shown in the foreground.

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to receive from 600 to 1,000 barrels of crude at one charge. On the top of the tank there is generally a dome similar to that fitted to a locomotive boiler, and which, in fact, serves the same purpose. As the steam in the railway-engine is generated it passes to the dome, and thence is led to the cylinders. In the petroleum still the vapours or gases ascend to the dome, and from there pass to the condensers.

The cheese-box still may be likened somewhat to a huge steel drum set on end. It has a domed top and a double curved bottom. Its diameter averages about 30 feet, while the height is about 9 feet, and the working charge approximates 1,200 barrels. These stills are set vertically upon a series of brick arches. The methods of heating are extremely varied. Some are fired from beneath by fierce fires, others have their contents raised to the desired temperatures by means of nests of coiled pipes, through which steam is circulated, and so on. But whatever method of heating is adopted, the primary object is the conversion of the liquid within the still to a vapour, and its subsequent reconversion to a liquid.

The condensing apparatus is not unlike that employed for the condensation of steam into water, after it has completed its designed duty in the steam-engine. There are huge tanks in which the condensing tubes are disposed, and where the gaseous contents of the pipes are submitted to a chilling process, to induce the vapours to assume the liquid form once more. Water is employed for this purpose, a constant cold stream being brought into contact with the pipes. But one of the most remarkable instances of economy in oil refining is to be found in connection with this process. The condensing pipes are immersed in an oil-tank which feeds the still. Here the gases are forced to surrender a great deal of their heat, and to be partially condensed. While they are so doing, the oil within the tank becomes heated to an appreciable degree, so that when it enters the still the heating process virtually has commenced. Distillation then takes place sooner than if the oil were passed absolutely cold into the still. The waste gases of combustion also are diverted on their passage from the furnace to the same end, so that by the time they pass from the chimney into the outer air they have been deprived of almost their entire heating efficiency. The process is somewhat analogous to that practised in raising steam, where the feed-water to the boiler is subjected to a preliminary heating by what may be termed "waste heat" before it enters the boiler, whereby the temperature of the water is raised, so that less time is required to complete the task of converting it into steam.

To a certain extent the refineries are operated upon self-supporting lines. A certain volume of gas, which has no marketable value, because it cannot be reduced to liquid form, is given off by the oil in the stills. This product is diverted and led back into the furnaces to be consumed for steam-raising.

The oil, as it arrives at the refinery, is deposited into tanks of the familiar form. As the reduction of the cost of refining to the lowest possible figure is imperative, an adequate supply of oil must be available to keep the stills working steadily and continuously at the required rate of production. As the oil arrives through the pipe-line, it is switched from one tank to another as required, and the flow from the tanks to the stills is controlled in a similar manner. As a rule the oil makes but a brief sojourn in the storage tanks, because the stills dispose of the crude product at a remarkable speed. The petroleum is pumped from the tanks into the preliminary heaters, where its temperature is raised by condensing the oil vapours as already described.

Although crude oil is divided into two broad distinctive classes, paraffin and asphaltic, these by no means exhaust the category. Crude petroleum, having a pronounced sulphur constitution or base, is known as sulphur oil. Vast quantities of this petroleum, often known as Lima oil, are drawn from Ohio and Indiana, while until recently it was the only grade of petroleum found in Canada. The presence of the sulphur formerly rendered this oil commercially useless. It imparted an extremely noisome smell to the article, which the prevailing methods of refining could not eliminate or even diminish, while the presence of this mineral impaired its value in numerous other ways. One has only to recall the pungent stench of sulphuretted hydrogen to obtain some idea of the aromatic qualities of crude sulphur oil. Indeed, the Canadians promptly and appropriately nicknamed it "skunk," which probably represents the superlative of the scent standard in North America.

Sulphur oil was first brought to light about the year 1868 at Petrolia, Ontario, Canada. The Canadians valiantly endeavoured to turn it to commercial value, but in vain. It was subjected to every known process for eliminating the sulphur—submission to sulphuric acid and soda—but to no avail. The smell defied conquest. Attempts to ship it in this condition, in the hope that the public in time might, as a result of familiarity, regard it with contempt, brought disaster swift and sudden. The smell was not only suffocating, but penetrating: it possessed the quality of being absorbed and retained by foodstuffs and other articles of commerce. Flour, bacon, and other comestibles displayed as marked an affinity for the nauseous aroma as a magnet for steel filings, and the odour impaired the flavour of the edibles.

The inevitable happened. The shippers of this oil were prosecuted for creating a dangerous nuisance, and damages were claimed for ruined produce. The facts could not be disputed. "Skunk" was too distinctive to provoke possibilities of mistaken identity. The unsavoury reputation which this oil gained brought its exportation to a sudden termination. Even the home consumers refused to have anything to do with it. The Canadian Government valiantly endeavoured to support the home industry. It imposed a duty of 9 cents (4½d.) per gallon, upon imported Pennsylvania oil, but Canadian consumers would rather incur this extra outlay to secure a wholesome oil than run the risk of being shunned by their neighbours for miles around for using "skunk" oil. The result was that the Canadian oil industry languished.

This oil deposit evidently extends southwards beneath Lake Erie. At all events, when the drillers of Ohio struck oil in the vicinity of Lima, they were disgusted. They tapped the malodorous sulphur oil, or, as it was dubbed by the drillers, "Lima" oil, from the point where it was first found in the United States. The toilers had every reason to be disgusted with their luck. The Pennsylvania paraffin oil at the time was fetching over $2 (8s.) per barrel. It was difficult to sell the Lima oil for 14 cents, or 7d., per barrel. And this crude petroleum was pouring out of the earth in increasing volume with every successive week.

The Standard Oil Company came to the rescue, and fearful of the waste, spared no effort to turn it to marketable account. They even erected a special refinery at Lima, and turned the whole of the chemical skill and knowledge they could command upon the task of removing the sulphur content from the petroleum. But their quest proved futile. Consequently the company decided to place the produce upon the market regardless of its odour. There was every inducement to go ahead. Some 30,000 barrels a day were available for immediate refining. In the effort to reclaim a part, if not all, of its properties, the Standard Oil Company restricted their energies to the production of an illuminating oil, but here they encountered another and equally serious drawback. The illuminating oil emitted an enormous quantity of soot, which soon choked the chimney of the lamp, and in addition caused violent smoking.

The organization strove to force it upon the market by sending it to its retailers, but the latter rose in rebellion. The consumers complained loud and long about the oil, voiced dire threats of going elsewhere for their necessities, and confronted the shopmen with disaster. In dismay, the retailers sent the unsold stocks of the defective oil back to the manufacturers with all haste. Finally, the Standard Oil Company reluctantly concluded that the oil could be used only for one purpose—as a fuel. Even here there was some difficulty in its disposal; but the company made the best of a bad bargain—built a pipe-line to Chicago, where there was a big market for liquid fuel, and sold it to all and sundry at 7d., or 14 cents, a barrel. Lima oil was condemned as useless.

In the meantime the Canadian Government had come to the assistance of its producers and refiners, who were suffering severely from the disability. Scientists were urged to take up the problem, and they wrestled with it valiantly, but to no avail. They could not remove the objectionable sulphur: all they achieved was the discovery of a means of disguising the noisome odour to a certain degree.

The struggle between science and Nature had aroused considerable attention throughout the world. Workers in every country took up the problem, realizing that, if success were achieved, a huge fortune would be made. Producers, shippers, and refiners—more particularly the Standard Oil Company—expressed their readiness to pay handsomely for the perfection of any practical means of increasing the value of the Lima oil from the existing take-it-away price to that prevailing for the Pennsylvania oils.

Among this host of toilers of all nationalities, one man set to work quietly and unostentatiously. He had followed the troubles and developments with intense interest. He went to Canada, purchased a small refinery, and in his laboratory embarked upon a well-defined path of research. It was not long before he made one important discovery. Minute investigation of the sulphur content of the Canadian oil revealed one salient point: Certain metallic oxides, when associated with the crude oil in a soluble form, displayed a striking affinity for the sulphur, and brought about the precipitation of the latter. Moreover, he found that if the oil were thoroughly saturated with the oxide—that is, if sufficient volume were added to precipitate all the sulphur present while the oil was undergoing distillation—all traces of the sulphur were completely eliminated from the resultant products. The offensive aroma was removed.

Science had triumphed; the perplexing problem had been solved. The investigator continued his researches, with the object of discovering which metallic oxide would prove the cheapest and most commercial to employ. Ultimately his selection fell upon copper, and for two reasons: (1) Because it dissolves into the petroleum without effort; (2) because the precipitant, sulphide of copper, is readily reclaimable, and capable of easy reconversion into oxide, when, of course, it is available for further use. It was as if a perpetual cycle in chemical action had been discovered.

The laboratory experiments indicating a positive and inexpensive method of bringing about absolute de-sulphurization of Lima and Canadian oil—they are virtually one and the same petroleum—the inventor proceeded to erect a refinery to test its commercial possibilities. A still, 22 feet in diameter by 16 feet in height, capable of holding some 1,000 barrels of crude oil, was built. Practical investigation supported laboratory discovery in every particular. The sulphur oil submitted to refining in accordance with this process yielded products in which the percentage of sulphur was no higher than in those obtained from the high-grade Pennsylvania oils. In other words, a means of converting Lima into Pennsylvania oil had been found and perfected.

These experiments were commenced in 1885, and were completed and duly patented within about three years, which tends to indicate how strenuously the investigator toiled. The man was Dr. Herman Frasch, and his invention aroused world-wide attention. He achieved a triumph which was without parallel in the whole romance of the oil industry. In 1885 his name was unknown; four years later his discovery was in universal request wherever sulphur oils were found. It was the first, and remains as the only, economical and commercial means of de-sulphurizating oil. In 1912 the scientific toiler received due recognition of the scientific value of his labour by the bestowal of the Perkin medal of the Royal Society of Great Britain, which ranks as one of the most highly prized awards in the world of science.

Dr. Frasch lost no time in turning his discovery to account.

His methods were adopted in Canada, and the former much-maligned Canadian sulphur oil, which hitherto could not be given away, was now in keen demand. It carried the inventor's guarantee that it would be found equal to the Pennsylvania oil. The Standard Oil Company, which had expended a fortune over the problem, but to no purpose, and was now suffering from a glut of Lima oil, though somewhat sceptical of Dr. Frasch's discovery, displayed its characteristic enterprise. It subjected it to a rigid investigation to determine its value, its experts visiting his small refinery to follow the whole process from A to Z, and submitting the resultant products to searching tests.

Precisely what this organization thought of the discovery may be realized from the fact that it purchased the fruits of Dr. Frasch's labours lock, stock, and barrel—his patents, refinery, and even his skill and knowledge, because he became the mainstay of its extensive research and scientific staff. Orders were given that the Frasch desulphurization process was to be put into operation at the Lima, Cleveland, Whiting, Philadelphia, and Bayonne refineries with all haste. Simultaneously the producers, who had been chafing under their ill-luck, were requested to deliver every gallon of Lima oil they could obtain, while the drillers were urged to resume their well-sinking operations in all directions. Prospectors likewise were induced to search the country to ascertain if the fields extended into neighbouring territories. A Lima oil boom set in. Farmers gave every assistance to enable drilling to be carried out upon their lands. The drillers overran the country, and laboured feverishly with their tools, while the producers snapped up every barrel of oil they could secure. Lima oil, which had been difficult to sell at 14 cents (7d.) per barrel, rose rapidly in price, and in a short while commanded about $1.00 (4s.) a barrel. New wells came into activity rapidly, one after the other, until in a short while Ohio and Indiana were yielding a round 100,000 barrels of sulphur oil per day. By this one discovery an entire branch of one industry was revolutionized. A further source of crude-oil supply, hitherto considered useless, was brought under commercial control.

Two or three years after the above-mentioned discovery—in 1902—Dr. Frasch applied himself to the unravelling of another serious oil difficulty. This time it was the Californian petroleum which was occasioning discontent among purchasers. The oil smoked, and no improvement in the lamps could cure it. The quest in this instance was of a different character. The removal of the cause of the smoked chimneys, and not odour, was the objective, the Californian oils having an insignificant sulphur content. Chemical research speedily revealed the cause of the trouble, the severe smoking arising from the high percentage of what are known as the "aromatic hydrocarbons" in the crude oil, and the inadequate proportion of hydrogen to carbon to maintain the temperature of the flame to bring about perfect combustion. In other words, the whole of the carbon could not be consumed, so accordingly became deposited upon the glass chimney of the lamp in a thick soot, in the same way as the unconsumed carbon from an imperfectly designed firegrate using coal, collects in the chimney.

The problem was the removal of the aromatic series of hydrocarbons, and the discovery of a means of restoring the balance of hydrogen to carbon to insure combustion. Elaborate experiments were undertaken, but Dr. Frasch found that the simplest, most economical, and efficient method of achieving the desired end was by subjecting the oil to a treatment with sulphuric anhydride. Alternative methods were tested, some of an intricate and complex character; but the foregoing proved the most advantageous from the commercial point of view, and cured the smoky chimney completely. Accordingly, the Standard Oil Company, for whom the investigations were carried out, embraced the process, and installed it without delay at its Port Richmond refineries in California. Another illustration of the thorough manner in which this organization carries out its work was given in this instance. It was essential to manufacture the sulphuric anhydride upon the spot. Dr. Frasch, as a result of his researches, recommended the adoption of one which was practised in Germany. Forthwith the Verein Chemischer Fabriken of Mannheim, the patentees of the desired process, were approached, and induced to dispose of their patents to the American company upon attractive terms. Californian oil refined at Port Richmond never once since has been responsible for a smoke complaint. The success of the application and Dr. Frasch's efforts may be appreciated from the fact that the refinery has undergone frequent extensions to keep pace with demand, until to-day it is the largest, using the sulphuric anhydride treatment, in the world.

CHAPTER X

THE OIL REFINERY AND ITS WORK

THE refinery is where a remarkable miracle of industry is wrought, where the uninviting crude petroleum is forced to resolve itself into its numerous component parts, each of which possesses a distinct commercial value. Crude oil, as such, is virtually useless. It may be consumed as a fuel, but that represents approximately its limit of application. As current knowledge reveals, this is about the most wasteful purpose to which it can be put, because, even after every ounce of the oleaginous contents have been extracted, the residue constitutes quite as good a fuel as the raw material.

As the conjurer is able to produce rabbits, flowers, birds, and other objects from an ordinary hat, so can a wide and varied range of substances be drawn from petroleum, and with apparently equal mystery. The magician is the chemist. Accordingly it is not surprising to learn that the skill and knowledge of the scientist are at a heavy premium in the oil-world. Although this indefatigable worker has revealed the ways and means of obtaining a vast range of products from the mineral liquid, his task is by no means completed. He is toiling more diligently and strenuously than ever in the hope that he may be able to make some more unexpected discoveries, thereby enhancing still further the value of, and dependence of the community upon, oil. His task has become extremely difficult, for the simple reason that the quest has been narrowed down to very fine limits.

The process employed to reduce the crude oil to its various component parts is known as "fractional distillation," which is quite distinctive from destructive distillation, although the latter, too, is embraced, especially in the later stages of reduction. As the term implies, the process is the resolution of the crude into its fractions, or elements, of constitution. The principle governing fractional distillation is that different liquids, under a common pressure, boil, and consequently evaporate, at different temperatures. If one took, say, three liquids, the boiling-points of which were 80°, 90°, and 100° F. respectively, mixed them together, then placed them in a still, and heated the mixture gradually, the first component would release itself in a gaseous form when the temperature attained 80°, the second would follow suit at 90°, and the third at 100°. If these three vapours were led into different receptacles, and there were condensed, the three original constituents of the mixture would be obtained.

The same effects take place to a certain extent when oil is submitted to gradual heating, only petroleum is not split up so definitely and readily. Other factors intervene which tend to render the process somewhat complex. Petroleum is composed of ingredients which possess the curious property of dissolving one another, and, as a matter of course, it is not a simple task to isolate the various components. One fraction, as it comes over in the gaseous form, is associated with varying quantities of each, or some, of the other constituents of the liquid. The foregoing is essentially a broad explanation of the principles governing the process of fractional distillation. So many factors and actions enter into the subject and process, that to attempt to set forth a fully comprehensive and lucid detailed description of what occurs under the application of heat would only confuse the ordinary reader.

Crude oil may be said to be distilled into three broad groups: the inflammable, the illuminating, and the lubricating oils respectively. Each of these series contains a number of smaller fractions, which, in due course, are reclaimed. Thus the inflammable oils include petrol or gasolene, benzine, and benzoline, which are broadly classed as the naphtha group. The illuminating oils include all those which, as the name implies, may be employed for lighting purposes, the paraffins, or kerosenes; while the lubricating oils comprise the heavier viscous and semi-solid, as well as the wax, products.

The crude oil flows into the stills, where, directly its temperature is raised by the heat from the furnaces, it commences to evaporate. Petroleum contains one or two constituents—cymogene, rhigolene, etc.—which have a low boiling-point, and are extremely volatile. Thus cymogene boils at 32° F., which is the freezing-point of water, while rhigolene boils at 62° F. These, accordingly, escape at an early period. Owing to the low temperatures at which these two constituents evaporate, they are virtually gases, and accordingly are classed as petroleum ether. They are far too volatile to be caught and condensed in an economic manner, it being possible to resolve them into liquid forms only by the application of pressure. In view of this difficulty to condense and render them sufficiently stable for ordinary commercial need, they are generally permitted to escape from the still to be conducted to the furnaces, where they perform a certain useful function by undergoing combustion to contribute to the heating of the stills. Their commercial application is extremely limited, being restricted to freezing machines to produce cold by rapid evaporation.

The first serious step to recover the evaporated products is made when the temperature reaches 140° F. At this point the petrol, or gasolene, escapes. This is the most volatile commercial element of the naphtha series, which comprises all products evaporating between 140° and 338° F. At the latter temperature the paraffin or kerosene products, grouped under the heading of illuminating oils, change to gas, and continue until a temperature of 424° F. is reached. The oil remaining in the stills, which has become increasingly thicker and denser as the more volatile constituents have been driven off, is classed generally as lubricating oils.

It may be explained that, although the thermometer plays an important part in the distillation process, its utilization is confined for the most part to the action of evaporating the ingredients of the crude oil. As the gases escape from the still and pass through the condensers, they assume the liquid form once more, and here they are divided into fractions, according to their specific gravities or densities. The specific gravity of an oil is the ratio of weight of a unit volume of oil to the weight of the same volume of water. For the determination of this point another instrument, the Baumé hydrometer, is employed, and the specific gravity is given in Baumé degrees, the specific gravity of water in this instance being taken as 10° Baumé—in fact, the reading of this apparatus, which gives the specific gravity or density of the distillate, as the condensed liquid is called, constitutes the standard means of deciding the commercial value or classification of the refined oil products. The lighter oils have a high reading on the scale, while the heavier have a lower value. Thus, for instance, the petroleum ether, composed of cymogene and rhigolene, has a specific gravity, ranging between 0·590 and 0·625; petrol or gasolene, 0·636 to 0·657; while the succeeding naphthas vary from 0·657 to 0·775. At the other end of the scale come the lubricating oils, the specific gravities of which range from 0·850 downwards.

As the more volatile products are the first to evaporate under the application of heat, so they are the first to be resolved once more into the liquid form when passing through the condensers. The latter are connected to receivers, or, as they are termed, "cut" tanks, so called because the flow of the liquid can be intercepted or "cut," and diverted from one tank to another as desired. On this part of the run the oil often traverses what is known as a "sight" box, which, owing to the provision of suitable transparent windows, enables the flow of the distillate to be observed.

The action of separating the distillate into its broad groupings is simple. The outflows from the condenser of several stills lead to one point. Here is stationed an operator called the "stillman," equipped with a hydrometer and a thermometer. The first keeps him in touch with the specific gravity of the flowing distillate; the second shows a record of temperature. By means of the latter he is able to instruct the firemen to increase or slacken the fires as required. From this point the pipes extend to the "cut" tanks, each of which is designed to hold the distinctive grade of distillate.

In order to reduce the process of distillation to its simplest form, we will suppose that the distillates are to be resolved into three broad groups or series. The stillman, directly the flow commences, tests the liquid with his hydrometer. The reading shows that the naphthas are coming over, and accordingly the liquid is turned into the designed receptacle. Frequent tests with the hydrometer reveal the fact that the specific gravity of the distillate is falling steadily, proving that the most volatile compounds of the crude oil are becoming exhausted, although there is no diminution in the volume of distillate flowing. In due course the hydrometer gives the reading indicating the line dividing the inflammable from the illuminating oils. The operator shuts off the flow to the naphtha tanks, and sends it into another series of receptacles, because the illuminating oils are now being yielded. The distillate is still watched closely, and hydrometer tests made at frequent intervals until the specific gravity reaches the line of demarcation between the illuminating and lubricating oils, when the flow of distillation is diverted once more, since the lubricating oils now are being produced.

But each of these three broad groups not only contains its particular grade of oil, but also the constituents of the other two groups to a greater or lesser degree. Moreover, although the first distillate is classed as the "naphthas," it has to be split up further, generally into five subdivisions, or fractions. To achieve this purpose, each group is subjected to a further distillation by steam, and as the distillate runs, it is turned into the various tanks successively, according to the hydrometer readings. The illuminating oils are

FIRING THE STILL.

The regulation of the heat constitutes a vital factor in the distilling process.

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" AGITATORS."

Owing to the products of distillation, or "distillates," being of an unmarketable colour, or containing certain adverse components, they are submitted to a cleansing process. In these towers the oil is associated with concentrated sulphuric acid, and a powerful air-blast is driven through the mass, which sets up chemical actions and reactions.

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subjected to a similar treatment to secure subdivision, and any oils lighter than 0·800 are driven off and added to the first distillate.

The oil remaining in the still, after the naphthas and illuminating oils have passed over, is chilled, and then broken up into various fractions. The process, which may be called a freezing one, causes the paraffin present to crystallize. This semi-solid mass is placed in canvas bags and subjected to intense pressure, which drives out all the loose oil which may be present. The third distillate fraction is subjected to a variety of processes, including chemical treatment, filtration, further refining, and so on, for the purpose of extracting every oleaginous fraction, while the residue itself is treated and re-treated until nothing more can be recovered.

The distillate fractions thus obtained possess a colour which reacts against their marketability, or contain certain components which militate against their successful use for the purposes intended. These defects are eliminated by subjecting the products to chemical treatment. The oil is passed from the "cut" tanks into what are known as "agitators." These are upright cylinders having conical-shaped lower ends, and capable of receiving several thousands of gallons of oil in one charge. Concentrated sulphuric acid is associated with the oil, and a powerful air-blast is driven through the contents from above. The deleterious substances in the oil, under the action of the air-blast, exercise a striking affinity for the acid, and a series of chemical actions and reactions occur.

This treatment causes the contents of the agitators to thicken and to assume a black colour. Finally the mixture in the vessel is left to stand to allow the contents to settle into layers of oil and "sludge" acid. The latter, being a sediment, is drawn off from the bottom, and is either subjected to a process to regain the sulphuric acid, or else is utilized in the manufacture of fertilizer or other chemical productions.

Upon the removal of the sludge acid, the oil is taken to another vessel to be washed with water, and then enters a further tank to be scoured with an alkaline solution, which removes all the remaining traces of free sulphuric acid, and simultaneously neutralizes any acid salts or other bodies which may be present. Then the alkaline solution is allowed to settle and be drawn off. As a rule this represents a waste product, since the process of recovering the alkali is not sufficiently cheap to be profitable. The oil is now conveyed to another tank to undergo a further washing with water to eliminate all traces of alkali, after which it is drawn off into settling tanks. It is now ready for market, although it may be subjected to further distillation, sometimes to resolve it into further fractions, or be treated with steam in a still to be reduced.

Although fractional distillation is the principal process in refining, destructive distillation is adopted also, especially in connection with the distillate remaining in the still after the full range of illuminating oils have been driven off in the course of fractional distillation. At this point the fires heating the still are slackened, with the result that the process of distillation proceeds more slowly. The vapours given off by the remaining heavy oil do not pass into condensers, as in the case of the lighter products, but condense upon the chilled surface of the dome of the still. The beads of liquid then fall back into the hot retort to be re-evaporated. In this second vaporization, however, the liquid suffers decomposition, and is induced to yield other substances, some of which are much more volatile than the gas which was previously given off and condensed upon the dome of the still. This cycle of conversion from liquid to gas, and reconversion from gas to liquid, is continued for a prolonged period, with the result that a large volume of gas, the predominating ingredients of which are methane, or marsh gas, and hydrogen, is produced, which, after condensation, can be added to the naphthas, together with a distillate which coincides with the specific gravity demanded for illuminating oils, while, thirdly, there is a heavy tar-like residue, known as "residum," left in the still. The last named is passed to the tar-still, where it is heated and passed through air condensers, at three points of which, coinciding to the places where condensation has developed, it is trapped and drawn off. That caught at the first trap is a distillate yielding paraffin wax, the second represents an article between wax and illuminating oil, while the third comprises illuminating oil. By the time this process has been completed, the last remnants of the crude petroleum, from which every vestige of the oleaginous ingredients have been extracted, resemble the residue from the coal-gas retorts, but somewhat blacker in colour. This is known as " petroleum coke."

The process of destructive distillation as described above is known as " cracking." During the past few months a great deal of attention has been devoted to " cracking " in connection with various processes for the production of the more volatile elements of petroleum from heavy oils, but in the main these processes are far from being new, since the method is in daily operation in all the largest oil refineries of the world. In these latest developments improved apparatus and methods may enable a higher proportion of the volatile constituents to be derived, but the fact must be borne in mind that the volatile fractions must be present in the oil subjected to such treatment, otherwise they cannot be derived in paying quantities any more than oxygen can be extracted from carbonic acid gas. Knowledge of this fact is responsible for the complacency with which the leading refining companies view these various developments, since the chemical skill, which by virtue of capital resources is at their command, enables them to keep pace with every development, and to appraise its commercial value.

The output of the various constituents of petroleum from the refinery is governed in a great measure by commercial demands. For instance, in the early days, the lighter fractions—that is, the naphtha group—commanded only a very limited market; in fact, the petrol or gasolene was a waste product, being sold in very limited quantities.

The pioneer motorists remember the days when motor fuel had to be purchased from the chemists or drug stores, and when the request for more than a pint of the spirit occasioned consternation. The refineries, in fact, regarded these fugitive spirits as an unmitigated nuisance. Their extreme inflammability restricted their possible applications very severely. The lighter fractions as a rule were collected, and at frequent intervals were dumped into a pit and ignited, to burn harmlessly away. On the other hand, the demand for paraffin or illuminating oil taxed the refineries to the utmost.

That day was the vogue of the paraffin lamp, and this oil earned the popular sobriquet of the "poor man's light." The consumption of paraffin reached an enormous figure, not only in the United States, but throughout the world.

Then came a sudden change. Baron von Auer invented the incandescent gas mantle, and an enormous fillip was given to the gas industry. The gas companies embraced the idea of supplying gas upon the prepayment or coin-in-the-slot principle, and offered to equip dwellings with fittings free of expense to the tenant. The dangerous and inconvenient paraffin lamp had been tolerated for years, because there was no alternative. Directly the new movement in connection with coal-gas supply came into being, the working-man adopted it without hesitation, because of its increased safety, cleanliness, and simplicity. When the idea was applied to cooking, the fate of paraffin, so far as the city dweller was concerned, was sealed. Even in the rural districts the oil-lamp fell out of favour. Mechanical ingenuity contrived a perfectly safe, simple, and cheap lamp in which petrol or gasolene could be vaporized, and be used in conjunction with the incandescent gas mantle, as if it were ordinary gas, and in this manner a more brilliant light was rendered available at a lower cost. Electricity and acetylene also have played their parts in effecting the complete supersession of the oil-lamp, which to-day is to be found only in the homes of the rural dweller and the unenlightened aborigine.

The transformation was as remarkable and as complete as it was sudden. The refineries, which had been devoting their energies to the production of paraffins upon a huge scale, and which had reaped enormous profits for the simple reason that this product is one of the easiest and cheapest to distil from the crude oil, in which it exists generally in large proportions, were caught with enormous stocks on hand, and for which the market was undermined completely. The price of the article fell to a ruinous figure. In order to reduce these accumulations, some refiners declined to supply any other petroleum products unless a certain quantity of paraffin were taken as well, the unwilling purchaser being left to his own devices in regard to its effective disposal. More often than not the latter used it wastefully, seeking reparation by increasing the price of the products which were in demand. Whilst the price of paraffin is now on the upgrade, this tendency is not due to a revival in oil-illumination, but because other sources of consumption have been created, such as, for instance, the paraffin tractor.

But the loss of the paraffin market was attended by a pronounced gain in another field. The high speed internal combustion engine demanded petrol or gasolene as a fuel. The naphthas, which hitherto had been the *bête noire* of the refineries, were offered an attractive market. The waste product came into demand, and to such an unexpected degree as to out-distance supply. This demand is more acute to-day than ever, and can be met in one way only. Slowly, but surely, the specific gravity of motor spirit is being lowered, because the highest grades are being derived in diminishing quantities, owing to the changing character of the crude. The paraffins are being subjected to repeated distillation in order to induce them to yield every drop of the more volatile spirit; in fact, it is not improbable that, twenty years hence, the three broad groupings of the distillates will be merged into two classes—the naphthas and the lubricating oils. The present-day higher-grade oils in the illuminating series will be turned into the inflammable class, while the lower or heavier oils of this group will be merged with the lubricating oils. In other words, the refineries will devote their energies to the production of inflammable, or explosive, and lubricating oils respectively. Such a development will only be in accord with the laws of supply and demand as expressed by the market.

CHAPTER XI

WHAT WE GET FROM PETROLEUM

WHAT do we get from petroleum? If this question were submitted to the average individual, probably he would produce a list comprising a round half a dozen articles—those with which he is most familiar, such as petrol or gasolene, naphtha, paraffin, or kerosene, and lubricating oils. True, this catalogue would be fairly complete, but it could be dismissed as imperfect, since it would indicate only the broad groupings of the series of products. It is not conclusive, for the simple reason that each classification is divided and subdivided to meet the requirements of exacting commerce. As a matter of fact, over 200 different products are derived from petroleum, each of which commands a distinct marketable value, but the majority of which are unknown to the general public, because they are utilized as substitutes, or in little-known industries, such as medicine and the manufacture of aniline dyes.

One would not be far wrong if one expressed the opinion that the community to-day eats, drinks, and sleeps—in fact, exists—upon petroleum. The fact that a round 200 articles are obtained from this liquid mineral conveys a vivid impression of the varied requirements which the nauseating, unprepossessing, raw material is made to fulfil, and also of the immense demand that is made upon the chemist to fit the products for such an array of applications. It emphasizes the extreme dependence which the world at large is forced to place upon oil to-day. Mankind cannot possibly get along without it. It is the most useful and ubiquitous servant which ever has been revealed. It was not so many years ago that coal was regarded as indispensable to our existence. This situation prevails no longer. The world could roll along very comfortably without coal: it would not miss it if all the supplies were cut off to-morrow. But if the oil resources of the world were extinguished, the whole advance of civilization would come to a dead stop. Every mechanical device would be condemned to idleness: machinery cannot move without oil any more than the human frame can subsist without water. The unique value and indispensability of oil lies in the fact that, not only can it be made to fulfil every purpose for which coal at present is employed, but can be utilized for a host of other applications as well.

Perhaps the most familiar member of the naphtha group is that used as a fuel for motor-cars, which has become colloquially known as "motor spirit." But this is not the highest unit of commercial value in the series. This position is occupied by pentane, which has a specific gravity of 0·625, and which is regarded as the unit of light measurement, the term "one candle power" being the illumination emitted by a pentane gas flame. The remaining members of the group of inflammable oils following motor spirit are subdivided into three broad classes, known respectively as "*A*-naphtha," "*B*-naphtha," and "*C*-naphtha," according to their specific gravities, and, incidentally, inflammability. *A*-naphtha embraces the range lying between 0·680 and 700 specific gravities. This is used mostly as a fuel in spirit lamps and stoves, both in its untreated distillate form, and when purified or deodorized; while it is an excellent solvent for resins in the preparation of varnishes, and also in the manufacture of oilcloths, as well as being a fuel for aeroplanes and racing automobiles. *B*-naphtha includes benzine (not the benzine derived from coal in gas manufacture), the deodorized spirit which is extensively used in pharmacy, as well as in the chemical laboratory, laundry, and clothes-cleaning trades, and is the representative motor spirit of to-day. The *C*-naphtha, with its specific gravity falling between 0·730 and 0·750, is used largely as a substitute for cheap grades of turpentine in the printing, dyeing, and painting industries. - white spirit

The second group of distillates comprises all the oils which are used for illuminating purposes—that is, in lamps for the emission of light, whether it be a humble glimmer in the bedroom, or a brilliant penetrating beam cast from a lighthouse to warn those who move on the seas. In this instance extreme confusion prevails, owing to the various names given to one product. It embraces all the members having specific gravities between 0·744 and 0·820, and may be defined as the paraffin or kerosene series. While paraffin ranks as a German discovery, having first been obtained from wood-tar in 1830 by Baron Reichenbach, it was the Englishman, Mr. James Young, who, in 1850, placed its production upon a commercial basis, and who was the first to refine it from crude petroleum and from coal, as described in a previous chapter.

The market value of paraffin is governed not only by its specific gravity, but also by colour, flash, and burning points. The colour difficulty is removed by purification and redistillation, the ultimate article ranging in line from water-white, which grade constitutes the hall-mark of excellence in illuminating oils, to a distinct yellow tinge. The flash and burning points are far more important. The flash point indicates the lowest temperature at which the oil will emit a vapour, which, upon mixing with the air, will form an explosive or combustible compound when brought into contact with a naked light or some other form of ignition. It is a critical factor, because thereby the element of safety to the user is determined. In Great Britain the number of fatalities arising from the explosion of paraffin oil, as used in the household lamps, prompted a Government inquiry. Here the whole subject was threshed out thoroughly, and with a view to determining a safe flash-point. A temperature of 73° F. was finally decided as meeting the case, and accordingly an Act was drawn up governing the storage, carriage, and hawking of oils emitting inflammable vapours below this temperature.

Those above this danger-point were free from such restrictions. Subsequently another investigation was held to consider the advisability of raising the flash-point, and this commission recommended that it should be increased to 100° F. The burning-point represents the temperature at which the body of oil can be ignited, and which, when fired, will burn freely and continuously.

The flash and burning points vary with the quality of the oil. Generally speaking, the flash-point now varies from 120° F. upwards, while the burning-point lies between 150° and 300° F. The water-white oils, or paraffins of lower flash and burning points, are those generally used, the higher grades being reserved for special purposes where a readily ignitible oil is not desired, such as, for instance, in lighthouse illumination. Oil lighting, however, is disappearing rapidly in the household, owing to the cheapness and facilities attending the consumption of gas in connection with the incandescent mantle, and to the advances of electric lighting. Even in lighthouses the demand is decreasing rapidly, because it is being displaced by dissolved acetylene, and also by resort to vapour gas in conjunction with the incandescent mantle, whereby a more powerful, penetrating, and brilliant light is procured at less expense.

The higher, or more refined and purer, grades of paraffin are being used more extensively as substitutes. Thus we have mineral sperm, mineral colza, and mineral seal oils, which are cheap substitutes for the genuine articles derived from the respective fish and vegetable kingdoms. They are not as good as the original articles, as they are deficient in their outstanding properties, but, owing to the high price of the genuine substances, they constitute fairly effective make-shifts.

Paraffin in a highly purified and deodorized form is becoming more extensively utilized in the medical world, while at the moment interesting experiments are in progress to adapt it for comestible purposes. Vegetable oils dominate the last-named situation at the moment, but chemical science expresses the opinion that mineral oil eventually will be made quite as suitable for the required purposes. The difficulties so far have been connected with the complete removal of taste and odour, as well as the solidification of the product. A low melting-point is demanded, and if this can be achieved by chemical agency, the utilization of paraffin in this field is assured, particularly in the manufacture of artificial butters, confectionery, and various other domestic edibles.

The last group, that of the lubricating oils, is probably the most productive of materials adapted to the exigencies of commerce, apart from the lubrication of machinery. An efficient lubricating oil must possess high viscosity, high flash, and burning points, as well as a low setting-point. The means of obtaining these oils and their adaptability to specific purposes are extremely varied. The lightest are really the heaviest in the illuminating series, and are generally submitted merely to a filtering operation. The varying degrees of heavier oils are derived by submitting the oil remaining, after the first and second main distillates have passed over, to further distillation, so as to drive out all remaining particles of inflammable and illuminating oils, extreme care being observed to prevent cracking. In the case of paraffin oils, a heavy contribution to the lubricating series is obtained by taking the wax from the tar stills, freezing it, and then submitting it to enormous pressure, which has the effect of causing the paraffin remaining in loose suspension in the wax to be expressed.

From the lubricating series an extensive array of products are derived. When the heavy oil known as "cylinder stock" is passed through a suitable filter, vaseline results, the colour of this article depending upon the extent of filtration. The article is then combined with a certain proportion of paraffin to impart the necessary consistency and melting-point. Ointments, salves, and drugs are also associated prominently with petroleum products. The American chews petroleum the whole day through, his inseparable companion, chewing gum, having a petroleum-wax base.

The waxes obtained from the tar stills are utilized in various ways. The traces of loose paraffin are removed by submitting the wax to pressure, dressing with chemicals, sweating, and dissolution in naphtha. The sweating is the most simple process. The wax, in the form of cakes, is disposed in trays in a room which is gradually heated to a certain degree. The loose paraffin, having the lowest melting-point, becomes liquefied, and drips away to be collected, this heating process being continued until the requisite degree of separation is obtained.

In the arts and manufactures this wax plays a very prominent part. Its recovery upon an extensive scale assisted in the relegation of the tallow dip and its noisome light to the limbo of things that were. It gave the world the wax candle, cleaner to handle, emitting a brighter light, improved wick dispensing with periodical snuffing, and absence of smell during combustion. In its pure form, however, the wax is not sufficiently stable, so a proportion of stearic acid is added, and in this way the tendency to soften and to bend while burning and in hot weather, is overcome. The textile industry absorbs immense quantities of this material for finishing soft goods, while the laundries are also appreciable consumers, the wax being utilized to impart the lustre or polish to the linen articles of attire, such as collars and shirts.

The perfume spray is an indispensable attribute to my lady's dressing-table, but the fragrant spirit within would be unobtainable but for petroleum. Paraffin wax is used for the purpose of absorbing the scent from the flowers in the process of enfleurage. Preserved fruits with their coverings of crystallized sugar are appetizing and toothsome, but their attractive appearance is due to paraffin wax. In the match-making industries the consumption of wax attains a huge figure, both for the wax and wooden articles. In the former the cotton fibres are consolidated with this material, while in the second instance the small wooden sticks are dipped into a solution to become impregnated therewith, so that combustion may be assured. Innumerable other applications might be cited, the foregoing being only a few of the foremost in the fields in which this commodity is in demand. There are numerous other industries in which the wax is used upon a limited scale.

By mixing petroleum products with animal oils, what are known as " compound oils " are produced. In this instance the fields of utility are practically illimitable. Such blending, not only with oils from the animal and vegetable kingdoms, but with a variety of other materials, provides a range of combinations which is almost infinite. New developments are being revealed every day, and, commercial practicability being assured, the triumphs pass from the laboratory to the manufacturing fields. In this particular sphere the chemist and scientist have extraordinary opportunities, of which they are making the fullest avail.

Waste in the oil refinery is unknown. What the -un initiated might consider as being useless, the refiner turns to profitable account. For this reason the term " residuum" or " residue," which represents the solids remaining after the volatile products have been taken away, is a misnomer. In the case of the paraffin oils a coke is all that is left after the process has been completed. As already mentioned, this forms an excellent fuel, but there is a far more profitable application available. This is in the manufacture of the carbons for electric arc-lights, and this industry absorbs the major part of the yield. In the case of the asphaltic oils, asphalt remains in the stills after the volatile products have been evaporated. Road-making absorbs this residue. This material is not only rapidly displacing the ordinary metalling used in macadam road construction, but is threatening to supersede the natural product from the Pitch Lake in Trinidad. Curiously enough, the latter cannot be used for road-making purposes without the former. The residuum from the petroleum still has to be used as a flux, as explained in another chapter.

The Mexican petroleum residue is challenging the Trinidad product very aggressively. The possibilities of this material, and the fact that road-building engineers are realizing that road-construction methods demand revision to meet modern conditions, have been responsible for increased attention being devoted to the preparation of the asphalt for this purpose. Mexphalte is not a residue in the accepted sense of the word, but is subjected to special treatment in order to provide a solid pure bitumen. Roads have been laid in Europe and the British Isles with this material, produced from Mexican petroleum, and the advantages of the substance, as compared with stone and wet rolling, have been revealed. Not only is the road more durable, will withstand the heaviest wear and tear arising from the most severe traffic without disintegrating, is dustless and noiseless, but maintenance charges show a pronounced reduction.

The pure bitumen which accrues from this special treatment of the asphalt residue also commands an individual market, being in demand for the manufacture of cables, for the transmission of electricity, as well as for telegraph and telephone purposes. Even what may be described as the fluid residue resulting from the preparation of the solid bitumen is not wasted. It is used for dressing ordinary roads to lay the dust evil. Fluxphalte, as this material is termed, contains 60 per cent. of solid pure bitumen, which when deposited forms a resilient, durable, and also noiseless asphaltic covering to the road surface. Gas tar was formerly employed for this purpose, but the outcry against the substance and the devastation the poisonous matter associated therewith wrought upon plant as well as fish life in streams and rivers brought about its abolition. Fluxphalte performs the same office in a superior degree; its prime cost is no heavier than tar, while, owing to the longer life of a dressing, it is cheaper in the long-run.

In the early days of refining what may be termed the "residues" were abandoned, because their commercial values were not appreciated. Creosote was used to a certain extent by farmers, who dipped their fence-posts in the liquid to give them a longer span of life, rotting being arrested, but that was approximately the only use made of the material. Creosote still is used, but nowadays it is regarded as one of the lesser products.

The coal-gas manufacturing industry is generally advanced as one of the most remarkable triumphs of chemical discovery and application, owing to the quantity of by-products obtained, and their commercial values. But the oil industry is far more extraordinary in this respect; it ranks as a far more impressive illustration of human activity, and the harnessing of skill and knowledge. The fact that a round 200 articles are derived from this liquid mineral is convincing testimony on this point. The refiner turns every content of petroleum to commercial account—except the smell.

CHAPTER XII

OIL AS A ROAD-MAKING MATERIAL

One of the most widely discussed problems of the moment is that of the design, construction, and maintenance of public highways of communication, both in city and rural districts. The methods evolved and perfected by those master road-builders, the Romans, which have been followed more or less slavishly through the centuries, no longer suffice. Their handiwork was adapted to the relatively slow-moving and light pedestrian and animal-drawn traffic. But the times have changed, and methods must change with them. The perfection of the internal combustion engine has enabled mechanical traction to supersede all other forms of transportation upon the highway, the surface of which, unable to resist weight combined with rapid motion, disintegrates severely and speedily under the ordeal imposed.

It is generally admitted that the whole art of road-making must be revolutionized. But the question is—How? The bogie of expense is disturbing. The reconstruction of the principal highways of a country, in order to meet modern conditions, would involve such an enormous outlay that even a Haussmann would shrink from tackling the question. The engineer knows how to solve the problem effectively, but if he proposed a comprehensive scheme to this end, the estimated cost would provoke such an outburst of adverse opinion among the ratepayers, who would have to meet the bill, that the daring promoter would be hurried into oblivion. It would be useless to argue that "first cost would be last cost"; the public is not sufficiently enlightened or far-seeing to appreciate the significance of this line of reasoning. Accordingly, the road-building engineer is compelled to make haste slowly, and, it must be confessed, the pace is very slow indeed.

The motor conquest of the highways, however, has brought about a curious situation. Oil in one form represents the destructive force of the present highway; in another guise it offers a completely successful constructive element. The volatile constituents of petroleum constitute the fuel for the explosion motor; the sediment or residue, known as "bitumen," obtained from distillation, offers a road-building material which is capable of withstanding the wear and tear set up by oil-driven traffic.

But it is not necessary to utilize the residue from the refineries for this purpose. Nature herself has come to the assistance of the engineer; she is making and delivering a ready-made material which is well adapted to the purpose. The reserves of this article are adequate to rebuild all the main highways of the world. The source of supply is the island of Trinidad, the principal depressions in which are filled with asphalt. While these do not constitute the only known beds of this substance, veins of asphalt being found in California, South America, and other oil-yielding countries, yet they are the most remarkable, and the only expanses to be worked upon a commercial basis.

These resources of Trinidad were discovered by Sir Walter Raleigh, and he christened the main expanse Pitch Lake. The name is appropriate, because it resembles a sheet of water in many respects. The situation of this asphalt storehouse is about half a mile from the sea, and it has an area of about 127 acres. Large pools of water, streams, and rivulets, fed from the thermal springs, intersect it in all directions, while it is freely dotted with islands clothed with tropical vegetation, imparting a very picturesque appearance to the spot.

Pitch Lake certainly ranks as one of the many wonders of Nature, and it was regarded purely as such until the middle of the nineteenth century. Then one or two enterprising spirits suggested the idea of extracting oils from the pitch by submitting it to a refining process. But the yield of volatile constituents was so meagre, and the cost of extraction so high, that the endeavour proved financially impracticable, especially when natural petroleum-wells were sunk in other parts of the world. Once more the Pitch Lake reverted to a curiosity, until scientific investigation revealed the fact that, owing to its peculiar composition, the asphalt offered a first-class road-making medium.

Spasmodic effects to turn it to account in this new field were made, but they were not very promising, recalling somewhat the working of claims by primitive means in a new gold-field. In 1871 an American company decided to exploit the lake upon a comprehensive scale, and approached the British Government for the requisite concession. The latter, recognizing the opportunity to improve the island's treasury, discussed the project. An equitable and mutually satisfactory export duty and royalty basis were prepared, and a concession for twenty-one years was extended. With their characteristic energy, the Americans laid down a plant, including tramways, aerial railway, and a jetty, alongside which steamers could be loaded. Simultaneously, the advantages of Trinidad Lake asphalt for road-making purposes were advertised far and wide, with the result that the trade expanded rapidly, until an annual output of 150,000 tons of asphalt was attained at the end of the concessionary period. During the twenty-one years of its activity the American company excavated and shipped 2,210,586 tons from the lake, from which the Government derived an aggregate revenue of £735,962 ($3,679,810). In face of such a result, it is not surprising that the authorities granted a renewal of the concession, especially as the outlook was particularly attractive. As new sources of consumption were created, the output of pitch increased steadily, no fewer than 208,000 tons being exported during the year 1913; while there is every indication, owing to the extended use of asphalt for road-making, that this figure will be doubled within the succeeding decade.

There is another curious feature of this lake which compels attention: It gives every evidence of being inexhaustible

As rapidly as the pitch is withdrawn it refills. Several hundred tons may be removed in the course of a day, yet thirty-six hours later the excavation will be recharged to its original level. The lake may be described as a huge funnel, the rim being formed of a substantial rocky ridge, which elevates the level of the lake 138 feet above the sea, the spout extending into the interior of the earth, where the pitch is formed, and which, under enormous pressure, is forced to the surface in a steady, never-ending stream. Evidences of this pressure are afforded by the numerous gas bubbles breaking through the water of the thermal springs. The asphalt itself, in a soft condition, is driven upwards through these pools, with the result that the expanses of water are continually changing in area and shape, while the islands are in constant movement from one point to another.

The aggregate of the deposit is merely a matter of conjecture. In 1894 an effort was made to sound the centre of the lake by means of a drill. Asphalt was traversed to a depth of 135 feet, but without touching the bottom, and the asphalt at this depth was similar in every respect to that found upon the surface. Consequently the bowl must be filled with many millions of tons of uniform asphalt, and it is certainly the largest known natural deposit of this material in the world.

Seeing that the pitch is being expelled from the bowels of the earth in a constant steady stream, one might naturally imagine that the lake would be so hot as to be unapproachable. This is not so. One may walk about the surface without experiencing the slightest ill-effects. The exposed area of pitch has the same temperature as the surrounding air, except at noon during the intensely hot tropical summer, when it may reach 130° F. or more. Furthermore, the soft pitch—that which has been recently forced to the surface—is no hotter than the solidified parts of the deposit.

The main constituents of this raw asphalt are three in number, and they are approximately of equal proportions. Crude bitumen preponderates, representing 39·3 per cent.;

water comes second with 29 per cent.; while mineral matter averages 27·2 per cent. It is the presence of the inorganic matter and its intimate association with the bitumen which renders this lake asphalt such an excellent road-paving material. The mineral matter is in an extremely finely divided condition. Evidently Nature is operating a huge mill in the depths of the earth, smashing, grinding, and pulverizing the mineral constituents to the consistency of flour, then mixing and kneading them thoroughly with the molten bitumen, finally delivering the resultant product, when the requisite uniformity has been attained, through the spout to the surface of the lake.

The pitch is excavated from open surface workings by native labour. Only the pickaxe is used, and with this the mass is broken easily into irregular shapes and sizes, as if it were a kind of coal, although it does not powder. It is dumped into trollies and transported to the refinery, which has been erected on one side of the lake. The pitch is not subjected to a refining process comparable with that followed generally with oils, but rather is boiled without being cooked, the object being to drive off the superfluous water. Seeing that the crude asphalt contains about 30 per cent. of moisture, the preliminary heating materially reduces the unremunerative bulk. For some purposes, however, the crude pitch is shipped direct from the lake, subsequently being refined as required.

Care has to be observed in this preliminary heating that the temperature is not raised to an excessive degree, otherwise the bitumen is ruined. The refined lake asphalt is designated "epuré," and is shipped in cheap wooden barrels without ends. The package is cheap and flimsy, costing about 2½d. (5 cents), and is used merely to facilitate handling. In this purified form the pitch is slightly plastic, having the consistency of soft india-rubber, but clean to handle, as it is not adhesive. Every cargo of lake asphalt which leaves the island of Trinidad carries a certificate of origin, issued by the local Government, which serves as a guarantee to the purchaser.

The United States of America are the largest consumers of this product, Great Britain taking about 25 per cent. of the annual output. In the former country it is being used more and more extensively for road-making, particularly in the towns and urban districts; while it is being utilized more widely for a similar purpose in these islands. In fact, its application in the United Kingdom is undergoing extensive and rapid development, long stretches of main country roads being paved therewith.

In the epuré condition the proportion of bitumen is 55·62 per cent., the mineral matter aggregating 36·85 per cent., and insoluble organic matter the balance of 7·53 per cent. But in its refined form it is useless for paving purposes. The peculiar traffic conditions which prevail demand a road surface with the maximum of resiliency, immune from disintegration when submitted to pressure from passing heavily laden and rapidly moving vehicles, combined with durability, and, above all, capability to be consolidated. At the same time it must be sufficiently plastic to facilitate application, and must maintain its characteristic elasticity under all and varying conditions of weather and temperature. To secure cementitiousness, cohesiveness, body, and stability, the epuré asphalt has to be combined with a bituminous oil flux. The latter is the residue from the petroleum stills. Fluxing has to be carried out with extreme care, because upon its successful completion the excellence of the final product vitally depends.

The epuré asphalt is dumped into a large tank, and is heated slowly. The temperature must not be raised above 320° F., or there is grave risk of the bitumen being burned and its inherent properties destroyed. The flux is likewise heated slowly in another tank until a temperature of about 175° F. is reached. The proportion of flux to asphalt varies considerably, this factor depending upon the purpose for which the material is required, and where it is to be used. When the constituents have been duly heated, the flux is run slowly into the tank containing the molten bitumen, where it is subjected to continuous agitation at a maintained temperature, until the two ingredients are combined both chemically and physically. Then the product may be drawn off for immediate use, or barrelled until required.

The methods of road-making with this material are broadly identical in America and Great Britain, slight modifications being made to meet local conditions. If the roadway has to carry motor-bus and similar heavy traffic, a firm, solid, and stable foundation is essential, as in the case of the ordinary water-bound macadam highway. This foundation consists of a layer of what is called "asphaltic concrete," 3½ inches in thickness. The base is made of silica of fine grade, Portland cement, and granite, or clinker from the dust destructor, broken up so that the largest pieces will pass through a mesh of 1½ inches. The materials are crushed and heated separately. They are then weighed to secure the requisite proportions, and dumped into a tank containing the necessary quantity of refined bitumen which has been duly fluxed. This mixer is fitted with revolving shafts on which knives are mounted, and the ingredients are speedily worked up and combined thoroughly, 9 cubic yards being produced in ninety seconds. The asphaltic aggregate, as this mixture is called, is drawn off into tanks mounted upon motor-vehicles, for conveyance to the spot where it is to be laid. Motor-traction has transformed this industry, because now it is possible to supply aggregate over a radius of thirty-six miles from a central point, the aggregate retaining its heat for eight to twelve hours after mixing. Upon reaching the site the mixture is laid, while in the heated condition, to the desired thickness, and consolidated thoroughly by road rolling.

The durability and stability of the wearing surface depends essentially upon this foundation. If this be of insufficient thickness, and is consolidated indifferently, the road surface will develop holes and ridges, instead of maintaining the smooth, level face which is required. The wearing surface consists of a layer of fluxed epuré bitumen, 1½ inches in thickness, likewise applied in a heated condition, and thoroughly compressed by road rolling. This layer acts as a kind of cushion, giving slightly, like india-rubber, when heavy vehicles pass over it, and returning to its original contour after the weight has been released. This resiliency, prevailing under all conditions of weather and temperature, constitutes the salient characteristic of this paving medium. It insures the reduction of wear and tear of the supporting surface to the minimum. For roadways carrying light traffic the substantial foundation of asphaltic concrete may be eliminated, a top layer of asphalt macadam, varying from 1½ to 2 inches in thickness, being laid upon the existing water-bound macadam surface; while in the case of thoroughfares subject to medium traffic, the thickness of this surfacing asphalt macadam, varying from 2½ to 3 inches, either may be laid directly upon the existing macadam, or, if the conditions do not permit of direct application, the surplus material of the latter is removed, the base compressed by heavy rolling, and the top layer then applied.

The consumption of Trinidad lake asphalt for road-making purposes, both in the United Kingdom and the United States, undoubtedly would have attained far greater proportions but for the appearance of a competitor, which promises to become formidable in character. The opening up of the Californian, Texan, and Mexican oil-fields, the petroleum of which is of an asphaltic base, has released vast quantities of bitumen. The possibility of utilizing this oil residue for paving purposes naturally occurred to the refiners, but the chemical analysis revealed a marked diversion from the constitution of the natural asphalt, while in addition there was the absence of the finely divided mineral characteristic of the natural article. However, elaborate experiments were undertaken with a view to constructing by artificial means a material similar in every respect to that yielded by Nature in the Island of Trinidad. Success was achieved, and stretches of roadways in different parts of the world were laid therewith to ascertain its wearing and other properties under actual conditions. These trials have proved completely satisfactory, and the road made thereof is stated to be equal in every respect to that laid with the natural asphalt.

This development has been of far-reaching importance, as narrated in another chapter. It has opened a new field for the use of asphaltic petroleum. Road oil has certain advantages over the Trinidad material. In its fluid form it can be used as a dust-layer, in which application it is effective; while the denser constituents may be prepared in the manner of the Trinidad asphalt, worked into a concrete, and laid in a similar way. The consumption of road oil has already attained huge proportions. In California and Texas the highroads are dressed with the oil; while the Southern Pacific Railway uses it to lay the dust upon the whole 2,600 miles of its system between San Francisco and New Orleans, a special appliance for spraying oil upon the track having been devised. In these two States the solid residue is worked up into the asphaltic concrete, and the majority of the roads in the leading cities and towns are paved therewith. In fact, it was the coming of the petroleum asphalt, which is produced in vast quantities by the Californian refineries, that put an end to the working of the natural asphalt deposits which exist in California, the former being found to be the cheaper medium. Petroleum asphalt is also making great headway in the British Isles, the consumption thereof in this one field advancing with remarkable strides.

During the past two or three years an interesting development in connection with this system of road construction has taken place. Formerly a contract for asphalt road construction was handed lock, stock, and barrel to a concern specializing in this work, but now another method is coming into vogue. The local authorities contract only for the supply of the aggregate in a heated condition. This is laid and the road completed by local labour under the direct supervision of the borough or municipal engineer. This procedure is rendered feasible by the design of a portable plant, comprising crushers for reducing the materials to the required size, furnace for heating the ingredients, and a mixer. This installation can be set up easily and speedily at any desired point, and the material can be delivered to the local road-building authority ready for application.

The simplicity and straightforward character of the process has brought about a further development in this connection. Municipalities and civic authorities having a considerable mileage of roads under their control, have decided to carry out the whole work themselves by direct labour. A certain initial outlay is incurred in the acquisition of the necessary plant, but this is not a serious item, and its cost is recouped within a short time. Subsequently there is only one expense—the purchase of the necessary asphalt ready for mixing. Consequently, in this manner, practically the whole of the money expended upon road-paving benefits the labouring element of the district or town.

This last-named tendency deserves to be fostered, and should be extended. Every town and city should possess its asphalt concrete-mixing plant. At the present moment nearly every municipality possesses its dust destructor, and the asphaltic concrete-preparing installation can be combined with it. Every effort is made to render the destruction of garbage as remunerative as possible, by the utilization of the heat produced to generate electricity, but economy is far from being realized. The residue from the destructor, the clinker and ash, represent an unmarketable product. It accumulates rapidly, and as a rule is given away, but even then it is wellnigh impossible to avoid the formation of huge unsightly dumps, especially in the case of large towns and densely populated boroughs.

By acquiring and adopting the asphaltic concrete road-making plant this vexatious problem is solved completely and profitably. Dust destructor clinker and ash forms an excellent ingredient for asphalt aggregate. Asphalt is generally conceded to be superior to any other form of road-paving material. At the moment cities and towns expend large sums annually in the purchase of metal for the water-bound macadam roads, and wooden blocks. By embarking upon a comprehensive road reconstruction policy, using the dust destructor clinker, this expense could be saved. It would be possible to dispose of the residue effectively and profitably, and in the long-run the community would be able to show a pronounced saving in its road-paving operations. Even the pavements could be laid with it, the paving either being made of clinker and asphalt compressed into large slabs, or made up continuously in the manner of the road.

In making the asphalt road there is no great demand upon skill and knowledge. The process for the most part is automatic—that is, so far as the preparation of the aggregate is concerned. The great advantage accruing from the acquisition and operation of a system as described would enable about 90 per cent. of the money voted for road-making and maintenance purposes to be distributed among the people contributing to the expenditure in the form of rates. In other words, road-making could be converted into a local industry, which is far from being the case at present. The heat-retaining qualities of the aggregate, motor traction, and ability to serve a radius of thirty miles or so from a central point, are overwhelming factors in favour of the practice. The time is not far distant when a road-making plant will be considered as an indispensable adjunct to the local dust destructor.

Some enterprising and far-seeing British municipalities have realized the significance of this practice, and have such installations in operation. The innovation is proving more than self-supporting. The roads of the district, built upon this principle, have achieved an excellent reputation, and a waste product has been turned to profitable account. Highways built in accordance with this principle are cheap to maintain, noiseless, easy to clean, dustless, and prevent that bugbear of motor traction, side-slipping. All things considered, it is evident that the busy thoroughfare of the future will be a combination of the worthless refuse clinker and asphalt, either from the natural pitch lake in Trinidad, or from the petroleum refineries.

CHAPTER XIII

OIL FIRES AND THEIR EXTINCTION

WHILE a "strike of oil" is almost certain to introduce Fortune in her most attractive garb, the fickle goddess does not leave the forces of undoing at a distance. Wealth and ruin generally stalk hand-in-hand through the oil-field. If one is able to keep destruction and devastation away, the stream of oil flowing to the refinery and tanks builds a substantial pile of gold in the bank. But if fate should be unkind, then Good Luck vanishes sky-high in a column of dense, black, suffocating smoke and lurid belching flame.

The oil producer and refiner are haunted night and day by one remorseless enemy. This is fire. It may be a flash of lightning, a match carelessly thrown to the ground, a spark generated by a flying piece of rock striking a metallic part of the derrick, or some other untoward incident which reveals the lurking fiend. In any event the result is invariably the same. The gas hovering above the well, or enveloping the top of the tank, is fired, and then there is a blaze beside which a building in flames is a match-flicker.

The losses incurred by the oil industry during the course of the year amount to millions sterling. In the United States alone they are estimated at 1,500,000 barrels a year. At 50 cents a barrel, which is a reasonable quotation, this represents $750,000, or £150,000. Although the most elaborate precautions are observed, and the rules and regulations concerning the handling of the oil from the moment it gushes from the earth are strict, and despite the fact that every device that human ingenuity can contrive to extinguish a fire in its incipient stage is adopted, the fiend seizes the first opportunity to assert its destructive powers.

Human effort counts for little; it is puny when pitted against such blind force.

The tank is perhaps the most susceptible to the attacks of this demon, while lightning is the most terrible foe. But so far as the tank is concerned, losses may generally be mitigated, because the seat of the fire is confined to the surface of the oil, owing to oxygen in the surrounding air being available to support combustion. A tank fire as a rule is not regarded with very grave concern. If an empty tank is available in the vinicity, 90 per cent. or more of the oil will be salvaged. The pipes for charging and emptying the tank enter the latter at the bottom. Consequently, the moment a tank is fired, the pumps are set to work, and the oil is withdrawn and run into another tank. In this way very little oil is left to feed the flames, which die out after licking up every drop of remaining fuel.

Of course, if no tank should be available to receive the oil, then the store of crude is doomed. Under such circumstances the situation assumes a far more serious aspect. The intense heat of the flames causes the steel walls of the receptacle to curl like paper; the oil is released, and runs in all directions, forming gushing rivers of flame. Then the problem is to restrict the movement of the blazing mass, so that neighbouring tanks and buildings may not be engulfed. By the aid of earthen embankments, which serve to dam back the flood, and the liberal use of steam jets, this end may be accomplished as a rule, though at the expenditure of enormous energy and activity.

It is the gushing oil-well which precipitates such a feeling of intense dismay. The spouting column of combustible liquid is converted into a fountain of flame. The conditions favour a devastating conflagration. The oil, spreading out in the form of a large plume, becomes finely divided, and an abundance of air being immediately available to support combustion, and the rushing oil maintaining this plume, the fire is at liberty to rage freely. The lower part of the column gives slight evidence of being aglow, since it is somewhat similar to a Bunsen burner. The stream of oil, perhaps 8 or more inches in thickness, is homogeneous. The air cannot penetrate the mass, so combustion is rendered impossible, although the main stream is surrounded by a ring of blue flame where the air comes into contact with the surface of the oil column. But at 30 feet or more above the mouth of the well the flame asserts itself, and grows in intensity and volume thence to the uttermost edges of the plume.

An oil fire is a terrifying spectacle, whether it be a tank or a gusher. In the case of a tank, the flame, being confined to the surface of the oil, does not reveal its actual extent or ferocity. Dense clouds of jet-black suffocating smoke are emitted, and completely envelop the tank, except perhaps on the windward side. Consequently one is unable to approach the conflagration. The smoke drifts away with the wind, and often will envelop an area of fifty to a hundred square miles. The hot gases lift the unconsumed carbon to a high altitude, where they spread fan-wise, and will often form a trail twenty miles in length, imparting an appearance strongly reminiscent of a sulphurous London fog. In one of the big fires at Bayonne some years ago the smoke-cloud was observed thirty miles at sea, and was dispersed finally by a heavy rainstorm, which precipitated the unconsumed floating particles of carbon.

The gusher is more awe-inspiring, because it resembles nothing so much as a volcano in eruption. The shaft of flame, opening fan-wise as it reaches the crest, is a living mass of fire at the plume, twinkling vividly through the dense ruffs of smoke which are emitted. In the Baku district the damage wrought from fires has been incalculable. Millions of gallons of oil have been lost as a prey to the flames, and it has been no uncommon circumstance for four spouters to be in full fiery blast at one and the same time. The roar may be heard for miles, and the flames often are so brilliant in their intensity as to illuminate the surrounding country as clearly as the noon-day sun.

Fire is extremely difficult to avoid on a new oil-field. The lack of facilities for storing an unexpected yield contributes to this state of affairs. In the leading oil-producing districts the men are fully aware of the risks from fire, and accordingly outbreaks are comparatively few and far between; but in new territories prudence is thrown to the four winds in the mad haste to get rich quickly. This was particularly the case in connection with the opening of the Texan oil-fields. The Texas " strikes " created wild rushes. On the Spindletop Field, which is somewhat limited in area, 220 derricks arose in a brief span of time, and were planted so closely together that they almost touched one another. Trenches were dug hurriedly to carry the oil to huge open-air reservoirs, formed by hastily contrived dykes, and pipes were laid to supplement the conduct of the petroleum to the storage facilities. But it was a striking illustration of the penalty attending a frenzied boom. The banks of the reservoirs leaked; the pipe lines were so imperfectly jointed that bursts were frequent; while even the open sluices became blocked by earth falls. Oil ran wild; the ground was so saturated that it could not absorb another drop, pools and puddles lying everywhere.

The Texan oil-boomers learned a terrible tesson. One night a workman had occasion to inspect a settling tank. A lamp guided him, but the door of the lantern was left unfastened. The gas in the tank came into contact with the flame. There was a terrific explosion, and a moment later the interior of the tank was a seething furnace. The force of the detonation hurled burning oil in all directions, some falling upon adjacent derricks, which, being similarly oil-soddened, afforded excellent meat for the flames. A 4,000-barrel tank caught some of the flying oil, and within six hours was nothing but a collapsed mass of twisted metal. For two weeks the conflagration raged fiercely, and devastated the most valuable part of the field, extending over ten acres.

The oil seekers, ignorant of the most effective methods of combating oil fires, deluged the burning area with water, which only made matters worse, because the flames were not quenched, but were forced farther and farther outwards on all sides, being picked up and floated while burning fiercely upon the rivulets of water. The "ten-acre" fire, as it was called, practically burned itself out, and virtually devastated the district, ruining fully one-half of those who had tempted, and had almost wooed, Fortune. The outbreak was mastered only by the erection of an earthen wall around the doomed area, which successfully prevented the escape of the oil.

The Spindletop Field was within an ace of being wiped out when one of the early gushers came into being. Had it not been for the presence of mind of the spectators, disaster, swift and sudden, would have overwhelmed it. Some oil lying on the ground became ignited. There was a roar; but instead of the spectators fleeing in terror, they rushed forward, hastily divesting themselves of their coats, and smothering the flames before they had secured a good hold. In the Hogg Swayne Field such good fortune did not ensue. The oil caught fire and leaped from derrick to derrick in a startling manner. Drillers hastily abandoned their wells; the pumping staffs stampeded in a wild mêlée. Within a short time numerous derricks were cracking torches. This conflagration swept the field with such startling suddenness that twenty men, trapped while at their work, fell victims to its ravages.

Water in reality is the most dangerous agent with which to combat an oil-fire, unless the outbreak is small. The oil floats upon the water, and may easily be carried out of bounds. Upon an organized oil-field buckets of sand are distributed liberally and within easy reach. Sand is not only cheap, but also an effective means of extinguishing an incipient fire. But the only weapon which is of any reliable service is steam. The jets are hurled upon the flames by means of force pumps, and unless the gusher is a big one the fire is smothered. But the demands upon the steam-raising plant at times are exceedingly heavy.

In Louisiana a rich well was struck, and was yielding about 20,000 barrels of petroleum per day. Unfortunately, although care had been observed in driving and equipping the well, a breakdown occurred. Machinery was ordered by telegraph, and the men strove might and main to control a heavy leak of oil. While engaged in this duty a severe thunderstorm broke out. The superintendent realized the gravity of the situation. The crude oil was exceptionally inflammable, as it contained about 20 per cent. of naphtha. The labourers wrestling with the leak—" greasy men " they are termed—were soaked from head to foot with petroleum. They were ordered to stand by the leak, but at the same time to keep one eye upon an adjacent stream of water, into which they were to plunge if a flash, as was considered probable, struck the well. The expected happened: the well was fired by lightning, and the " greasy men " had a narrow escape. Instantly the combat against the outbreak commenced, since, owing to the height to which the flames were leaping, due to the pressure of the gases in the well, neighbouring property was seriously endangered. Twenty-five steam boilers were hurried out of the nearest city. Connection was made with an adjacent natural gas well to fire the boilers and raise the steam. Within a short time a battery of steam jets were directed against the burning well, but the conflagration was extinguished only after a desperate forty-eight hours' struggle.

As may be supposed, a tank farm is an exceedingly dangerous spot, owing to the enormous quantity of oil under storage. A violent thunderstorm is liable to cause a holocaust, as well as wreak gigantic losses. Consequently, elaborate precautionary measures are provided. The general method nowadays is to lay a network of high-pressure water and steam pipes throughout the farm, with plugs for the connection of hoses at frequent intervals, and in such a manner that the whole of the extinction forces available may be concentrated upon any one spot. Around the rims of the tank, on the outside, a sprinkler is fitted, while other similar pipes are installed within. If the tank catches fire, the outside sprinkler pours a heavy stream of water down the exterior of the tank, thereby keeping the metallic fabric cool, while simultaneously high-pressure steam spurts from

THE WORLD-FAMED "DOS BOCAS" ABLAZE.

This fire was one of the most terrible in the history of oil. This Mexican gusher caught fire immediately after it came into activity. The flames leaped to a height of 1,000 to 1,500 feet, the glare being visible 200 miles out at sea. Over 4,000,000 gallons of oil spouted forth daily and were consumed. The fire defied all attempts at extinction, and finally burned itself out.

By courtesy of the Oil Well Supply Company.

A BLAZING PETROLEUM WELL.

The derrick has been consumed, and from the mouth of the borehole to about one-half the he'ght of the column is a roaring mass of flame.

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the sprinklers within the tank. In this way a fire generally can be extinguished with comparative ease, especially when the oil is drawn from the bottom simultaneously, and turned into other tanks. Special emergency staffs, trained in fire-fighting, are retained under a capable chief, and, being expert in this peculiar work, it is seldom that a serious fire ever sweeps a farm. It may be pointed out that, owing to the unusual conditions and character of the task, the oil-fields have developed a race of what may be described as expert oil-fire fighters. These men, from their remarkable successes, have achieved a peculiar reputation, and accordingly are in great request, not only in the United States, but also throughout the whole American continent, in waging war against this relentless and devastating enemy.

The most destructive and baffling fire which has ever overwhelmed the American oil-fields, at least within recent years, was the monster gusher in the Caddo fields, North-West Louisiana. This catastrophe was remarkable in many ways. In the first place it was the most prolific spouter of high-grade oil which had been struck upon the continent, if not in the world, the naphtha content being unusually high; secondly, the flow was estimated at some 25,000 barrels a day. It is computed that during the fire, which lasted twenty-five days, oil to the value of $1,000, or £200, per hour was lost. In the second place, it offered exceptional resistance to efforts of the fire-fighters, and was only overcome by dint of tremendous exertion; while, thirdly, it is notable for the ingenious method by which success was eventually achieved.

The well was driven by the rotary drill to a depth of 2,300 feet, and on May 12, 1911, oil was struck in such volume that it poured out of the 6-inch borehole at the rate of 1,000 barrels an hour. The oil was accompanied by a huge flow of gas, which caused the liquid to burst high into the air. But the rush was brought under control, and the men were engaged in shutting down the flow by means of a gate-valve. Suddenly there was a terrific explosion. The four "greasy men" at the valve, soaked to the skin with oil, were hurled to one side as a sheet of flame spurted upwards. One man was killed on the spot, and his three comrades were burned severely. The cause of the explosion was never ascertained, but it is divined that the gas, being heavier than the air, spread along the surface of the ground for a considerable distance until it came into contact with a lighted cigarette. The force and report of the explosion was so tremendous that it was felt and heard for a considerable distance round.

In the course of a few seconds the well was burning furiously, and it was realized that herculean efforts would have to be made to save it. Steam extinction was the obvious remedy, but the character of the fire revealed the fact that a tremendous pressure and volume would have to be brought to bear upon the flames. No fewer than thirty-six boilers, each of 40 horse-power, were brought up and disposed in batteries. The steam was led through 4-inch hoses, and the men handling the nozzles, approached as closely as they could to the fountain of fire and smoke. The flames were leaping 100 feet into the air, and the smoke, being seen from a distance of twenty-five miles, attracted hundreds of people to the scene. Labourers were recruited by the score. They toiled in day and night shifts, firing the boilers and performing numerous other duties at a wage of sixty cents—half a crown—per hour, because the speedy extinction of the fire was the primary consideration in order to minimize the loss of valuable oil. Some of the men laboured for no less than thirty hours continuously, which indicates the severity of the conflagration, and the arduous nature of the work of extinction.

The situation was aggravated by the fact that within a short time the well was spouting more oil than the flames could consume, the result being that the ground was being deluged with streams of boiling petroleum. The combined output of the thirty-six boilers were concentrated upon the flames, the steam being discharged at a pressure of 120 pounds per square inch. Six days were occupied in the preliminary preparations, and the spectacle when the steam was turned on was awe-inspiring in the extreme. The noise was ear-splitting; the screech of high-pressure steam mingled with the roar of burning and escaping gases. The heat was terrific at the point where the man stood directing the steam jets—so hot, in fact, that special pumps had to be set going to keep the firemen drenched with cold water. The jets were poured from all sides, and for ten minutes the battle raged. The flames grew whiter and whiter, and the firemen, stimulated by these symptoms, redoubled their efforts, because victory appeared in sight. But just as one and all thought that the fire was dying down, the flames gave a terrifying leap upwards, and once more became masters of the situation, compelling the men to withdraw, utterly defeated.

The firemen voiced the opinion that they had been beaten in the initial effort because the lines of hose were laid upon the ground, whereas they should have been elevated, so as to drive the jets of steam into the flames at the point of maximum intensity and combustion. Trestles, colloquially termed "horses," were hurriedly contrived, as well as a number of screens, which the men pushed before them in their advance towards the flames to secure protection from the intense heat. By elevating the jets the steam was concentrated above the valve mouth, from which the oil and gas were pouring. Another titanic struggle raged for ten minutes, but the flames declined to be extinguished. They died down as if retreating, and then burst forth with redoubled fury. The firemen, caught unawares, scampered to a safe distance before the rush of boiling oil.

Water was now brought into service with the idea of drowning the boiling oil and smothering the flames, but the effect was negligible. To make matters worse, the metallic portions of the derrick had collapsed over the valve, shielding the latter from the action of the steam jets. This débris had to be removed. But how? In the neighbouring city there was an old muzzle-loading cannon which fired a 4-inch ball shot. This was brought up, and nine rounds were discharged at the débris, the men hoping that the bombardment not only would drive the latter to one side, but would knock the gate-valve off the casing. The artillery fire did more harm than good. The valve resisted the onslaught, but the casing immediately below was punctured in two or three places, and the oil, having additional outlets, caused the fire to rage more furiously than ever.

Steam and water proving of no avail, a bold expedient was recommended. This was to drive a ditch and tunnel at an angle towards the well, uncover the casing some distance below the valve, tap the flow, and flood the well with water, thereby depriving the flames of fuel. At a point 208 feet from the well the tunnel was started. It was 4 feet wide by 7 feet high, and was driven by pick and shovel through the hard clay at a slight angle dipping towards the well, so as to pick up the casing about 11 feet below the valve. Trees were felled and cut up to form props and roofing. But the work of the tunnellers was exceedingly arduous, especially upon the last 50 feet. The heat was so intense that the men had to be relieved every thirty minutes. The gallery was filled with turpentine fumes, given off by the green timber under the blistering and roasting action of the flames.

Despite the intensely difficult conditions, the well casing was reached and laid bare. Here what is known as a saddle, or split-clamp, was placed around the casing and made oil-tight. From this a 6-inch pipe was carried for 208 feet through the tunnel. The outer extremity of the pipe was fitted with a stuffing-box, while an inner length of piping, 4 inches in diameter and 210 feet in length, was inserted. This inner pipe was equipped with an acorn cutting tool, which was brought to bear upon the surface of the well-casing. On the outer end of this 4-inch pipe a sprocket was mounted, and this was connected by endless chain gearing to the driving gear of a drilling engine. In this way it was rendered possible to rotate the 210-feet length of 4-inch pipe with its cutter, and thus drill through the well-casing.

The casing comprised three pipes. The outer casing was

10 inches, the intermediate 8 inches, and the main casing, through which the oil flowed, 6 inches in diameter. The three pipes were drilled successfully, and the oil-flow, being tapped, was diverted through the horizontal lengths of 4- and 6-inch pipe, the total yield being 19,500 barrels per twenty-four hours. The oil flow being weakened in this manner, steam extinction was once more attempted, but too much oil was flowing vertically past the acorn cutter to enable the desired end to be achieved.

It was now decided to flood the well, thereby rendering it unproductive for the time being. Pumps were connected to the end of the 4-inch horizontal pipe, and water was forced into the well under a pressure of 1,200 pounds per square inch. As the oil and gas were issuing at a pressure of 900 pounds per square inch, the oil-flow was overcome. Considerable quantities of the water passed the acorn cutter, and flew out of the mouth of the well, and helped to deaden the flames. In order that the whole of the water should enter the borehole and drive the oil downwards, small balls of asbestos were made, placed in a trap, and were pumped into the well. These balls filled the space around the acorn cutter, so that neither water nor oil could escape upwards. After the vent had been choked in this way, the fire was extinguished in eighteen minutes. Muddy water then was pumped down the well, thereby killing it for the time being. The débris at the surface was cleared away, new lengths of pipe casing were sunk into position and connected to the existing pipes below the acorn-cutter, and the well rendered ready for reawakening. A section of pipe was run to the bottom of the borehole to agitate the oil and to set it flowing—"bailing in," as it is called. The flow now was under absolute control, but a test showed that it was coming out at the rate of 40,000 barrels per day. Owing to lack of piping facilities, the well was shut down to 10,000 barrels per day until thirty-five miles of trunk 8-inch pipe line had been laid and connected up.

This ingenious method of combating the flames, though somewhat expensive, was completely successful. From the moment the tunnel was commenced only fourteen days elapsed before the fire was quenched. But for twenty-five days the fire roared continuously, during which time it is estimated that over 30,000,000 gallons of high-grade petroleum, representing a value of over $700,000 (£140,000) disappeared in smoke, while the cost of extinguishing the fire was enormous.

But the most gigantic and the most terrible fire in the history of the oil industry was that which swept out of existence the first and biggest strike made in Mexico. The terrible fires which have ravaged the United States oil-fields sink into insignificance in comparison with it, while it even eclipsed the most terrifying outbreaks which ever have been encountered in the Russian oil-fields, famous though the Baku oil conflagrations have been. In 1908 the Pearson interests were probing for oil in Northern Vera Cruz. On July 4 the drillers were hard at work with the rotary rig. They had reached a depth of 1,820 feet, and the going was hard, since the drill was biting its way slowly through the very hard marl formation which overlays the oil sands. Suddenly the resistance was observed to diminish. The drill had entered the shale. Immediately a heavy gas pressure developed. Something abnormal had been encountered. The engineer supervising operations hurriedly ordered the fires of all the boilers to be drawn and douched, while all lights in the vicinity were extinguished.

The commotion in the well increased in violence, and frantic endeavours were made to master the situation. But the pressure of the pent-up gases, profiting from the vent offered, increased so rapidly that the drillers were frustrated. The wire-wrapped hose connecting the slush pumps with the drill-stem were burst by the gas. The oil commenced to flow, gathering in volume and velocity every succeeding second. "Dos Bocas," as the well was named, came to life with a vengeance. In the course of a few minutes oil was pouring out at the rate of 350 gallons per minute. Strenuous efforts were made to extricate the 4-inch pipe, but in vain. The flow of oil increasing in volume, the drillers were driven from the scene. In twenty minutes after the drill had bitten into the shale, the well was absolutely out of control. A river of oil, 8 inches in diameter, poured from the ground with such force as to hide the derrick from view.

It was evident that an unusual big strike had been made. The subterranean pressure was so enormous that the borehole was an inadequate vent. The ground around the well heaved, and fell as if riven by an earthquake. Fissures opened up from which gas and oil spurted in dense clouds. The heavy and substantial drill-pipe made a hurried exit, being broken up and hurled from the well in long lengths, some of which were hurled 150 feet into the air. The derrick was smashed to fragments. As if this devastation was not sufficient, the 8-inch well casing, which was anchored at the top, but not at the bottom, collapsed under the extremely violent agitation, and, falling into the hole, told the engineer only too plainly that no hopes of regaining control of the flow remained.

Meanwhile the area of the fissures had extended rapidly, until at last they broke up the ground beneath the boilers. Here disaster was completed. Although the ashes from the fires had been drenched with water, evidently a few embers remained glowing, because the gas and oil suddenly burst into flame. Instantly the most impressive and terrifying sight which ever had been witnessed upon an oil-field burst into activity. The column of oil, shooting high into the air, became ignited, while the huge crowning plume was converted into a living mass of flame and smoke. Nine days after Dos Bocas revealed its strength the flames were leaping to a height of 1,000 and 1,500 feet, and at the broadest part the fan of fire was 90 feet wide.

The unusual spectacle threw the natives residing in the vicinity into a state of abject terror. The roar and cracking was so deafening that it could be heard for miles, while at night the fountain of flame was plainly visible in Tampico, and was seen from 200 miles out at sea. In fact, navigators often mistook the light for that thrown from the Tampico lighthouse, which appeared to be a dim glim in comparison.

A newspaper could be read in the open by the glare of the fire at a distance of twenty miles.

The fire raged so furiously, and the heat was so intense, that approach within 300 feet of the borehole was absolutely impossible. The precise yield of the well never was known accurately, but competent authorities estimated that it exceeded 100,000 barrels—over 4,000,000 gallons—per twenty-four hours. The news of the huge fire spread rapidly, and hundreds of the curious hurried to the spot. Expert fire-fighters, who had vanquished conflagrations among the fields of the United States, hastened to the well to offer assistance, but the outlook, exceeding anything in character and immensity with which they ever had been confronted, appalled them. The beaten experts watched the spectacle in silence; but they did not hesitate to venture the candid opinion that human effort would never cope with the flames, and, as events proved, they were correct in their surmises, although from a different reason.

Notwithstanding these discouraging opinions, the engineers who had supervised the drilling-in of the well did not despair of conquering the fire. Steam extinction was out of the question, for the simple reason that it was impossible to venture sufficiently near the fire to produce the requisite effect. Another plan, therefore, was evolved. This assumed the form of a huge drag, made from the heaviest steel plates from a 2,000 barrel tank. These were riveted together, and weighted down with 30 tons of steel rails. This was placed on one side of the well, and steel cables attached thereto were carried round either side of the well and hitched to steam winches. The idea was to haul this weighty shield along the ground and over the mouth of the well, in the hope that the weight would be adequate to counteract the pressure of the oil and gas, so that the fire, unable to derive further fuel, could be quenched by steam jets or die out. This scheme might have proved successful if the ground around the well had not caved in, and, becoming filled with running oil, formed a huge crater. Some idea of the ferocity of this outbreak, and the titanic nature of the natural forces opposed to human endeavour, may be gathered from the fact that the crater developed into a yawning depression no less than 1,000 feet across.

The drag idea being rendered futile, another scheme was prepared. This was to drive a tunnel from a convenient point, at an angle of 45 degrees, towards the borehole. When the borehole was reached, a heavy charge of nitro-glycerine was to be laid and detonated. The resultant explosion, it was averred, would bring about such a displacement of earth that the well would become choked with débris, thereby sealing the borehole. But, unfortunately for this ingenious proposal, the ground caved in so seriously around the borehole that the possibility of driving the tunnel and successfully planting the mine was rendered extremely remote. Consequently, the idea of blowing in the well was abandoned.

In the meantime the Mexican Government had given assistance in a tangible form. An entire battalion of 450 sappers was despatched to the field and placed at the disposal of the engineers to assist in any scheme that might be undertaken to quell the fire, and in the arrangements for collecting the oil; while other forces were sent to maintain order, and to reassure the terrified natives in the neighbourhood. In addition to belching oil and gas, it is estimated that over 1,000,000 cubic yards of solid matter were discharged into the air, so that Dos Bocas was not only an oil-well, but a devastating miniature volcano as well.

The third attempt to extinguish the fire was drastic. It was resolved to run the risk of losing the whole of the oil-bearing ground in the vicinity. The crater was now a deep depression, and the fissures made by the escaping gas, oil, and caving ground were so deep as to conceal a man to the armpits. A battery of powerful pumps were set up on the banks of the Tamahua River, 2,000 feet distant, and they were set to work pumping water and sand into the crater, thereby converting the latter into a huge lake, the depth of which around the borehole would become sufficient to insure an adequate water seal. This scheme was actually started, but shortly afterwards Dos Bocas died a natural death. After burning fifty-eight days, the fire suddenly collapsed, owing to the exhaustion of the oil and gas supply from the earth, and because the vent was becoming choked with débris of all descriptions. But although the fire was extinguished, the well did not lapse into complete quiescence. The flow of oil gave way to one of salt water, which was estimated to average some 70,000,000 gallons during the twenty-four hours, and the temperature of which ranged from 160° to 170° F., so that the oil-well became transformed virtually into a prolific thermal fountain. But the fire completely changed the character of the surrounding country. What had been a stretch of undulating Mexican bush is now an immense area of water, in the centre of which Dos Bocas comes to life spasmodically, throwing a stream of salt water and gas into the air, recalling the geysers of New Zealand and the Yellowstone Park.

While it is estimated that over 50,000,000 barrels—more than 2,000,000,000 gallons—of oil, representing over £5,000,000, or $25,000,000, in value, were lost by this fire, the disaster was not without its compensating features. Hitherto Mexico had been regarded as an indifferent oil-producing country. This terrifying conflagration caused the attention of the whole oil world to become riveted upon Mexico. If a well could produce such a fire and send 1,000,000 barrels of oil into smoke during the twenty-four hours, then the country must be underlaid with incalculable deposits of oil. This was only a logical conclusion. An oil-rush set in, and this received a decided fillip when the Potrero de Llano No. 4 came into life, with a daily yield of 125,000 barrels. The flaring Dos Bocas was the greatest advertisement the country could have received. It discomfited the sceptical, urged the enterprising to further effort, and tangibly assisted in making Mexico the second greatest oil-producing country in the world, the resources of which have barely been touched.

CHAPTER XIV

OIL FROM SHALES: A BRITISH INDUSTRY

THE British Islands, as previously mentioned, are deficient in mineral oil resources. At all events, the deposits of petroleum which have been discovered are so meagre as to render their commercial exploitation unprofitable. But oil is found and is reclaimed from various substances—cannel coal, shales, and clays. James Young, the creator of the paraffin or kerosene industry, distilled illuminating oil from the cannel or boghead coal, which is found in the vicinity of Bathgate, Scotland. The derivation of oil from coals attained a certain vogue, being practised subsequently in the United States, while the process was adopted also in other parts of Great Britain. The price of the raw material at Bathgate rose to such a high figure, however, owing to the demands for the coal in other fields, that the process was rendered unremunerative, especially when the petroleum boom set in as a result of Colonel Drake's momentous discovery. Consequently the Scottish enterprise was abandoned. Distillation of oil from coal as practised in other parts of these islands was continued for a time, but with rapidly diminishing prosperity. The unsatisfactory nature of the products obtained finally brought about their gradual abandonment, and accordingly the practice of rendering oil from coal fell into disuse, although it has been recently revived.

While Young was engaged upon his line of research, a French scientist, Du Buisson by name, was striving to distil oil from shales, which abound in certain parts of France. The perfection of such a process was of vital importance to that country, seeing that France likewise has been ignored by Nature in regard to the distribution of petroleum. Du Buisson achieved a certain measure of success, and a new industry was created for the production of oils from shales. It became established in that country, and is prosecuted upon a limited scale to this day.

In the meantime a Scottish investigator, Dr. Robert Bell, had been attracted to a similar line of research. Immense quantities of shale exist in Scotland, and laboratory experiments revealed the circumstance that this black slaty rock possessed an appreciable oil content—sufficient to render the extraction thereof a commercial possibility. He continued his researches, and finally elaborated a process which he decided to test upon a practical scale. In 1859 he erected works at Broxburn, in close proximity to the extensive shale beds, and commenced operations. This was the first serious attempt which ever had been made to win oil from shales in Scotland, and it proved so successful that in 1862 the industry became planted upon a firm basis.

Dr. Bell's discovery appears to have been responsible for a kind of shale-oil boom. At all events, at one time some sixty firms were engaged in the task. But the industry has passed through many vicissitudes owing to the fierce competition offered by petroleum. The weaker companies came to grief, but the stronger concerns successfully resisted all efforts to bring about the extinction of the industry, and to-day it is in a highly flourishing position.

The shale-oil boom was never comparable in magnitude or character with those associated with petroleum, which startle the world from time to time. Rather the industry has grown slowly but surely. It has passed through many critical phases, and the periods of distress have been weathered only by the display of inventive ingenuity combined with shrewd financial management. One factor has contributed materially to the survival of the industry. The Scottish shales vary considerably in character and oil content. The Broxburn shales are generally admitted to be the richest in oil, and naturally proved to be the most profitable to work so long as oil alone was extracted. But

GENERAL VIEW OF THE PUMPHERSTON SHALE OIL WORKS.

ONE OF THE "HUTCHES" EMPLOYED FOR TRANSPORTING THE SHALE.

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as time wore on important discoveries and radical improvements were effected, tending to reduce the cost of production. One of the most striking of these developments was the ability to recover sulphate of ammonia in paying quantities as a by-product. Every farmer knows that sulphate of ammonia is one of the finest known stimulants for the ground, and the demand for this fertilizer always has exceeded the supply. The result is that steady prices constantly prevail, and, what is more vital to the issue, the price always has been somewhat high, having ranged for many years past about £13, or $65, per ton. The extraction of this commodity in paying quantities strengthened the Scottish shale-oil industry to a pronounced degree; in fact, it passed from being a mere by-product to a staple product, and as such it is recognized to-day.

During recent years the industry has experienced a period of prosperity, and the outlook at the moment, owing to the greater reliance which the world at large is placing upon oil, is certainly attractive. The present era of prosperity may be said to date from the early eighties, although intermittent waves of depression have been experienced. Such fluctuations are inseparable from any ramification of commerce. But in the shale-oil industry these spasmodic crises have been sufficiently severe to reduce the number of concerns engaged in the industry from seventy to six. These six companies, all of which are in operation and flourishing to-day, are united under the title of the Scottish Mineral Oil Association. This, however, is merely a combination for consultation and mutually protective purposes, not a fusion of the different companies, or a community of interests. There is no shale-oil trust, because each concern operates separately and independently. It is only when the industry as a whole is threatened by foreign rivals that unity is manifested to discuss ways and means of meeting unfair competition, and it must be admitted that in every instance the traditional Scottish "canniness" has proved equal to the occasion.

Among the six companies concerned in the industry at the present moment, the Pumpherston Oil Company occupies the foremost position, if only because it was founded by Mr. William Fraser, who is acknowledged to be the father of the modern shale-oil industry, and the leading authority upon matters pertaining to the distillation of oil-products from this mineral. At the same time it must be pointed out that the company whose destinies he controls deals with the largest quantity of crude oil produced by any single company in the United Kingdom. Mr. William Fraser, in collaboration with Messrs. James Bryson and James Jones, perfected a means of handling double the quantity of crude shale distilled per day by the evolution of a new retort. Prior to 1894 the retort adopted could handle only 3,300 to 4,400 pounds of shale daily. By means of the new retort devised by these gentlemen it was rendered possible to deal with at least 8,800 pounds of shale per day. At the same time they contrived ways of rendering the new retort self-supporting. In other words, they perfected a system of firing the furnaces with the incondensable gases given off by the shale during the process of distillation in such a manner as to be able to dispense with coal and other fuel. The latter was a notable achievement. It represented a tangible reduction in the cost of production by decreasing the fuel bill, and at the same time enabled distillation to be carried out with a smaller staff of men than had been possible hitherto.

The process of extracting oil-products from shales differs radically from the production of similar substances from petroleum, at least so far as the first stages of the operation are concerned. The oil first has to be won from the rock. The requisite installation comprises essentially the crude-oil plant, the sulphate of ammonia plant, and the oil and wax refineries, respectively. When one recalls the facility with which petroleum is derived from the earth, the crude drawn from the well coinciding with the shale excavated from the mine, because it represents the raw material, it will be realized that this Scottish industry is placed under a heavy initial handicap. It is easier, simpler, and cheaper to pump a liquid from the bowels of the earth, and to send it through pipe-lines to the refineries, than to mine a rock and to convey it to the stills. The fields where the shale is excavated cover thousands of acres, and to reduce the cost of obtaining the crude oil every possible time- and labour-saving appliance has to be introduced, many of these tools, by the way, being of special design. The shale, as mined, is dumped into the continuously travelling buckets of an aerial railway, or into the cars of the hutch railway, which constitutes the standard system of transportation. Upon arrival at the works, the shale is discharged into breaking machines, where the lumps of rock are reduced to the size most convenient for effective and complete distillation.

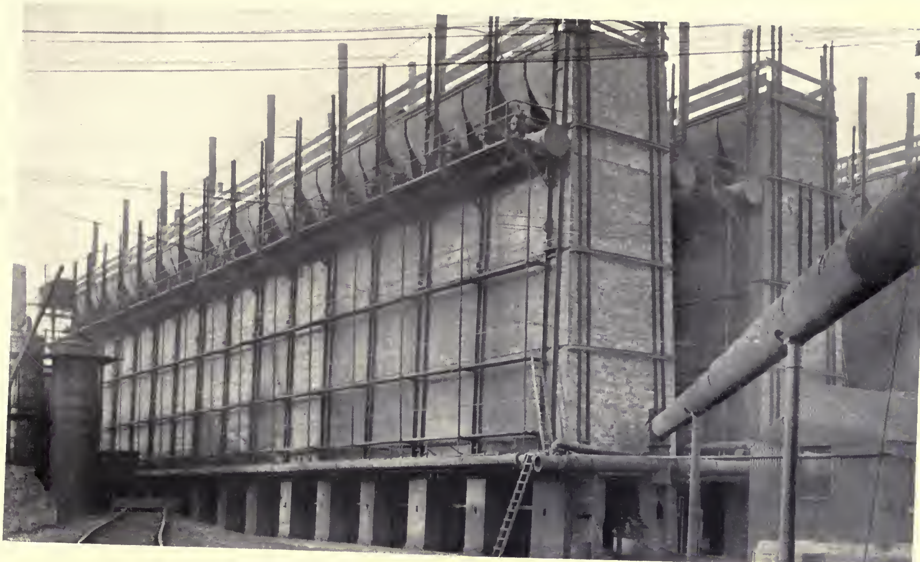
When crushed, the raw material passes to hopper-shaped hutches, each capable of receiving 2,200 pounds of material, which are conveyed to the top of the retort by means of an endless chain, running round an inclined scaffold. In the bottom of the hutch is a sliding door, which is operated by a lever. Directly this is moved the door opens, the contents are released, to fall into a magazine, or hopper, communicating directly with the retort. Each of these feeding-hoppers is capable of containing 8,800 pounds, or sufficient raw shale to keep the retort going for twenty-four hours.

In the petroleum industry the retorting stage is not necessary because the oil is ready for distillation as it issues from the earth. But in the shale industry it is requisite because the first step is the winning of the oil from the rock. In order to compel the shale to give up its oil-content destructive distillation has to be practised, so that preliminary retorting is peculiar only to this industry or other similar processes where oil is derived from a rock or clay.

The retort which is used at the Pumpherston Works, and which has wrought such a change in the industry, is of novel and interesting design. It is cylindrical in shape, and built vertically in ovens of four. The upper portion of the retort is of cast-iron. The whole retort is slightly tapered in form, measuring 2 feet and 2 feet 4 inches in diameter at the top and base respectively, while it is about 20 feet in length over all. The lower portion is built of fire-brick. Heat, generated from the gases thrown off by distillation and which cannot be condensed—when the shale is of poor quality and the yield of this fuel is inadequate, producer gas is added —is applied externally, and is caused to circulate round the retort by butt-brick, or stoppers, which act as baffles. The heating gas, associated with a certain proportion of air, enters the heating chamber, which envelops the whole retort, at the base of the brick section. Owing to the high temperature of the gases (1,200° to 1,600° F.) maintained in this section the nitrogen in the shale is converted into ammonia by the action of a continuous supply of steam, which is injected under slight pressure into the bottom of the retort.

The heating gases continuing their journey, and diminishing in temperature as they proceed, at last reach the upper, or cast-iron, portion of the retort. By the time they reach this point the temperature thereof has dropped to about 400° F., and the oil is thus distilled in the cast-iron section of the retort under a gentle heat. The oil-gases and the ammonia-gas are drawn off together by means of exhausters, and are led into the condensers. These are of the atmospheric type, and they condense the oil-gases into oil, while the ammonia dissolves into the condensed steam, forming ammonia water, the three substances—oil, ammonia, and condensed steam—being intermingled.

From the condenser the mixture flows to what is known as a separator tank. Here, owing to the condensed oil and the ammonia water having distinct specific gravities, separation occurs, the oil floating on the water. Consequently the individual constituents may be drawn off into separate receiving tanks. The uncondensed gases now undergo a "washing" in the ammonia scrubbers, to recover any remaining ammonia associated with them, passing afterwards through naphtha scrubbers, where the lighter gases, which could not be caught in the atmospheric condensers, are washed out with oil, and a good quality of the lightest, or naphtha, oils are thereby recovered. It is from this point that the gases which cannot be condensed are trapped to be



By courtesy of the Oil Well Supply Company.

A BENCH OF RETORTS AT PUMPHERSTON.

THE ATMOSPHERIC CONDENSERS AT PUMPHERSTON.

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consumed for heating the retorts. When an average shale is being treated, this supply of incondensable gases is adequate for heating purposes.

In the Pumpherston retort there is a remarkable arrangement for withdrawing the spent shale—that is, the rock from which the valuable properties have been extracted—in a continuous stream. It is a mechanical device, and it effectively keeps the whole mass within the retorts in constant movement, thus avoiding fluxing or "dandering" of the shale, with its attendant troubles and severe losses. Beneath each pair of retorts is placed a cast-iron hopper, fixed to girders supported by the brick piers or columns between each oven. A cast-iron disc, or table, is placed at the top and within each of these hoppers in such a manner as to come immediately beneath the bottom of the retort. An annular space is left between the edge of the table and the sides of the hopper. The mass of shale dumped into the retort rests upon this table. The latter is mounted upon a central spindle, the upper end of which projects above the table, to receive a curved arm which rests upon the table. This arm and spindle are revolved, the table remaining stationary, and in the course of revolution the arm pushes the shale towards and over the edge of the table to fall into the hopper below.

The lower end of the shaft carrying the curved arm is fitted with a ratchet and lever. This is moved by a bar or rod of T-iron, which has a horizontal travel, and which is driven by an electric motor through gearing. The motion is comparatively slow, the arm making only three complete revolutions per hour. In this manner the discharge of spent shale is controlled satisfactorily, while the throughput thereof may be regulated as desired.

The spent shale which collects in the under-hopper is discharged therefrom once every four hours into a hutch immediately beneath, this emptying action being completed by the lowering of a lid of conical form, generally known as a "bell." When this hutch is filled, the retort-man pushes it out on to the haulage, by which it is carried away and up an incline, to permit the contents to be dumped on to the waste heap or "bing."

The ammonia water which is recovered from the atmospheric condensers is pumped through a heater, where the temperature is raised by the spent, or waste, water flowing from the still. The ammonia water then passes to the still. This is of cylindrical shape, about 30 feet in height, and the interior is fitted with shelves, or trays, disposed at intervals of 2 feet from top to bottom. Each tray is connected to its fellow below by means of a seal-pipe, while there is a chamber attached which contains milk-of-lime. The ammonia water enters the still at the top and falls into the trays successively, while it also passes through the attached chamber. Steam is forced into the bottom of the still under a pressure of 40 pounds per square inch, and as it passes over the trays it collects the free or volatile ammonia. The water which has not given up its "combined" ammonia content is forced to do so as it passes through the chamber containing the milk-of-lime, the released gas being caught by the passing steam. By the time the water has reached the bottom of the still it has been compelled to deliver the ammonia it contains, and then flows into a concrete tank. This is fitted with a cast-iron worm, and constitutes the heater through which the ammonia water passes before it enters the still.

The steam, associated with the ammonia gas, which it has collected during its passage through the still, passes over into a lead-lined tank, or saturator, to bubble through holes in a lead worm disposed around the circumference at the bottom of a vessel containing sulphuric acid. The precipitate sulphate of ammonia produced by the chemical action falls into a well formed in the centre of the vessel base, where are placed two steam ejectors, which blow out the sulphate of ammonia, together with some of the liquor. This mixture passes into hutches having perforated bottoms, through which the ammonia liquor drains off on to a lead-lined table, and passes back to the saturator through a connecting pipe, the solid sulphate being left in the hutch. The hutch is picked up by an overhead railway, and carried to the drying or storage cells, after leaving which it is packed and is ready for market. The spent water is pumped to the spent shale heap, or bing, being filtered thoroughly during its passage before it is permitted to escape.

There is a special plant, comprising lead-lined tubs, or crackers, for dealing with the weak acid water recovered from the refinery. A quantity of acid water is run into these vessels, and is saturated with ammonia gas until it is near what is known as the "salting"-point. Then it gravitates into settling vessels to enable any tar carried over with the acid water to be separated. The clear liquid is drawn into the saturator, where it is speedily converted into sulphate and blown out in the manner previously described.

So far as the refining of the crude oil recovered from the shale is concerned, this follows broadly the process practised in the refining of petroleum, only it is perforce somewhat more complex and intricate. In connection with the Pumpherston plant four installations—at Pumpherston, Seafield, Deans, and Tarbrax respectively—deal with the recovery of the crude oil and the sulphate of ammonia from the shale. The crude obtained at these four places is pumped into railway tank-waggons, and transported to Pumpherston to undergo refining. In view of the success of the pipe-lines in other countries for the conveyance of the crude to the refineries, one might wonder why a similar method is not practised in Scotland. The explanation is that the Scottish crude oil is too viscous to be pumped at natural temperatures through piping.

The crude oil is discharged from the railway tank-waggons into large tanks, which are placed at a sufficient height to insure gravitational feed to the refining stills. Previous to refining the crude is allowed to settle for twelve to eighteen hours at a suitable temperature to secure the complete separation of any water which may be present from the oil. The water is drawn off, and the oil then is permitted to feed the central of a battery of stills. Fractional distillation ensues, the lightest oils, or fractions, in the series—that is, those comprising the naphthas and illuminating oils—being distilled over and condensed subsequently in a condenser immersed in a tank of cold water. As the water of the condenser becomes heated by radiation from hot coils containing the oil-gases, it is led off to be cooled, when it is used again, this cycle being repeated continuously.

After the more volatile oils have been driven off from the crude, the latter passes into the stills disposed on either side of the feed-still. Here further quantities of the lighter oils are vaporized to be condensed. The residuum, which is now far heavier and more viscous, passes into a third series of stills, where further distillation takes place. It will be observed from this process that the crude is made to give up every particle of volatile oils—those comprising the inflammable and the illuminating series—by successive passages through three stills. After the third distillation a very heavy oil remains, and this is passed into the cast-iron pot-still. Here the oil is subjected to heat and distillation until nothing but a dry residue remains. This is oil-coke, which constitutes an excellent fuel, and which finds a ready market, owing to its high percentage of fixed carbon and low yield of ash. It may be mentioned that, during the process of distillation, steam is forced into the stills in large quantities to facilitate the vaporization of the fractions, the water being separated from the distillates subsequently. Fundamentally the process of distillation does not differ very much from that practised in connection with the refining of petroleum. It is merely in details that any differences from the latter practice prevail.

The removal of impurities from the distillates is accomplished by the aid of chemicals and agitators. The oil is run into an iron vessel, where a certain proportion of sulphuric acid is added, and the mixture is agitated by a stream of compressed air. The contents are afterwards left to settle, the acid sludge and tar forming a sediment at the bottom, and the oil comprising the upper layer. The precipitate is run off, and the tar is separated from the acid sludge. The acid-treated oil is carried into another vessel, where it is

GENERAL VIEW OF A ROW OF STILLS AT PUMPHERSTON.

THE SWEATING HOUSES.

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neutralized by treatment with a solution of caustic soda, is once more left to settle to permit the soda tar to dissociate itself from the oil, the first named being drawn off to enable the recovery of the tar to be carried out, and the neutralized oil then is conveyed to another vessel, where all traces of chemicals are removed by washing.

The acid tars are subjected to steaming and washing treatments. The acid water thus obtained is sent to the sulphate of ammonia house for the manufacture of this fertilizer, whilst the tar is mixed with that derived from the soda vessels, and is used as liquid fuel for heating the stills, an air or steam jet being used for spraying it into the furnaces to secure efficient combustion.

A certain proportion of the oil which is distilled at the second, or green, oil stage—that is, from the stills on either side of the feed-still—is sent to the paraffin sheds to be cooled and to allow the scale to be extracted, so as to enable it to be manufactured into paraffin wax. This is an interesting process in itself. The oil, after passing through the stills and the condensers, is run into tanks, and allowed to cool to the temperature of the surrounding atmosphere. Subsequently it is subjected to a freezing operation. From the tanks the cooled oil is pumped into the inner chamber of a freezer, which consists of a series of four tubular vessels having inner and outer compartments. As the oil is passed into the inner compartment, anhydrous ammonia is forced into the surrounding vessel, or jacket. As this absorbs the heat radiated from the contents of the inner compartment, the oil in the latter has its temperature persistently lowered until it congeals or freezes, in which form it is a pasty mixture of liquid oil and solid crystals of wax. This plastic mass is pumped into filter-presses, where a portion of the loose oil flows away, while the wax is left in solid cakes. But the latter still contain a certain proportion of oil, and this has to be expelled. The cakes are delivered by conveyors to a hydraulic press. Here each cake is wrapped in cloth, and is placed on a metal shelf in the press. When the latter is fully charged the pressure is applied, and the remaining free oil is squeezed out, leaving a solid mass in the cloths.

These cakes, or slabs, are known as "paraffin," or "scale," but, being discoloured by a certain proportion of oil remaining which pressure cannot remove, its expulsion has to be brought about by what is known as "sweating." Steam heat is necessary to achieve this end, and the process is completed in sweating stoves, which are large brick apartments. The plant comprises large iron trays, which are provided with false bottoms of iron lattice-work, and sufficient water is pumped into each to cover the lattice bottom. The scale, which has been melted in a boiler tank after removal from the hydraulic press, is pumped into each tray until it attains a thickness, or depth, of 2 inches above the lattice. It is left to cool and settle into the solidified form once more. When this has been accomplished the water is run out of the trays, the doors of the stove are closed, and the temperature of the interior is raised gradually by passing steam through coils disposed on either side of the building. As the scale becomes heated under this treatment it expands and becomes porous. The discolouring yellow oil effects its escape from the mass, and, draining into the tray beneath the false bottom of lattice-work, is carried away.

After this oil has been removed sweating is continued to remove that proportion of the wax which has a low melting-point. Naturally, as this action takes place, the wax assumes a whiter colour and a higher melting-point. When the colour and melting-point have reached the required degrees, the temperature of the stove is raised rapidly by blowing steam through perforations in the bottom of the trays. This brings about the melting of the wax, which is run off in a fluid condition into suitable vessels, where it is subjected to further steaming with open steam, finally being permitted to cool and to settle. Any water which has become associated with the wax during this treatment becomes separated, and may be run off. The wax is pumped into another vessel, where it is mixed with a decolourizing powder, which eliminates the remaining traces of yellowness, finally being passed through a filter-paper and moulded to the required shape, size, and weight in special trays. It is once more left to cool and to solidify into a solid white cake, known as "paraffin-wax," and is then ready for the market.

The products obtained from shale oils are almost as varied and as numerous as those derived from petroleum. The most volatile fractions which are recovered range from motor-spirit to the lower grades of benzoline, and are used for the manufacture of varnish, as a substitute for turpentine, a solvent for india-rubber, in the seed-crushing trades, the manufacture of linoleums, oil-cloths, illuminant for safety-lamps, and so forth. The second group comprises the illuminating oils, which, by the way, are superior to those obtained from petroleum. The "pearline" oil has a very high flash-point, gives a clear bright light with freedom from smoke, and is eminently adapted to domestic consumption for lighting and cooking purposes. The safe nature of this oil may be judged from the fact that no accident ever has attended its use, although it has been extensively used for many years. At the heavy end of the illuminating group there is another series, described as "intermediate oils," which are excellent for cleaning metals, grease-making, gas-making and enriching, as well as for fuel purposes, and so on. The lubricating oils have very high viscosities in proportion to gravities, as well as a striking freedom from oxidation. These are valuable properties, and render them eminently suitable for blending with seed and animal oils, as well as with mineral oils of a different base. For this reason these oils are in pronounced demand for blending purposes, especially in the United States, where this practice has an extensive vogue in the preparation of synthetic specialities. The paraffin wax is of high purity, is tasteless, odourless, and colourless. It finds a ready market in the manufacture of candles, night-lights, tapers, matches, explosives, the water-proofing of papers, textiles, and fabrics, as well as for preservative wrappers. Its peculiar qualities have also rendered it highly valuable in connection with the production of foodstuffs, notably crystallized fruits, jellies, and chewing-gum, while it is not improbable that in the near future it will be in demand for the preparation of artificial butters, elaborate experiments in connection with this application being now in progress.

In addition to the foregoing range of oils, there is last, but by no means least, the valuable fertilizer, sulphate of ammonia. This article commands a ready sale, Japan and the United States being the largest consumers. The fact that sulphate of ammonia is obtained as a by-product and in paying quantities offers an assurance to the Scottish shale-oil industry; it compensates to a marked degree the low prices that may be current in connection with the foregoing oils.

The success and prosperity of the Scottish shale-oil industry is a decided triumph for British inventive ingenuity. It is additionally valuable and important when one remembers that it is the sole source of native oil-supply. Curiously enough, the process never has flourished in any other country to the degree prevailing here, which offers a striking tribute to Scottish financial management and endeavour. Other countries possess vast deposits of shale comparable with those found north of the Tweed, notably Australia, Canada, and France. An ambitious attempt was made to exploit the Australian shale resources, but it proved a ghastly failure, a round £1,000,000 or $5,000,000 being wasted in the effort. It is proposed to introduce the Scottish process into Canada, the deposits of shale in New Brunswick being extensive and rich in the essential constituents. The industry in France, founded upon Du Buisson's discovery, is still flourishing, but upon a limited scale. It is hoped that the shales which have been found in Natal may be proved to be worthy of exploitation by the Scottish process, in which event South Africa, which is sterile of petroleum resources, may be brought into the list of oil-yielding countries.

Few people have any conception of the proportions of the Scottish shale-oil industry or the output of the companies concerned. While the aggregate may be somewhat small in comparison with the petroleum output of the United States, Burmah, or South-Eastern Europe, it has assumed impressive proportions. The various companies engaged in the enterprise employ about 10,000 men, the majority of whom are engaged in mining the shale, while a round £1,000,000, or $5,000,000, are disbursed annually in wages. The average yearly output is 20,000,000 gallons of illuminating oils, 5,000,000 gallons of naphthas, 22,000,000 gallons of lubricating oils, 25,000 tons of paraffin wax, and 54,000 tons of sulphate of ammonia. Thus it will be seen that the oil producing industry of Great Britain is of far greater importance and magnitude than is generally supposed. Certainly it should be fostered, and it is deserving of greater recognition than it receives at present.

CHAPTER XV

NATURAL GAS AND ITS USES

In the early oil days the emission of petroleum, or natural, gas from a well that was being drilled was not regarded with unalloyed delight. The driller appreciated the discovery merely because it offered a fairly reliable intimation that he was likely to strike oil if he continued sinking to a sufficient depth, somewhat upon the lines of the theory that where there is smoke the probabilities are that fire will be found. Otherwise he paid it scant attention, considering it to be an unmitigated nuisance as the flow thereof increased. Its presence demanded the observance of greater care in the drilling operations, and emphasized the advisability of refraining from indulgence in the company of " My Lady Nicotine " while at the borehole, and the necessity to keep naked lights at a respectable distance in order to avoid a sudden flare-up. When the flow attained significant proportions, a pipe was laid from the borehole and carried to a safe distance. A light was applied to the mouth of this conduit igniting the gas, which was permitted to burn away of its own free will. The driller was getting rid of a troublesome factor in a simple effective manner, and he was perfectly content. That such a gas should possess any commercial value never occurred to him for a moment. Even if he had favourably appreciated its economic worth it would have been of little avail, because he would have been unable to turn the supply to remunerative advantage, owing to lack of suitable markets. This attitude is somewhat puzzling because as far back as 1821 the petroleum gas which escaped from the earth at Fredonia, in New York State, was tapped and turned to profitable advantage.

But with progress came enlightenment. Chemists analyzed the product, and found that it could be utilized for all the purposes to which coal-gas is applied with equal success. This prompted a greater interest in the new fuel, and in 1872 natural gas, derived from the Pennsylvania oil-fields, was regarded with favour in domestic circles. One factor mitigated against rapid development—the brief and uncertain existence of the gas-wells. The majority lasted for only some four years, and then suddenly gave out. This capriciousness reacted seriously against general utilization, the result being that its use for the most part was confined to the raising of steam in the boilers of the drilling plant. In the course of a year or two the public confidence was gained, manufacturers turned their attention to this product for industrial uses, and it was adopted extensively in the smelting of iron. Rapid expansion followed the success of this application, and in 1884 natural gas was displacing 400 tons of coal per day among the manufacturing plants of Pittsburgh, the Sheffield of the United States. The supplies were derived from the contiguous oil-fields, but the demand over-reached the supply, so that ultimately a reversion to coal occurred, although the situation was relieved somewhat by bringing supplies from a point over 100 miles away.

Natural gas represents approximately the one solitary form in which petroleum is found in the British Isles, and that only in a very limited quantity. Even this supply was discovered quite by accident. A water-well was being driven upon the property of the railway company at Heathfield Station in East Sussex. The drillers detected a strong smell of gas while driving the bore, and when out of curiosity a light was applied to the mouth of the borehole, and a flame shot to a height of some 15 feet, the workmen were profoundly astonished. The well was capped, and the supply devoted to the lighting of the station premises. Although the yield was approximately only 1,000 cubic feet per day, it was responsible for the circulation of sensational stories concerning the oil reserves of Britain, and of Sussex in particular. If oil does exist in Sussex it never has been tapped yet, though evidences of gas are frequently encountered in this, as in other countries, during artesian well-sinking operations.

The North American continent is far more bounteously blessed by Nature in this respect. The country is not only an enormous subterranean oil-tank, but is a gigantic gasometer as well. From the Atlantic to the Pacific seaboard, and from Nome to the Gulf of Mexico, gas is found in abundance. While at places the yield is insignificant, at other points it gushes from the earth with terrific force, showing the degree to which it is compressed below. Nowadays, when a flow of natural gas is struck, the well is capped and facilities provided for the conveyance and distribution of the commodity among the adjacent and even distant manufacturing and residential centres, even although it may entail the laying of miles of trunk-mains. For instance, Chicago draws its natural gas from a field about 120 miles away. In Kansas, Louisiana, California, Alberta, and numerous other States, coal-gas is virtually unknown. Nature meets all the demands of the population from her inexhaustible store. In other countries, where vast quantities of oil are drawn from the earth, similar conditions prevail; gas is emitted in abundance, and is turned to commercial advantage in some form or another form.

Some idea of the enormous supplies and consumption of natural gas in the United States may be gathered from the fact that over $65,000,000 (£13,000,000) worth are drawn and used annually. The quantity which is wasted, owing to lack of facilities to cap and conserve the gas, assumes stupendous proportions. When the Caddo oil-field was opened up, it is estimated that over 100,000,000 cubic feet of gas escaped into the air every twenty-four hours. Even assessing this loss at one cent, or ½d., per cubic foot, the daily wastage represented no less than $1,000,000, or £200,000. Under these circumstances it is not surprising that every effort is made to control the yields when they burst into activity, or that the Government compels control of the wells, since natural gas represents a substantial item in the fuel resources of a nation.

The gas-belt of the United States extends northwards through the Dominion of Canada. While the crude oil resources of British North America are somewhat limited, at least so far as results at present go, there is a prolific supply of natural gas. This fact was revealed accidentally by drillers engaged in sinking wells for water on behalf of the railway company, tapping the natural gasometer instead. The strike was made in the vicinity of Medicine Hat, and this town has since developed into the centre of the exploited Canadian gas-field.

The discovery of the railway employees prompted definite investigation by the authorities, while the young enterprising town of Medicine Hat seized the opportunity to municipalize the resources within its own jurisdiction. The gas area which has been exploited in this territory extends from Bassano, ninety-five miles west of Medicine Hat, to Dunmore, on the east of the latter town, and, as the pressure at Dunmore is approximately the same as at the central point, it is evident that the field extends considerably beyond Dunmore. On the western side of Medicine Hat the flow gradually decreases until at Bassano the flow is more or less limited in character, so that this point evidently indicates the western edge of the field. North and south borings have not been carried out so continuously and methodically as in the other direction, but wells have been drilled at Bow Island, seventy miles south of Medicine Hat, and these, though carried to a greater depth than at the latter point, give an excellent yield, indicating that in all probability the gas territory extends continuously south into the United States. On the northern side the boundary is still undefined, but flows have been struck between Medicine Hat and Edmonton, while at Pelican Rapids, 300 miles north of Edmonton, very large flows have been tapped. Consequently, it is only justifiable to surmise that the area extends to an extreme northern point, and possibly connects with the oil and tar asphalt beds which are known to exist in the extreme northern reaches of Canada, and which as yet are practically unrealized. Experts rather incline to the opinion that the field extends in an unbroken line parallel to the Rocky Mountains, and as gas is invariably found at the top of an anticline it would seem that this anticline might be caused by the weight of the mountain-range. But the width and thickness of the belt, together with the depth at which the gas is to be found, vary considerably, so that years must elapse before the exact area of the gas-bearing country is defined, even with approximate accuracy.

Curiously enough, although enormous reserves of natural gas exist here, and the gas is compressed to an enormous degree, as is evidenced by the pressure of the flows, practically little oil has been found. This may be due to the fact that drilling has not been carried to a sufficient depth to traverse the gas-belt. In the early part of 1914 oil-strikes were made in the vicinity of Calgary, which is situate on the western boundary of the gas-field, but the yield was not as sensational as those incidental to the opening of other famous districts. No signs of a gusher were revealed, because the oil filled the well slowly, so that no apprehensions whatever arose as to its being found in sufficient volume as to defy control. Possibly the provision of vents, as represented by the boreholes for the compressed gas, has reacted against the possibilities of a gusher coming into activity.

At Medicine Hat gas is first struck at a depth of 125 feet, but as it is heavily impregnated with moisture, it is not commercially exploited. At a depth of 650 feet a more prolific stratum is reached, but this likewise is not used to an appreciable degree. The main supplies are derived from a stratum laying from 950 to 1,050 feet below the surface. By drilling to this bed the city obtained a flow varying between 2,500,000 and 4,000,000 cubic feet per twenty-four hours.

Well-sinking is not particularly expensive. The strata for the most part are easily penetrated, soft shales predominating. Cost is increased by the necessity to instal various strings of casing in order to reach the depth required. The average cost of drilling, including casing, valves, and regulators for controlling the supply, is approximately $10,000, or £2,000, per well.

With the exception of three wells, which are private property, the whole of the boring rights have been vested by the Federal Government in the city, so that the supply is under municipal control, and this arrangement has contributed conspicuously to the prosperity and growth of the town. This control extends over four townships, and as each township is six miles square, the municipal gas rights are vested in an area of 144 square miles. Public ownership maintains the balance between supply and demand, and enables the item of waste to be reduced to practically nothing. The first well was sunk twelve years ago, and is still in service. At the end of 1912 there were twelve wells in operation, but in order to make ample provision for future needs a contract for nine additional wells was let at an outlay of $75,000 (£15,000). This brings the total to twenty-one wells, the gas-supply from which will be adequate for many years to come. As the wells are brought into productivity they are capped, so that they can be brought into service when required.

The Canadian natural gas, in common with the greater bulk of that derived throughout the North American continent, is marsh or methane. The analysis of that derived at Medicine Hat shows methane, 99·5 per cent. (0·5 hydrogen). Oxygen is virtually non-existent, only the very slightest traces being observable. Owing to the depth from which the article is drawn, it is extremely dry, and it is this feature which renders it so eminently adaptable to domestic and industrial application, since the pipes are relieved from obstruction by condensed moisture and other impurities associated therewith, and which in time collect in the same way as chalk suspended in water will be deposited in the form of fur, and clog the mains.

The gas is supplied direct to the consumer from the bowels of the earth. That is to say, there are no above-ground storage facilities, such as the gasometers used in connection with the manufacture of coal-gas. But, owing to the pressure—550 pounds per square inch—with which the gas issues from the earth, means have to be introduced to reduce this factor to domestic and industrial exigencies. In the first-named instance a pressure of 6 ounces per square inch is adequate; on the other hand, the pressure of the supply has to be varied for industrial purposes, according to the character of the application and the objects for which it is required. To achieve this end regulator stations are provided. The gas as it comes from the well is passed through the high-pressure regulator, where its pressure is reduced from 550 to 50 pounds per square inch, and at this figure it enters the high-pressure distributing mains laid throughout the town. At intervals low-pressure stations are installed, and here the gas-pressure undergoes further reduction, from 50 pounds to 6 ounces per square inch, at which pressure it is sent into the pipes supplying domestic consumers. In the case of the manufacturing and industrial plants regulators are installed to give whatever pressure is required for the individual concern. Thereby the pressure may be varied to meet fluctuating requirements. The load factor varies very considerably throughout the day, as may be supposed, but roughly the maximum is about five times the minimum consumption.

As may be supposed, manufacturers and residents who happen to be in close proximity to an abundant supply of natural gas are in a fortunate position. Light, power, and heat are obtainable very inexpensively. For domestic purposes in Medicine Hat gas costs 13½ cents (say 7d.) per 1,000 cubic feet. The total cost for lighting, heating, and cooking by natural gas in a six-roomed house ranges from $30 to $50 (£6 to £10) per annum. For manufacturing purposes the rates are considerably lower, scaling from 5 cents, or 2½d., per 1,000 feet downwards. In fact, if manufacturing is contemplated upon an extensive scale, and the consumption of fuel is likely to be heavy, gas may be obtained

By courtesy of the Oil Well Supply Company.

A TERRIFYING TORCH.

The "Maggie Vanderpool" natural gas-well near Caney, Montgomery County, Kansas, U.S.A., was struck by lightning on February 19th, 1906, and fired. Some 3,000,000 cubic feet per hour were burned, the flame reaching a height of 225 feet, and it took thirty-eight days to extinguish the blaze.

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A FLAMING ADVERTISEMENT.

Blowing off Big Chief Gas Well, Medicine Hat, Alberta, to illustrate the extent of the natural gas resources of this district in Western Canada. The pressure was 500 lbs. per square inch, and the daily flow 3,000,000 cubic feet.

for 1 cent, or ½d., per 1,000 feet by making a long-term contract.

Provided raw materials are available upon the spot, or can be brought in at a low rate, a centre possessing an abundant supply of this fuel offers many inducements to manufacturers. For instance, in Medicine Hat, assuming the gas costs 5 cents, or 2½d., per 1,000 cubic feet, and estimating a ten-hours' day, $3·05 (about 12s. 6d.) per horse-power represents the fuel outlay per year. This is equivalent to anthracite coal at $1·10 (4s. 6d.) per ton, exclusive of operating costs, which is a ridiculously low figure for this class of coal in Alberta. What applies to Medicine Hat is reflected in a far more powerful form in other parts of the continent, where similar resources obtain. It is not surprising, therefore, that every effort is now being made to husband the natural gas resources, because it offers a complete solution of the cheap fuel problem.

The manufacturer entertains only one apprehension. Are the natural gas-supplies likely to cease at any moment? This has occurred so frequently in proved gas-fields throughout the continent that the anxieties of manufacturing interests are well founded. But so far as Medicine Hat is concerned, the fact that the first well sunk is yielding gas at the pressure which was recorded when the natural gasometer was tapped for the first time, proves convincingly that the subterranean supplies are enormous, and unless some abnormal cataclysm occurs, such as an earthquake, which might disturb the conformity of the earth strata, the natural gas-supplies are not likely to give out for centuries. But the possibility of the unexpected happening has not been overlooked at Medicine Hat. The municipal authorities set aside 20 per cent. of the annual net profits derived from the sale of natural gas as a contribution to a sinking fund, which is to be devoted to the provision of cheap power whenever the natural gas resources shall become exhausted.

The industrial uses of natural gas are practically illimitable

It is compressed into the cylinders of railway coaches both for lighting and for cooking in the kitchens of the dining-cars; the flow from the earth is turned direct to ordinary gas-engines, and even to the high-speed internal combustion motors. Electricity is generated cheaply by its aid; it constitutes a cheap source of power for the driving of any machinery—in fact, it is applicable to any phase of human activity, with the exception, perhaps, of the blast-furnace.

During the past two or three years a new development in connection with natural gas has been revealed, and is undergoing considerable utilization in the United States. The pipes through which the gas is conducted accumulate appreciable quantities of liquid, the volume of which is greater in winter than in summer. At first this liquid was regarded as water; the moisture associated with the gas condensed upon coming into contact with the cold surface of the pipe. But investigation revealed that this "drip," as it is called, was a highly volatile spirit, virtually high-grade, gasolene, or petrol. It was carefully collected, the refineries, in their anxiety to obtain every ounce of oil, proving ready purchasers. This peculiar fact set one imaginative inventor thinking. If the gas deposited this liquid voluntarily, could not scientific force be applied to make it yield greater quantities? In other words, could not the gas be squeezed? The more he pondered over the question the more thoroughly he became convinced that a process could be contrived to produce motor spirit from natural gas upon commercial lines.

The inventor, John Lathrop Gray, who was the first to study this question in its broadest aspects, set to work and erected a plant for the condensation of natural gas. Realizing that simplicity and economy would govern the issue from the commercial point of view, he resolved his idea into a simple straightforward process. The results achieved were somewhat startling, and forthwith he embraced the protection the law affords, and patented his idea. Curiously enough he appears to have been the first to have viewed the issue from such a standpoint; at least he was the first to take out a comprehensive patent to extract motor fuel from natural gas. His scheme was regarded as a scientific phantasy; he was ridiculed on all sides. But as time progressed, and the fact that Gray was deriving a stable volatile spirit from the gas in paying quantities, and cheaply, became realized, scepticism gave way to appreciation, and in turn to realization, of the immense value of the idea. So much so that those who exploited natural gas immediately conceived wondrous castles in the air from the derivation of motor spirit therefrom, irrespective of the fact that the constitution of the gas has to be such as will yield the spirit. To trap gasolene from natural gas it is imperative, as reflection will convince, that gasolene must be present, otherwise one might just as well endeavour to condense motor spirit from steam. Yet the task of squeezing gasolene from gas appears to be so attractive and simple that the wild-catter has made a rich harvest.

At first sight one would think that the condensation of the vapour would be a straightforward operation, following the broad lines observed for condensing any liquid vapour suspended in a gaseous medium. To a certain degree this impression is correct, but complexity arises for the reason that the vapours suspended in natural gas belong to three or more chemical series. The consequence is that, in order to achieve complete success, it is necessary to possess a suitable plant, and to carry the compression and cooling of the gases to the requisite degree to insure the recovery of the article desired.

Gray was sufficiently astute to concentrate his energies upon the perfection of the simplest and most effective means of achieving this end, and it is due to this observance of an immutable commercial law which has insured his success. A very simple type of compressor and cooler was evolved, in which economical operation is insured by the use of the gas, after the stable spirit has been extracted, to drive the machinery. He also uses simple separating devices, with an automatic trap to transfer the liquid in a continuous stream to a proper receiving tank. The automatic system for collecting the precipitate solves the question of imparting to the liquid the essential stability, and also reduces losses from atmospheric evaporation to the minimum.

Within a few months of the commercial recognition of Gray's process, the amount of gasolene recovered in this manner exceeded 2,000 barrels a day. Since then it has advanced with great rapidity, and now, instead of being merely in the light of a scientific demonstration suited to the laboratory, it is being practised upon all sides. It must be remembered that the fundamental properties of the gas so treated are not affected in any way; the latter can be used just as effectively as if it were not submitted to the squeezing operation. By this process the gasolene which formerly escaped recovery is being derived. When the "drip" was first discovered it was regarded with doubt. The refiners classed it as inferior, although water-white in colour, and apparently equal to the distilled spirit. This impression probably arose because the liquid was drawn off only periodically. Having lain stagnant in the pipes it possibly became contaminated with rusty surfaces and association with dirty oil products. At all events, the producers were quite content to dispose of it for about 25 per cent. of its real market value.

This gasolene in its purest form represents the fraction succeeding the petroleum ether, so that its specific gravity is about 0·610. It may be distilled in exactly the same manner as crude oil, so that it can be reduced to more homogeneous fractions. If it is to be marketed as pure gasolene, the fraction which is too volatile to be rendered stable at atmospheric pressure and normal temperature is driven off, thereby bringing its specific gravity to about 0·680. But the fact that, in its raw condition, it represents the highest grades of petroleum spirit render it exceedingly useful for another purpose. For the lack of a more accurate description this application may be termed "blending," and this doubtless will constitute its most popular use. If it is associated with an inferior quality of motor fuel, the specific gravity, and consequently the marketable value of the product, is raised very appreciably. It acts as a stimulant, or " enlivener," enabling the whole mixture to be vaporized with facility, and without recourse to any adjustment of the carburettor, for the reason that this natural gasolene, as it it described, has a very high fuel value. The condensate is perfectly miscible—that is to say, it will dissolve itself readily into another naphtha fraction—and, curiously enough, the action is so complete that even fractional distillation will not completely separate the two fractions.

This virtue has not escaped the notice of the refiners. Natural gasolene, or natural gas, condensate is too valuable to sell in its purified condition. The low-grade naphthas, which are appreciably cheaper, may be blended therewith, and then be sold at the highest prices obtaining for motor spirit. Experiments have proved that it may even be mixed with the higher grades of paraffin—illuminating oils of 0·800 specific gravity and upwards—and give a product which to all intents and purposes is equal to the present motor fuel, which is vended as gasolene or petrol. The " blended fuel " fails to reveal in any way the circumstance that it has been subjected to enlivening. This discovery is being shelved for the time being, as the exigencies of the moment do not demand extensive marketing of a blended motor-fuel, but, as the yield of volatile distillate from the crude oils diminishes, it will have to be brought into operation. Thereby the refiners will be enabled to dispose of a fraction—the paraffins—which at present are in decreasing demand.

As in the case of oil, the natural gas is exposed to one terrible enemy—fire. Here again carelessness, accident, and Act of God are the principal contributors to disaster Natural gas is an obsequious servant but a terrifying master Now and again there is a catastrophe of abnormal magnitude, but man eventually proves to be equal to the situation

This was notably the case in connection with the "Maggie Vanderpool" gas-well, which was brought into productivity near Caney, Montgomery County, in the State of Kansas, U.S.A. This well was extraordinarily productive, the flow being estimated at 3,000,000 cubic feet of gas per hour. On February 19, 1906, during a severe thunderstorm, a flash of lightning fired the well. Immediately a huge sheet of flame shot into the air to a height of 225 feet.

It was a gigantic gas-jet illuminating the country for miles around; a newspaper could be read a mile away with ease. At 1 cent, or ½d., a 1,000 feet gas to the value of $720,000, or £144,000, was disappearing in an intense white sheet of flame every twenty-four hours, and as the fire defied extinction for five weeks the huge sum of $25,200,000, or more than £5,000,000 was lost beyond recovery. The heat was so intense that approach within 100 feet was rendered dangerous, and the fire-fighters who succeeded in driving their way to 50 feet of the jet had their clothes burned off their backs. The heat radiated wrought a wonderful change upon the surrounding countryside, which was converted into a huge hothouse. Although it was midwinter, and an exceptionally low temperature prevailed, the shrubs burst into leaf, while the prairie flowers came into blossom.

The roar was so deafening that it could be heard miles away. At a distance of 200 feet the fire-fighters could not make their voices heard, and all instructions had to be conveyed by signs. The wind in the vicinity offered another serious handicap, because the flame set up a powerful induced draught. Loose articles, such as hats, coats, and other articles lying upon the ground, within a radius of 100 feet, were whirled into the air as if caught by a tornado, and sucked into the flames. The extinction of this fire was one of the most difficult in natural gas history. Although the colossal quantity of 2,520,000,000 cubic feet of gas vanished in flame, the well, when brought under control once more, revealed no signs of depletion or reduction in pressure, and is in good productive condition to this day.

Generally speaking, little difficulty is experienced in controlling the heaviest flows of gas. Provided reasonable precautions are observed, when a strike is made, there is little risk of conflagration. The well is capped directly the flow is established, and it is left untouched until the need arises upon the completion of facilities to enable it to fulfil the multifarious behests of man.

CHAPTER XVI

THE OIL INVASION OF THE TABLE

WHILE the mechanical world presents the most familiar commercial conquests of oil, they are by no means confined to that realm. Oil has advanced in several other directions, and has even invaded the table. It has come to be regarded as a staple article of food for mankind. It offers an effective solution to the eternal problem of the cost of living, which at the moment is perplexing every home, not only in Great Britain and the United States of America, but in every civilized country to a greater or a lesser degree.

The average individual may resent the suggestion that he is becoming dependent upon oil for sustenance; nevertheless the fact remains. What the eye does not see, and what the mind does not know, occasions the heart no grief. The word " oil " is used in its most elastic sense in this particular instance, embracing as it does fats and greases of various descriptions. While it does not necessarily refer to mineral oils these, too, are implied to a certain extent.

So far as comestibles are concerned, the oils employed for the most part are of animal and vegetable origin. Some of these are avowedly known as such, as, for instance, olive oil, which is derived from the olive, and so on. But what is not generally known is the utilization of oils for various other edible purposes, of which one has not the faintest conception, a result due to indefatigable and successful chemical, mechanical, and physical research. This is essentially a synthetic age, and there are few provinces in which the scientist has such a golden opportunity to manifest his prowess as in the production of artificial edible products at about one-half or one-quarter of the cost of the genuine article. Substitution is always preferable to adulteration, and hence arises the scientist's activity. The community reaps the benefit especially when the artificial is equal to the genuine substance, since there is no susceptibility to physical deterioration.

Substitution, so far as the table is concerned, is represented in its most compelling form by synthetic butter, generally known as "butterine," or "margarine." The practicability of making a butter substitute was demonstrated for the first time by a French chemist, Mégè Mouries. He prosecuted this peculiar line of investigation at the instigation of Napoleon III., who argued that, as his more humble subjects, impoverished by the ravages of war, could not afford pure dairy butter, it would be preferable to provide them with a cheap wholesome substitute than a pernicious adulterated article. His motives were essentially humanitarian, and his attitude stimulated Mégè Mouries to supreme effort.

Pure dairy butter is composed of butter fat and small proportions of casein and milk sugar. The latter impart the distinctive flavour to the article made from the cow's milk. Profiting from this knowledge, Mégè Mouries indulged in numerous experiments of an interesting character, the most fruitful of which, from his point of view, was the discovery that it was not necessary to feed a cow on pasture, or other milk-producing foodstuffs, to induce the yield of a milk rich in butter fat. When the animal was kept off water it continued to yield milk rich in this constituent. From this he concluded that the fat contained in the milk was not extracted from the food, but was given up by the creature itself from its own bodily structure. This discovery prompted him to take theoil from the caul fat of the bullock, which is generally known as "oleo," and to blend it with fresh milk, virtually reproducing in a machine the action which takes place in the udder of the cow. Oleo, or the clarified oil of beef-fat, is practically pure butter-fat, and accordingly it came to be regarded as the fundamental constituent of synthetic butter.

It was a pretty and interesting line of research, but it is doubtful whether the French chemist ever realized the radical revolution his discovery was destined to make. He was content with the results of his investigations, and indicated the lines along which future developments should proceed. They were so correct that they are followed to this day in a manner consistent with progressive developments in scientific research.

While Mégè Mouries' discovery came as an unmitigated blessing to one class of the community, other interests rose up in arms. The substitute threatened the very existence of the dairy-butter makers, although at that time it was very easy to detect the difference between the genuine and the synthetic article. Those who embraced the new industry christened the product " butterine," but the dairy farmers, arguing that such a description was not sufficiently distinctive, and was liable to provoke fraudulent dealing, enlisted Parliamentary assistance to prohibit the use of the affix " ine." The wail did not go unanswered. In Great Britain the use of the word " butterine " to indicate the substitute for butter became rigorously prohibited. Other countries in Europe followed suit, adding additional stipulations to meet individual requirements. Only one country among the leading nations of to-day permits the use of this controversial word, and that is the United States of America.

In Denmark, which is one of the leading butter-producing countries, the substitute must not be coloured to resemble butter; it must retain its natural white appearance. But the colouring matter is sold separately, so that the Frau may " fake " the substance before placing it upon the table. In Great Britain it may be coloured, but it must not contain more than 10 per cent. of genuine butter-fat. In Germany it must contain a certain proportion of sesamum oil, which is readily revealed under analytic investigations, while in Belgium, for the same purpose, a small quantity of starch must be added. Consequently the nefariously inclined to adulteration are offered no opportunity to defraud.

Rigorous legislative action demanded the evolution of a new generic name for the artificial article, and, as a result of considerable discussion, the word "margarine" was accepted, and is used to this day in Europe to indicate any form of artificial butter.

One may wonder how such a name as "margarine" came to be evolved to meet the situation. The explanation is simple. The product of Mouries' ingenuity possessed a texture which under the microscope was observed to be formed of globules. They glittered like pearls. This feature readily indicated the fact that the article was artificially produced from animal fats. Forthwith it was decided to christen the article according to its outstanding characteristic. In this way it would be possible to dispute the contention of the dairy farmers that "passing off" was being practised. The Greek word "margarites," meaning a "pearl," offered a way out of the dilemma, and accordingly the word now in vogue was created. It fitted the situation to a nicety. No one, not even the most antagonistic, could possibly construe a similarity between the two titles, so that all possibility of fraudulent dealing was removed.

In a way it was an unhappy name, because it stamps the synthetic product unequivocably as a substitute, and does not indicate any apparent relationship to butter. Moreover, it was responsible for the creation of considerable and deep-rooted prejudice, fostered by the butter industry, which has not been overcome completely to this day.

Notwithstanding the vehement antagonism of the vested interests, the discovery of Mégè Mouries made a wide appeal not only among the poorer classes of France, but among those of other countries. Its consumption increased by leaps and bounds, despite the numerous and emphatic drawbacks attending its manufacture and its liability to rancidity. The butter manufacturing industry, elated with its legislative success, spared no effort to decry its competitor. In rural districts especially margarine was described contemptuously by its opponents as "glorified cart-grease," a term which has not yet disappeared entirely, notwithstanding the huge strides that have been made in the manufacture of the article.

The opposition of the butter interests did not perturb those concerned in the production of the wholesome substitute. Rather it spurred them to further effort to make an article which would be as like as possible to butter, which would be quite as wholesome and nutritious, and would be above suspicion in regard to purity. Patient chemical research, experiment, and improved chemical contrivances eliminated the inherent defects in margarine one by one. Money was expended lavishly upon scientific knowledge and endeavour, with the result that at the moment the ordinary individual cannot detect margarine from dairy-churned butter; the analyst alone is able to tell the difference. It is legislative action and activity solely which now prevent imposition and fraud among those tradesmen who are so inclined.

The prosperity of the margarine industry in time became dependent upon the stock-yards and meat-packing industry of Chicago. Consequently, in due course oleo became a cornered article. There was a ready market for the animal fats in Europe, Holland becoming one of the largest buyers of this commodity. In the neighbouring country, Denmark, the synthetic industry has been fostered to such a degree that to-day it is probably the largest manufacturer of the basic constituent of margarine, and of the complete article, in the world. But here again it was decided at all costs to maintain the integrity of the Danish dairy butter, which has a world-wide reputation. So the export of margarine was prohibited by the Danish Government. A curious situation has been created in Denmark as a result of this legislative action. The farmer concentrates his energy upon the manufacture of butter for export. He himself lives on margarine, which is quite as good, but is only half the price. In this manner a greater quantity of dairy-butter is released for export—that which the farmer would consume were the substitute not available.

The increasing popularity and consumption of margarine in time brought its peculiar crisis. Animal fats, suited to the needs of the industry, are limited in number. Consequently, when the stock-yards of Chicago experienced a shortage of cattle and the price of meat rose, the cost of the oleo rose proportionately, until at last it attained a prohibitive figure. Demand being far in advance of supply, it became necessary to search for another medium to take the place of animal oleo—to find, as it were, a substitute for the substitute.

This contingency had been anticipated by two keen, far-seeing, and enterprising British industrialists, Messrs. Loder and Petty. They were in partnership, and at the time were interested in the margarine industry, as well as the supply of suitable oils and fats for soap manufacture. To them it was obvious that experiments and investigations would have to be conducted with fats derived outside the animal kingdom to relieve the situation which had become critical. They turned to the vegetable world as a possible source of oleo supply. Mr. Francis William Loder threw his whole energies into the quest. At that time the firm with which he was associated was supplying considerable quantities of cocoanut oil for soap production, and naturally, being conversant with the chemical qualities and peculiar properties of this oil, he was convinced that oleo could be obtained therefrom. Forthwith he set out to adapt it to the production of margarine. This was in the early eighties, when the current facilities and knowledge of the subject were in their infancy. But his self-imposed task appeared to baffle solution. Two serious obstacles stood in his way—the peculiar distinctive taste, and the pungent aroma of the cocoanut. Strive how he would he could not eliminate these defects, and their presence was fatal. It was not until 1887—after five or six years of diligent labour—that he met success, though at a heavy price. The product was not completely perfect, but it was marketable for certain purposes. Naturally he was elated by his achievement; for the first time cocoanut oil had been made edible, a rival to animal oleo had been revealed.

At that time the comestible value of cocoanut oil was not appreciated. Loder, like many another inventor, suffered from making his discovery prematurely. No doubt the slight remaining traces of taste and aroma reacted against the commercial application of the commodity, but this attitude was primarily due to the fact that the shortage of animal oleo had not been fully experienced at the time. The outcome was a bitter disappointment in view of the large sums of money which had been expended upon experiments. The losses were so great that the business was dissolved. This turn of events did not alarm the British inventor; he continued his efforts upon his own initiative and responsibility. Perseverance eventually brought its own reward—an absolutely tasteless and flavourless vegetable fat similar in every respect to animal oleo.

Everything now was ready for manufacture upon an extensive scale directly the demand for the article developed. Loder set out upon a campaign of unostentatious education. He laid down a plant, and produced the material upon a small scale. He introduced it to his customers, but they manifested hostility, keenly resented the idea of using cocoanut oil. Undismayed he continued his work, and finally succeeded in inducing the biscuit, chocolate, toffee, and general confectionery trades to adopt his vegetable product. Shortly after commencing manufacturing operations he was amazed to learn that his former partner, who had broken away from the firm owing to differences under this head, had embraced the idea, although he was confronted with the same obstacles which had worried Loder himself for such a long time.

But the British inventor's work had not been in vain. The measure of success he had achieved and his broad lines of operation had leaked out. Continental experimenters were attracted to the problem, and within a few months there were numerous workers of all nationalities engaged upon one common line of investigation. Fortunately Loder had the advantage of a good start. He was actually manufacturing the substance while his contemporaries were struggling with the difficulties which he had subjugated years previously. This start proved too pronounced to be overtaken by the toilers in Germany, Belgium, France, Denmark, Austria, Norway, and Russia—the United States of America manifested an indifferent attitude towards the problem because the economic issue had not developed in that country. When Loder died and Petty retired from business, their successors came together once more, recombined forces, and laid the foundations of what to-day is the largest and most successful British organization engaged in the refining of oleo from cocoanuts essentially for the margarine industry.

Although the distinction of having discovered the means of preparing an edible base for artificial butter from the cocoanut is undeniably British, the French were not far behind. Messrs. Rocca, Tassey, and de Roux, of Marseilles, took up this line of study. They broadly followed Loder's principles, and in 1895 perfected a process for the production of what they call " vegetaline " from a cocoanut derivative. Partly from the peculiar conditions prevailing in France, where margarine is in heavy demand, and partly from the assistance extended by fiscal considerations, this firm was able to establish the young industry upon a firm basis, and to-day probably possesses the largest cocoanut-oil refining plant in the world. Its success completely changed the economical aspect of the French colonies, where cocoanuts thrive luxuriantly, and which hitherto had been considered as of little commercial value. These abundant reserves of raw material enabled the French industry to forge ahead by leaps and bounds.

Meantime the British firm had progressed slowly but surely, although confronted by the formidable opponents prejudice, ignorance, and conservatism. Cocoanut oil at first was received with indifference. The artificial butter, confectionery, and biscuit industries could hardly bring themselves to use an article which formerly had been restricted to soap manufacture. But the hesitation of the older firms gave the younger rivals a great opportunity, which they did not permit to pass. They took up the cocoanut oil readily, because experience revealed that 1 pound of this oil goes twice as far as the material generally used, while it is 50 per cent. cheaper. This 75 per cent. advantage gave them a powerful lever, and enabled them to establish a footing upon the market with their specialities which otherwise would have been impossible. Business grew rapidly, and finally forced the older and entrenched rivals to adopt the same basic material. The public failed to detect whether a biscuit or a bar of chocolate was made from cocoanut oil or from the articles which it superseded; chemical analysis alone could reveal the truth. Consequently to-day cocoanut oil has a large consumption in the preparation of biscuits, toffees, chocolate, and general confectionery, although the quantity used for the production of margarine for table consumption greatly exceeds its other uses.

Directly the new article secured a firm hold in the foregoing industries, another interesting development happened. Hitherto in the manufacture of chocolate the cocoa-bean had been used exclusively. As every housewife knows, this bean contains a heavy proportion of rich fat, and in the production of chocolates this is derived in large quantities, being known as cocoa-butter. The leading chocolate manufacturers hitherto had been able to dispose of this butter at a remunerative figure, but cocoanut oil threatened this source of income seriously. Stimulated by the success which had attended the farmers' agitation years previously, when margarine first appeared upon the scene under the name of "butterine," these powerful interests endeavoured to bring about the proscription of cocoanut oil in the manufacture of chocolates. But this time the movement failed; cocoanut oil had secured too firm a hold upon the public, and as nothing detrimental could be argued legitimately against it, agitation proved unavailing.

At this juncture Mr. Francis H. Loder and his brother, the sons of the inventor, played a master-stroke. There was the possibility of the cocoanut and the cocoa-bean becoming confused; the uninitiated might possibly consider them to be

By courtesy of Messrs. Otto Monsted, Limited.

NATIVES HUSKING COCONUTS.

This photograph shows the tool employed and the process of removing the outer shell.

By courtesy of Messrs. Otto Monsted, Limited.

REMOVING THE KERNEL, OR COPRA, FROM THE NUT.

The fleshy portions, collected in the trough, are dried and packed in bags for shipment to Britain.

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one and the same, although they are vastly dissimilar. To avoid such a contretemps, and to frustrate any surreptitious belittling of the prime product, the elimination of the final "a" in connection with nut-oil was advocated. The significance of the suggestion being apparent, it was universally adopted, which explains the present spelling of the word "coconut" to distinguish it from the "cocoa"-bean.

A quarter of a century ago the coco-nut palm was regarded somewhat as a superfluity upon a tropical seaside estate, or was retained merely for decorative purposes, while the fruit was considered to be suitable merely for an Aunt Sally at fairs. What a contrast to its position to-day! At least seventy different trades are dependent upon this nut. Now it is carefully nursed, and is raised upon scientific lines, as if it were a valuable exotic plant flourishing in a British or American conservatory. But the cultivation of the palm is by no means easy. It demands a peculiar soil and a seaside situation in a suitable tropical clime. It will not thrive except within some 600 feet of the water. It flourishes most luxuriantly and bears most prolifically in a climate which, generally speaking, is by no means congenial to the white man. Its growth is comparatively slow. Eight years pass before the young tree yields a single nut, and fifteen years elapse before full bearing is attained. Again, the number of white men who are familiar with its cultivation is extremely limited; those who are prepared to spend their whole lives in its habitat are still more difficult to find. Consequently while coco-nut raising constitutes one of the most attractive and financially remunerative callings of the moment it is also one of the greatest gambles. It is essentially an occupation for the specialist, while the financing of such operations must be carried out with extreme circumspection.

The coconut boom set in during the year 1909, and spread with the characteristic speed and virulence of such crazes. Unlike the majority of such sporadic outbursts, it lasted three years, when it subsided somewhat. Prices soared to an abnormal figure, and speculation went mad. The boom served to emphasize the possibilities of coconut oil upon the man in the street, enhanced its favour and popularity. Finally, the price of the raw coconut kernel, or "copra," as it is commercially called, attained a figure which rendered its commercial use for margarine purposes impossible; the cost of production approached that of animal fats.

The market value of the raw material varies according to the fatty content of the flesh of the nut. The primest qualities of copra are derived from Ceylon, and consequently are the most in demand, though other countries, notably Malabar and Cochin China, yield high quality nuts.

The process of refining the oil is a secret. The essence of the invention was the perfection of ways and means of removing every trace of the peculiar coconut flavour and aroma from the oil. Each firm engaged in the industry follows its individual method of refining, and is extremely reticent concerning its particular process. This attitude is perfectly justifiable when one remembers the large sums of money which have been expended in perfecting manufacture.

Through the courtesy of Messrs. Loder and Nucoline, the British pioneers in this particular trade, I am able to describe briefly the various stages through which the coconut is passed to yield the desired product. The word "oil" is scarcely accurate, because one generally associates such with a more or less fluid substance, whereas this product is hard and firm, resembling frozen butter very closely, though of a different texture, and void of any trace of its oleaginous character under normal temperature conditions. Consequently coconut fat or coconut butter would be a more fitting description. The mechanical processes through which the material passes are elaborate in character, demanding an extensive and expensive plant. This is probably one reason why so few firms are engaged in this peculiar field of activity.

The coconut, or copra, arrives at the factory in a dried, brittle condition. The nuts, gathered upon the plantations, are broken open, and the kernel, with the white flesh of which one is familiar, is extracted and exposed to dry in the sun. One might think that the flesh would decompose, but this is not the case. The fierce tropical solar heat completes the work of evaporating the superfluous moisture from the kernel within a very short time, and preserves the copra from decomposition. The shrivelled brittle flesh is then packed in bags for export. In this condition the fatty content of the nut is approximately 65 per cent., though this is a variable quantity, fluctuating with the country in which the nut is raised.

In its raw condition the copra has a decidedly uninviting appearance. It is certainly far from appetizing, being associated with sand and other extraneous substances, but its peculiar pungent aroma betrays it. On arrival at the mills the contents of the bags are emptied into a large hopper, where the copra is fed through a machine, which cuts it into short shavings somewhat similar to those obtained when planing a piece of wood across the grain. Conveyors pick up this shredded nut, and dump it into capacious kettles, where it undergoes a preliminary heating. Below the kettles are disposed huge grinding mills, into which the shavings fall in continuous streams to pass between sets of grooved rollers. The latter are of varying form. Those in the first mill are grooved broadly, while those where the nut is subjected to its final grinding are considerably finer. The "meal" is then fed into presses in which the greater proportion of the oil is expressed to fall into troughs, and to be conducted through sluices into large settling tanks.

Although the grinding plant is highly efficient and the work is carried out thoroughly, the whole of the available oil is not thus extracted from the copra. So the nut, now resembling a pulp, has to be subjected to a final pressing. It is imperative that the maximum yield of oil shall be obtained, and when it is stated that about 94 per cent. of the fatty content of the nut is secured, some idea of the complete character of the oil extraction process may be gathered.

The types of presses differ in various mills. Some are equipped with rotating rollers which exercise a grinding action; in others the press is of the flat plate hydraulic type. The pulverized flesh is disposed in layers between plates, and when the press has been fully charged the ram is released. It has a vertical action, and its movement is so slow as to be imperceptible to the naked eye. The pulp is subjected to a squeezing pressure of 5,000 pounds per square inch. Visible indications of the tremendous pressure exerted are shown by the continuous streams of oil which exude from between the plates, and likewise fall into sluices and pass to the settling tanks. When the ram has completed its upward movement, and the last drop of oil has been extracted, the piston is released. The pulp is now in the form of highly compressed hard slabs or cakes, about an inch in thickness, some 18 inches long by 12 inches in width, somewhat resembling wholemeal bread in colour.

A few years ago this cake commanded no commercial value whatever. Although it is highly nutritious, contains 6 per cent. of oil as well as the cooked fibrous and fleshy parts of the nut, and forms a valuable cattle-food, the farmers regarded it with disdain. Oil-cake was their staple foodstuff for stock, and they would have none other. But coconut cake is every whit as good, if not superior to that made from linseed and cottonseed. Consequently, the disposal of this residue raised a difficult problem, especially in such a factory as the above, where several hundred tons of copra are passed through the plant every week. At last one or two prominent farmers were induced to give the coconut cake a trial. They were completely satisfied with the results. The suitability of the foodstuff for stock becoming noised around, a heavy demand set in therefor. To-day the outcry for this cake, like that of the oil, exceeds the supply.

The oil is permitted to settle and cool. In this form it is yellowish-white in colour, although soft. This is due to the fat containing a certain amount of acidity, which is useless for margarine purposes. Consequently the next step is the elimination of this constituent. This residue, it may be mentioned, forms one of the basic constituents of soap.

The next stage of the process is the removal of the aroma and taste which is carried out in enormous stills. When it comes over the character of the oil has completely changed. No one, except from analysis, could possibly associate it with the coconut: every trace of colour, taste, and odour has vanished.

Coconut oil as a rule is manufactured in two or three grades. One is utilized for biscuit-making, another for margarine, and the third for the highest qualities of chocolates and confectionery. The best grade is somewhat expensive, since it may command as much as £60 ($300) or more per ton. It is packed also in a variety of forms, according to destination and the purposes for which it is intended. It may be run into huge barrels, and there permitted to set, being withdrawn by knocking in the head of the cask; packed in tin-lined wooden cases; or even wrapped carefully in small cakes.

One great feature of coconut oil—and this is a point which has much influenced its widespread utilization—is that it is free from rancidity, will keep for an indefinite period under normal conditions, and may be transported without suffering deterioration. A sample from every still is preserved, and some of these are ten or twelve years old. Yet to-day the oil appears as if it had been refined only just recently, and as it contains nothing susceptible to decomposition, its age cannot possibly be detected either by the palate or smell. It may be passed through the torrid and frigid zones without anxiety, and does not require to be kept in a chilled temperature. Although the demand at home is heavy for this margarine base and butter substitute, a large proportion of the output is despatched to foreign markets—Canada, South America, India, Japan, Africa, and Australasia are heavy buyers—the various civilized countries evidently having become keenly alive to the manufacturing possibilities of this edible oil.

The United States is probably the smallest consumer and producer of this butter substitute. No doubt this is because the dairy-butter industry is conducted upon an extensive and scientific scale. The butter-canning interests also constitute a formidable and successful competitor. Some years ago Mr. Francis H. Loder went to New York and established a factory. At first it proved an exceedingly difficult task to force coconut oil upon the market, as it was brought into spirited competition with butter and animal fat substitutes. Persistent action finally introduced it to the biscuit, toffee, chocolate, and confectionery manufacturers. Although the United States to-day is far behind the other countries of the world in extending commercial recognition to this latest achievement of science, coconut oil is rapidly gaining ground and favour.

It is probable that within a few years wider recognition will be extended to the article, when manufacture will have to be conducted on a far more comprehensive scale than prevails at present, in order to meet the demand, since the United States, with its population approaching 100,000,000 souls, offers a huge market for the commodity. The outlook is particularly attractive, owing to the alarming decrease in stock-raising, which must cause dairy products to rise in price. Directly this tendency develops to an acute degree, coconut oil is certain to come into its own in the United States, as it has in the older countries of Europe.

CHAPTER XVII

BUTTER FROM OIL

WHILE the production of an edible, odourless, and flavourless oil from a vegetable derivative, as narrated in the previous chapter, is one notable conquest of science, the construction of a synthetic butter upon this base is no less remarkable. When it is recalled that the artificial article differs in no respect from that obtained from the milk of the cow, that it is equally nutritious and wholesome, that it possesses all the essential qualities of the animal product, and that no one but the analyst is able to distinguish the difference, then it must be conceded that a striking triumph has been accomplished. One may cherish the idea that one has never tasted "margarine," that it never appears upon one's table, and that one would never think of eating it. But that is a false expression of security. Margarine appears upon the epicurean table of the millionaire in some disguise or other as much as it does in its confessedly unblushing condition upon the humble table of the working man. The former is deceived; the latter is not, because he is fully aware of the nature of the article. What is more to the point, the working man prefers margarine to ordinary butter, not because it is cheaper, but because it is not a victim of probable adulteration. He depends upon margarine the livelong day, and enjoys it; the millionaire shudders at the name of the substitute, but in ignorance he partakes of his share of the disguised article.

In these islands the consumption of margarine is enormous. In fact, the popular appreciation of the article is so pronounced that this country eats twice as much of it to-day as it did seven years ago. It is displacing other fats used essentially in culinary and food-manufacturing operations, because it is cheaper and more economical, and last, but not least, because it is of unassailable purity. In the other European countries the displacement of the genuine by the artificial is equally startling. In the United States the consumption is far below that of the Old World, but this is due to the enterprise and energy of the dairy-butter interests, although, from the dietetic point of view, the American consumes a far inferior article, notwithstanding that it is made from the milk of the cow. Still, the consumption of the United States, even for domestic purposes, is increasing rapidly. In Great Britain the margarine ranks as a most successful and prosperous industry. One British firm—Otto Monsted, Limited—produce no fewer than 3,000,000 pounds of margarine, or "nut-butter," as it is called, from the nut-oil base, per week, and this enormous output is so far below the demand that not a pound is available for export.

The romantic circumstances which brought about the discovery of margarine by Mégè Mouries is related in the previous chapter (XVI.). The foundation of the Monsted organization is quite as romantic: it is one of the most fascinating and interesting stories of human endeavour. The warm reception the invention received from the humbler classes of the community in France naturally attracted the attention of other countries. The working populations were attracted by the possibility of living cheaper, and forthwith the invention was taken up eagerly. In time it reached Denmark, which is essentially a butter-producing country.

One young man, Otto Monsted, in common with hundreds of his fellow-countrymen, was engaged in dairy-butter making, although his operations were conducted upon a far from impressive scale. Margarine claimed his attention, and, perhaps, being a little more perspicacious than his comrades, he devoted more than a passing interest upon the invention. He foresaw the day when the demand for dairy butter would exceed the supply, because the raising of suitable stock, even at that time, was dwindling rapidly. He conjectured that within a few years the working man would be compelled, by force of circumstances, to abandon the consumption of prime butter and be content with an inferior adulterated article.

Accordingly, he decided to abandon the dairy butter trade, and to set out upon the manufacture of margarine. He realized the enormous difficulties that loomed before him: that his material would have to compare with the genuine article in what is undoubtedly the most hypercritical country in the world in regard to dairy products. But he was not dismayed. He laid down the lines upon which he was resolved to go forward, and he adhered to them rigidly. The result was that in a very short time "Monsted's Margarine" became a household word; the butter-raisers who previously had ridiculed the idea that a synthetic butter comparable with the real article ever could be manufactured upon a commercial scale at a competitive price extended him tangible support by purchasing his product.

In the course of a few years, however, Monsted realized that there were limits to development in his homeland—that he would have to dispose of his wares in other countries offering a wider market. He decided to try his fortune in the British Isles. In this resolution he was stimulated by the attitude of the Danish Government towards the artificial substance. He came to England to search for a suitable manufacturing establishment. An abandoned hat-factory at Godley, near Hyde, Cheshire, could be adapted to his requirements, and accordingly was acquired. The necessary alterations were carried out, and the requisite plant was installed. On April 15, 1889, the churns were set to work. It was a modest commencement, the daily output being about 1,000 pounds. But the "Monsted Margarine" appealed as keenly to the British people as it had to his fellow-countrymen at home. The demand for the substance became so heavy that within four years, although the factory had been rebuilt and enlarged, more extensive works were wanted. Another reconnaissance of the country was made, and finally it was decided to purchase a vacant stretch of 56 acres of land adjoining the Great Western Railway at Southall, Middlesex, in close proximity to the Grand Junction Canal, thereby securing adequate rail and water transportation facilities. Here a modern factory was raised and brought into operation in March, 1895.

The successful production of oil from nuts gave the industry a tremendous fillip, and within a year or two even this latest factory was overtaxed, rendering further additions and extensions absolutely necessary to keep pace with orders. The growth was so rapid and continuous that finally it became the largest individual margarine factory in the world, which distinction, with its 1,000 employés and output of 3,000,000 pounds of margarine per week, it still holds. One factor was revealed speedily. The supply of copra, whence the nut oil is produced, was somewhat uncertain and speculative. To insure a regular supply of this constituent, and to steady prices, it was decided to acquire coconut-palm estates. When one bears in mind that no fewer than 500 tons of coconuts are required to produce the volume of oil which this factory consumes every day, the wisdom of this step is apparent. Extensive coconut farms were purchased, and others laid out. In this manner complete control of the situation was obtained, and a supply of over 1,500,000 coconuts per annum assured. While the Otto Monsted Company raises such enormous quantities of nuts, it does not depend entirely upon its own resources. Immense quantities of the raw vegetable fats are purchased from the leading manufacturers of the commodity. In fact, to guard against a sudden shortage of this ingredient, no fewer than 6,000 huge barrels of oil are held in hand upon the premises.

The process of manufacturing nut butter is one of extreme fascination. It demonstrates the skill of the chemist in a striking manner, emphasizes one of the greatest triumphs of British enterprise, and incidentally illustrates how a factory devoted to the production of an essential foodstuff should be equipped and conducted to meet the exigencies of purity and cleanliness. The Otto Monsted factory is run upon a far more scientific and hygienic basis than any dairy-butter-making organization between the two Poles. Necessity so compels. A deep-rooted prejudice against the artificial article still exists, though it is decreasing in virulence. So to overcome this feeling, the manufacturers of the synthetic substance spare no effort, and discountenance no expense, to secure a position in advance of the makers of the article which is being superseded. On all sides one hears and reads of the lack of hygiene, science, and care manifested in the handling of milk and the production of dairy butter; but one looks in vain for a similar outcry concerning the methods and arrangements practised in the production of the artificial article. This is due to the fact that the latter is operated by scientists who are fully alive to microbic ravages and the dangers of adulteration, while the dairy-butter factory is run by ignorance. This is responsible for the anomalous and paradoxical fact that the artificial is purer and more immune from adulteration than the genuine substance.

One has only to refer to official statistics to realize how serious the competition between butter and margarine has grown. To-day, the sale of lower-grade butters in Great Britain has virtually disappeared. They appealed essentially to the poorer classes as an edible, or were used for culinary purposes. But they are exceedingly indifferent for either application. On the other hand, nut butter is wholesome and nutritious, while it has the advantage of being one-half the price of cheap butter. Consequently it has ousted the latter from the market. It is only those dairy butters which carry a full guarantee from the Government of the country of origin which are able to command a sale. Even some of these, owing to the activity of the adulterator, are regarded with suspicion.

This development has become a serious matter for the British Colonies, in many of which dairy-butter production plays an important part, and some of which still labour under the delusion that anything, so long as it is labelled "butter," will suffice for the Mother-Country. But they are making a huge mistake. The working man is the largest consumer in both the cheap butter and margarine markets, and consequently governs the situation. Nut butter has become his standard of comparison. If the dairy article is superior, he gives it his unstinted support, higher price notwithstanding; if it is inferior, as it is at present, he refuses to accept it.

In the production of nut butter everything depends upon the milk; it is the vital constituent. The artificial butter manufacturer has far greater control over this article than the dairy-butter maker. The purity and behaviour of the milk is checked and counter-checked at every step during the process—from the farm until the combination with the oil has been completed. An elaborate and highly trained organization is demanded to achieve this end, and this wonderful control is the sole reason for the striking purity, wholesomeness, and nutritiousness of the nut butter. The art, like the refining of coconut oil, is partly a secret, because of the expense that has been incurred in devising the best ways and means to secure the desired result. Through the courtesy of the Otto Monsted Company, I have been able to follow the production through all its stages. This firm possesses the most up-to-date and interesting nut butter manufacturing installation in the world, many of the details of which have been involved, designed, or suggested by the employés themselves.

Nut butter is composed of two ingredients—milk and oil. The production of the latter has been described, so I will relate the treatment of the milk first. To meet the demands of this organization, the total production of some eighty farms in the western shires of England is required, and the milk is delivered to the factory by rail, in the familiar churns, twice daily—at midnight and at noon. Some idea of the enormous quantity of milk required may be gathered from the fact that the consumption is no less than 35,000 gallons weekly.

Immediately the milk arrives it is subjected to tests, to detect whether it has undergone any deterioration during transit, and also to ascertain whether it has suffered adulteration by the addition of water or a boric preservative. It is stipulated that the milk shall be delivered to the factory in the condition in which it is drawn from the cow. Dilution impoverishes its composition, as may be imagined, while the addition of any preservative will nullify subsequent treatment. There is an expert "taster," as in the tea and other industries, who, by his sensitive and cultivated palate, can tell instantly whether the milk has soured at all since collection. He tastes the contents of every churn.

The second test is bacteriological. A sample is drawn indiscriminately from the consignment from each of the eighty farms, and taken to the laboratory. Within a few moments the chemist is able to pronounce whether the milk has been subjected to tampering, whether the farmer has employed clean utensils, or has handled the milk properly while it is in his hands. The milk, immediately it is drawn from the cow, should be chilled. As is well known, milk is particularly sensitive and attractive to germ life. The milking-pails may not be thoroughly clean, or germs may be collected from the atmosphere as the milk is carried about from place to place. If the milk be placed in the churns directly, this germ life flourishes and multiplies, but if the milk be subjected to the preliminary chilling, all microbic development is arrested; the germs lie dormant for several hours, enabling transit to be completed satisfactorily.

Seeing that the handling of the milk upon the farm cannot possibly be controlled, the stringent elaborate investigation upon its arrival at the factory is imperative. The farmer, knowing that his product cannot escape this preliminary inspection, spares no effort to maintain the prescribed standard of purity. Any dereliction in his duty, which can be detected instantly, meets with its just reward—the milk is refused and thrown upon the farmer's hands. This is a pecuniary loss, and it serves to make him extremely careful, more especially when he knows that a second complaint is likely to be accompanied by the termination of his supply contract. But, as a matter of fact, the Western farmer strives hard to meet requirements, and it speaks volumes for his honesty and care to learn that it is very seldom indeed that a consignment is refused, and even then unsuitability is attributable to circumstances over which the milk-raiser has no control—such as, for instance, oppressive, thundery weather, which, as the housewife knows, sours milk very quickly.

Passing the tasting and bacteriological tests, the milk is turned into huge tanks and pumped to the top of the building, where the treatment for margarine purposes proper commences. Now, raw milk contains from 3½ to 4 per cent. of butter-fat, which the margarine manufacturer does not want. It is a waste product, because the coconut oil is designed to take its place. Consequently the butter-fat must be extracted. The milk is first pasteurized to destroy all inimical germ life. Then it is passed through electrically driven milk separators, which remove the butter-fat from themilk. The butter-fat, in the form of cream, is discharged into one tank, and the separated or skim-milk is passed into another vessel.

The British law relating to the sale of margarine prohibits the butter to be manufactured with more than 10 per cent. of butter-fat. Under these circumstances, there is necessarily a considerable surplus of butter-fat produced from the volume of milk handled, either in the form of cream or butter, which has to be sold separately, as a by-product to dealers in these articles.

The skim-milk is then passed over a cooler, and its temperature reduced to freezing-point, in which condition it is transferred to capacious tanks, where the low temperature is maintained until it is required for the succeeding stage. Everyone is aware of the fact that milk is extremely susceptible to decomposition or souring, and is equally sensitive to contamination from dirt, dust, and unclean vessels. These defects are fully appreciated in this establishment, and consequently no effort or artifice is spared to maintain the purity of the article. The whole of the milk is passed through its preliminary stages, and consigned in its skim or separated form to the chilled reservoirs without any delay. All the rooms are kept spotlessly clean, and so designed and constructed that the walls, ceilings, and floors may be washed with a steam jet and boiling soda-water. Large air-ducts insure ventilation with washed, deodorized, and cooled air. Every room in which the milk is handled is maintained at an even temperature, irrespective of the time of year, so that no opportunity is given for injurious bacteria to enter the milk at any of its stages. Handling is eliminated, all the processes being carried out automatically by electrically driven mechanical appliances. In fact, neither the oil nor the milk is touched by hand from one end of the process to the other. Directly the last drop of milk has passed through each vessel, the latter is subjected to a powerful steam-jet cleansing process, and is scoured thoroughly with boiling soda-water. This applies also to the churns, which are returned to the farms in a spotless condition, ready to receive the next consignment of milk.

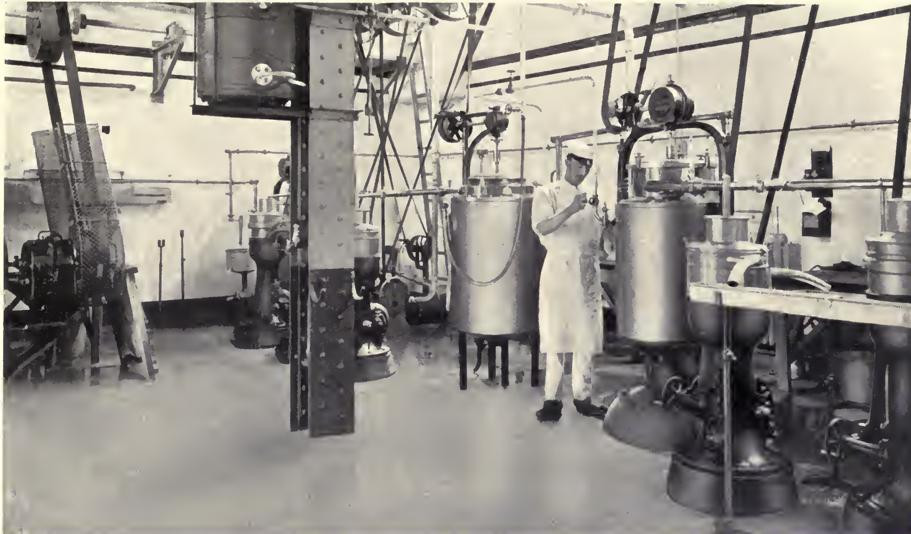
But, it may be asked, why should milk be used at all in the manufacture of margarine, when its essential ingredient, the butter-fat, is extracted ? The explanation is simple. Margarine, or nut butter, in order to be an effective substitute for the dairy product, must possess the peculiar butter flavour, so as to appeal to the palate. This peculiar flavour can only be imparted by the milk. To achieve this end, the milk must be matured or soured, and this constitutes the crux of the whole process; it is the place at which the chemist steps in to complete the illusion.

In order to mature or sour the milk, certain germs are necessary. While they are cultivated for this particular purpose they are by no means foreign, inasmuch as they are the identical germs which are present in the lactic acid of the cow's milk, and which are essential to the manufacture of dairy butter. Only in the case of margarine they are separately raised and added to the milk. In the laboratory the chemists have scores of tiny tubes, which are nursed as carefully and tenderly as delicate babies. Each tube contains a suitable medium upon which the lactic germs may thrive and multiply. These tubes are preserved in a dark cupboard maintained at an equable temperature. Under such congenial conditions the bacteria multiply at a rapid rate, until at the end of a few hours the tube is swarming with these microbes. The active life is then transferred to another and larger vessel, where the increasing numbers have more elbow-room in which to develop and to grow in a healthy manner. This vessel is similarly stored for a short time, and when finally examined is found to be inhabited with millions of healthy, vigorous microbes. They undergo another removal to a larger residence to permit still further growth and development, until at last the chemist is satisfied that they have attained the desired degree of maturity to perform their allotted duty.

The cultivation of these germs is a peculiarly fascinating branch of the craft. They are curious organisms. When examined under the microscope they resemble nothing so much as a minute drop of oil floating upon water, and move slowly to and fro. The chemist watches the growth of his peculiar charges with unceasing vigilance, subjecting them to minute examinations at every stage. He wants vigorous, healthy, and fully developed germs, as their work makes or mars the margarine. At intervals he has to raise an entirely new stock, since bacteria, in common with other members of the animal kingdom, suffer degeneration in physique, energy, and size by being inbred too severely.

All milk and at all stages, despite elaborate sterilization, is certain to attract and produce some form of bacteria life, and it is to make doubly sure of the triumph of his own armies that the chemist takes such pains and care to raise an overwhelming force. When the souring microbes are finally turned adrift, they make short work of any other germs in the milk, and set about their appointed task.

Observation is able to demonstrate that the souring microbes are winning their battle in the milk. The character of the latter undergoes a change, while it emits the peculiar acid aroma incidental to butter. The mass is kept in agitation by means of oscillating blades, so that the



By courtesy of Messrs. Otto Monsted, Limited.

THE DAIRY WHERE THE CREAM IS SEPARATED FROM THE MILK.

As the cream is not required, being replaced by the oil, it is removed and sold as a by-product.

By courtesy of Messrs. Otto Monsted, Ltd.

BLENDING THE OILS FOR THE PRODUCTION OF MARGARINE.

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maturing culture is able to carry out its work thoroughly. Souring completed, the chemist takes a final sample, to convince himself that the article is up to the desired standard, and then the soured milk is ready for combination with the oil.

The second basic constituent has to be used in a fluid form. While coconut oil is the staple oleaginous ingredient employed, other oils, which are naturally fluid, are employed. Arachide oil, like that from the coconut, is absolutely flavourless and odourless, and when combined with the coconut oil, in certain proportions, renders the latter more fluid. The oil arrives in various forms. The greater quantity is brought up in bulk by barge from the refineries, the liquid, in a warm condition, being contained in large tanks, from which it is pumped direct into the oil-vats. In addition, large quantities arrive in huge casks and drums. The blending of the oils is an important phase in the operations, because it influences the texture of the nut butter very appreciably.

In its solid form coconut oil is a flaky, granular mass, and this texture is useless for margarine. The latter must possess every characteristic of the dairy product; butter-like consistency is one of the most vital attributes. But there is one drawback to the dairy butter which the manufacturer of the artificial article is able to overcome. In winter the low temperature causes the former to harden, so that it is difficult to cut. In summer it is directly opposite; it becomes soft and semi-fluid, in which condition it is wasteful to use. No such objection can be levied against artificial butter. Through artifice of the chemist this drawback is overcome, so that the article maintains a uniform texture and consistency the whole year round. This end is achieved by adding a small proportion of the oil refined from the arachide, or, as it is more familiarly known, the pea, nut, the proportion thereof varying with the season.

The oil is pumped into huge tanks some 40 feet in height by 15 to 20 feet in diameter, having a capacity of 90 tons

The oil is heated to secure the desired fluidity, and then is discharged into agitators, where the arachide or other nut oil, together with a certain proportion of colouring matter, is added, and stirred so as to be mixed thoroughly. The colouring matter is a perfectly harmless ingredient of vegetable origin, and is merely added to impart the yellowish butter appearance to the margarine, which naturally is a dead white.

The two fundamental ingredients are now brought together and mixed in the correct proportions. The machine which accomplishes this end is exceedingly small and wonderful. The blending is watched carefully, the operator being provided with various devices to enable him to see at a glance that the proportions of oil and milk are maintained. This operation, to a certain degree, may be likened to butter churning, only with this difference: the combination is effected practically instantaneously.

All this time the cultivated microbes, owing to the steady congenial heat maintained, have been performing their allotted task, though they are under the constant control of the chemist. Now they receive a tremendous shock: the margarine has to be solidified. There are two enormous steel-faced cylinders mounted side by side, and revolving in opposite directions. They are some 8 feet in diameter by the same in length. They are set so closely together that to the eye they appear to be touching one another, but, as a matter of fact, there is about $\frac{1}{16}$ inch space between them. These cylinders are internally cooled to such a degree that the temperature of the surface of the drum is about 5° F.—27° below freezing-point. Visible evidences of this low temperature are revealed by the snow—condensation of moisture in the surrounding atmosphere—forming here and there in thick layers upon the ends of the cylinders.

Immediately above the clearance line between the two cylinders, and about 5 feet in length, is what looks like a huge rake, with the teeth pointing downwards. Each tooth is a tiny stream. The margarine, resembling custard in its fluid condition, is driven through these outlets, and falls between the cylinders. The moment it strikes the chilled surface it congeals or solidifies, the microbes having to withstand an instantaneous change of nearly 100° in temperature. Owing to the extremely thin space between the two cylinders, the margarine becomes deposited upon the faces of the latter in the form of a very thin film, or "emulsion," which is carried round by the cylinders until it meets finely adjusted knives, which, set across the length of each barrel, scrape the cylinder surface and remove the congealed substance, which falls into a trough beneath. In this form the margarine resembles large, irregular, but extremely thin, flakes of yellow snow.

The material now has to be submitted to its final mechanical treatment to assume the attractive form in which it appears upon the table. It is permitted to stand for a few hours after its emergence from the solidifying process, so as to crystallize. Then it is inserted in large revolving churns. When one of these machines has received its charge, the cover is fixed and the churn is rotated rapidly for a few minutes. When the drum is opened, the contents have assumed a perfectly homogeneous texture of the consistency of natural butter. Chemistry has completed its wizardry. The margarine is now ready for the table.

CHAPTER XVIII

OILS FROM FISH

Fish are admitted to possess a high dietetic value, and, accordingly, the table has been the principal field of consumption. But to-day the sea is being netted for more commercial reasons. Fish are rich in oils, and science has discovered economical methods of extracting this content and rendering it available for a wide variety of purposes. Probably cod-liver oil is the fish oil which is the best known to the public; while the fact that the whale is hunted for its blubber, otherwise oil, is common knowledge. These two species, however, do not exhaust the list by any means. Any member of the finny tribe, whether it be edible or otherwise, possesses a certain marketable value essentially for the oil which can be recovered. This development has changed completely the whole aspect of the fishing industry, and has prompted the harvesting of fish, which a decade or so ago were regarded as worthless, except, perhaps, as a fertilizing agent.

The general impression prevails that the medicinal properties possessed by the liver of the cod are mainly responsible for the exploitation of this organ of the fish. This is true to a certain degree. Only the primest livers are adapted to therapeutic purposes, and as a large proportion of the livers have to be discarded as inferior, diseased, or otherwise unsuitable, they are turned into other commercial channels, such as for leather-currying, soap-making, and so on. At times there has been such a glut of the medicinal oil, and prices have been depressed to such a low figure, as to render the refining process unremunerative. On the other hand, the price of the inferior oil remains fairly constant, supply approximately balancing demand.

The most prolific sources of supply are Norway, Newfoundland, Labrador, the Atlantic States of North America, and Japan; but the primest article is derived from the Norwegian cod, which is caught in enormous quantities off the Lofoten Islands. The average catch in these waters is about 30,000,000 cod per season, and, seeing that the harvest is confined to only a few months of the year, some idea of the magnitude of the fishery and the energy with which it is prosecuted may be gathered. Conditions facilitate a rich harvest as the fish approach the shore so closely in order to spawn, that often two catches may be landed in a single day.

This huge catch yields about 30,000 barrels, or 900,000 gallons, of oil. Under normal conditions the average weight of the liver is about 2 pounds, and 1,000 fish will yield one barrel of livers, from two of which 30 gallons, or one barrel, of oil may be obtained. The yield fluctuates considerably, being governed entirely by the condition of the fish. Thus, in some years, when the cod have been lean and hungry, as many as 5,000 livers have been required to give one barrel of oil.

Careful selection of the livers is imperative. Only the healthiest and primest are used in the preparation of the medicine oil. The oleaginous content is obtained by submitting the livers to a moderate heat for about two and a half hours. Overcooking results in the production of an oil which is dark in colour and unpalatable; while, owing to the process of oxygenizating, which develops during submission to heat, there is a risk of the oil, when administered, provoking internal irritation. In Norway they have adopted a means of extracting the oil in such a way as to prevent oxidization. From the moment the liver is placed in the cooking vessel until the product is packed for market the oil is kept free from contact with the atmosphere.

Cooking completed, the mass is left to cool. The oil rises to the surface, while the solid part of the liver forms a layer or sediment at the bottom of the vessel. The oil is drawn off, and the sediment submitted to pressure, to express the remaining content of oil. The latter, however, being inferior in quality, is only fit for currying and similar uses. The residue, after the last traces of oil are driven out, is worthless, and either is sold as a fertilizer or burned.

The free oil withdrawn from the cooker is subjected to further treatment, such as filtering, refrigeration, and pressure, to remove the stearin, which is used for soap and candle making. The final product is virtually a tasteless and odourless oil, and is packed in tin-lined barrels for bulk despatch. Care has to be observed in packing, because this oil possesses the peculiar property of absorbing the flavour of materials with which it is brought into contact. The inferior grades of oil require no such careful handling, and generally are packed in empty petroleum barrels and drums, or any other convenient vessel.

The Newfoundland and American cod-fisheries prepare cod-liver oil for manufacturing purposes almost exclusively. The Norwegian oil commands the highest value for pharmaceutical preparations, being in demand throughout the world. Unfortunately for the Norwegian manufacturing interests, adulteration is practised somewhat extensively, with the result that cod-liver oil has depreciated in value as a therapeutic, owing to the doubt concerning its purity, and the difficulty of establishing this desideratum.

In preparing the oil for commercial applications, less care and elaborate plant are required. In fact, the process is partly completed upon the fishing-boats while at sea—a process which is impossible when medicinal oil is the objective, since the agitation of the oil, due to the motion of the boat, depreciates its valuable properties. On the other hand, when the oil is required for leather-currying purposes, the rolling of the craft, and the consequent churning set up, are advantageous. The livers of the fish, as the latter are opened, are thrown into vats or butts, where they are left to decompose. Putrefaction breaks down the walls of the cells in which the oil is contained, and, consequently, within a short time a thick layer of oil appears upon the surface of the vats. This is skimmed off from time to time and barrelled. Upon reaching shore, the putrefied residue remaining in the vats is dumped into the cookers, so that the liberation of the oil may be completed. In this instance cooking is carried to an extreme degree to secure the maximum yield of oil, while the process is completed by squeezing the cooked pulp, which, after pressure, is sold as a fertilizer or discarded.

The output of cod liver oil for manufacturing purposes from the Newfoundland fisheries is approximately 1,000,000 gallons per year. The Japanese fishermen practise the industry upon broadly similar lines, and produce a round 500,000 gallons of the oil in the course of the twelve months. During recent years the livers of other fish, such as hake, pollack, ling, tusk, and so forth, which are not generally considered as coming within the category of edible fish, are submitted to a similar process, the resultant oil being mixed with that extracted from the cod. To all intents and purposes it is equal to the latter—at least, for manufacturing purposes.

The shark ranks as the most detested member of the finny tribe, and one would scarcely think that it possessed any marketable value. But the liver is rich in oil, especially when the creature is in full health, and is caught in the proper season. The sleeper and the basking sharks are those most highly valued, though all the members of the species contribute to the supply of this commodity. The liver of the basking shark will yield from 12 to 50 gallons of oil, according to its size. The sleeper shark, which grows to a length of 35 feet, is more prolific still, a prime large liver yielding from 80 to 100 gallons of oil; while individual livers from the largest fish have been known to produce 400 gallons of oil.

Vessels engaged in this fishery have to go far afield for their quarry, the waters in close proximity to the home stations having been depleted. The Norwegian fishermen hunt the sleeping shark to a certain extent, using large hooks, baited with a toothsome dainty; while the basking shark is caught off the Atlantic coast of South America, and is found also in the Pacific. The brute is harpooned, and, being kept afloat by hauling tightly on to the line, is despatched by means of lancing, the crew approaching in small boats to achieve this end. Care has to be observed that the capture does not "sound," otherwise it is likely to be lost. When killed, the shark is hauled alongside, lifted partly out of the water, disembowelled, and the liver removed in chunks, a man entering the body to complete the work. When the liver has been extracted, the carcass is abandoned. The liver is placed in suitable vessels on board and cooked, to bring about the release of the oil, while the resultant pulp is placed in canvas bags, which are slung up and permitted to drain. When the last drops of oil have oozed out, the pulp is thrown overboard.

Practically every member of the shark family—even the dreaded white, or man-eater—can be turned to commercial account, the yield of oil from the liver varying considerably, according to the species of the fish and its size. While for the most part only the liver is sought, the carcass being thrown away, in one instance—that of the oil shark, found off the coast of California—the fins also are removed. The latter are dried, and find a ready market among the Chinese, who consider them a delectable dainty for the concoction of soup.

The dog-fish is likewise hunted for its liver, but it has not developed into a special fishery. The yield is high for the size of the fish, and the oil extracted therefrom is combined with the lower grades of cod oil for the leather trade. The fact that this oil commands about the same price as that derived from the cod offers some compensation to the fishermen for the damage wrought by this fish to their nets. The dog-fish is generally considered to be the pest of a fishery-ground, and inflicts widespread damage.

Probably no phase of the fishing industry has been the theme of so much romance and fiction as that of whaling.

Thrilling stories and sensational adventures without number have been associated with the chase of the Monarch of the Ocean. But romance has failed to reveal the most interesting and fascinating features of the enterprise; it has omitted to emphasize the reliance which the world placed upon this oil only a few years ago. Before the coming of petroleum, whale oil lubricated our machinery, supplied light for our lamps, illuminated streets of cities and towns; while, converted to gas, it offered a light for theatres and other public buildings. Many arts and crafts depended upon the supply of this commodity and the success of the whaling fisheries; the market of a thousand and one articles relied upon whether the harvest of oil was meagre or plentiful. The story runs that sailors, when they visited the centres where whale oil was refined and used, did not hesitate to swarm the street lamps to imbibe freely from the vessels from which the wick drew its sustenance for combustion and the shedding of light.

The abundance of mineral oil changed the whole outlook; it drove whale oil completely from the majority of the fields of application in which it had reigned supreme. Mineral oil was cheaper, so the fish oil could not withstand the competition. The fishing fleets were compelled to roam farther and farther from home for the whales, and the enterprise became a greater gamble with every succeeding year. The whale could not produce its species in sufficient force to replace the destruction by mankind, with the result that the oil increased in value. Petroleum oils thus had a unique opportunity. They were tested with diffidence at first, but when the market found that the mineral was quite as good for the purpose as the fish oil, the latter fell into disuse.

Fortunately, the whaling industry always has had another string to its bow. Whales are not chased for their blubber alone. The bone is an even more valuable article, and commands the market, because science and mechanical ingenuity have failed to discover a perfect substitute therefor. While the price of the oil steadily decreased, owing to the narrowing of the fields of application, the price of the bone increased, so that what the fishers have lost in one they have recouped in another direction.

Whaling still remains of considerable importance in the fishing industry, although the number of vessels engaged in the traffic is shrinking rapidly. This, however, is due in a great measure to the coming of the steam-driven craft. The vessels roam the seven seas, and penetrate to the loneliest stretches of water in their quest for the oil and bone-yielding mammals. Yet it is doubtful whether the annual yield of whale oil of the whole world exceeds 2,500,000 gallons. By this is meant pure whale oil, not that derived from other denizens of the deep, which, owing to its close resemblance, often is marketed under the foregoing title.

At the same time, whaling is one of the most precarious and dangerous callings of the sea. Time after time tragic news of the unfortunate fate of a whaling vessel trickles round the world. Two or three years ago one scouring the seas between Labrador and Greenland was caught in the ice and crushed to matchwood, less than a handful of the crew effecting an escape. In 1871 a whole fleet of thirty-three vessels were lost among the ice of the Arctic Ocean; while five years later the same foe brought about the abandonment of another twelve vessels. Formerly the United States possessed the largest whaling fleets in the world, but the Civil War virtually exterminated the industry. No fewer than eighty-two vessels were lost during that terrible conflict. One fleet of thirty-six craft was sunk in Charleston Harbour, while forty-six were ransacked and scuttled by privateers. Within fifteen years approximately one hundred and fifty American whaling vessels were lost from one cause and another, and never have been replaced.

While all the whale species are hunted for their bone and blubber, some command a higher value than the others. For instance, the sperm whale has always been in keen demand, the oil which it yields being peculiar. So far, it has not been possible to discover an efficient substitute for this article from either the vegetable or mineral kingdoms; even the animal kingdom has failed to produce an equivalent product in quantities. The porpoise is the nearest approach thereto.

The blubber of the whale, which is the layer of fat between the skin and the flesh, varies in thickness. In some animals it has been found to be no less than 24 inches thick. It is removed in huge slices, axes, large knives, and crowbars being employed to tear the fat from the carcass. The oil-yielding body matter is varied, and widely distributed, comprising not only the body blanket, but the tongue, head, fins, and even internal organs. The oil is extracted from the blubber by means of heat. As the chunks, or "horse-pieces," come on board, they are minced and thrown into a vessel known as a "try-pot," or large copper. This part of the work is carried out as a rule upon the whaling vessel, and, to solve the fuel problem satisfactorily, the residue remaining after the extraction of the oil is burned to heat the coppers. A somewhat fierce heat is maintained night and day, and the contents stirred vigorously during the operation. Great care has to be exercised to prevent the entry of water, otherwise the oil, when barrelled, is apt to turn rancid.

To reduce blubber to oil upon a whaling vessel is no enviable task. In calm weather it is simple and straightforward enough, but when the elements commence to rage, and the vessel to roll, pitch, and toss, the operation becomes dangerous. The contents of the copper surge to and fro, boiling and bubbling madly. If the ship gives an unexpectedly heavy lurch, the contents rush over the side, and, meeting the fires below, ignite with a roar. Often the staff superintending the boiling task has to beat a sudden and undignified retreat to escape the boiling and flaming liquid, which runs hither and thither, viciously cracking and spluttering, over the deck. Fires are damped hurriedly, and large pieces of raw blubber are pitched pell-mell into the pot to steady the agitated liquid within. As the oil is reduced, it is turned into barrels and stowed until the shore station is reached.

But the initial reduction of the blubber, as carried out upon the vessel, is the least important in the whole gamut of operations. The refining process may be divided into two well-defined classes—one relating to the treatment of sperm oil, and the other to ordinary whale oil. The former is more elaborate, because it is considered to be more valuable, although, as a matter of fact, to-day its market price is approximately the same as that of the other. The oil is first subjected to a heating treatment for the purpose of driving off all water which may be impregnated therewith; while at the same time all solid matter, such as fibrous tissue and impurities, settle to the bottom of the vessel. The oil is then permitted to cool. The top layer of oil is drawn off for further refining, while the sediment is withdrawn and made into soap. The first draw of the oil now undergoes a chilling operation—in fact, it is frozen, and this task, for the purposes of economy, is generally carried out in the winter season, to avoid the expense and labour incidental to artificial refrigeration. The freezing operation causes the oil to granulate, and in this condition it is placed in canvas bags and submitted to immense pressure, varying up to 2,000 pounds per square inch. This pressure causes a clear cold oil to be expressed. This run is known as "winter sperm oil," which is capable of resisting congelation at an exceedingly low temperature. This characteristic is one of the virtues of sperm oil, and is responsible for its horological application, in which it may be mentioned it finds one of its most remunerative markets.

The contents of the bags are now subjected to another term of pressure, but at a higher temperature. Further oil is exuded, but it differs in quality and character from that derived from the first squeezing. Consequently, it is kept distinct from the former. Finally, the bags are emptied. The granulated oil resembles cheese in texture and consistency. After a short storage in a uniform heat, it is passed through a machine, which reduces it to thin shavings, and once more it is bagged, to undergo further squeezing. On this occasion immense pressure is applied—about 40 tons per square inch. This third yield represents another grade of oil, which, like the two former grades, is kept distinct. Each of these grades, it may be mentioned, has an individual chilling-point, the first, or winter sperm, having the lowest. After the third squeezing the residue in the bags is crude spermaceti, which is passed through subsequent clarifying processes, to render it suitable for its particular market.

Whale oil is submitted to a process somewhat similar to that followed with sperm oil, but the process is not so prolonged or intricate. As a rule only one pressing is carried out. The oil expressed, which is about one-eighth of the bulk of the bag contents, is then bleached. It is run into a tank and agitated, soda ash or caustic soda being added during the operation. The thick, gummy constituents of the oil settle to the bottom, while the clearer and more fluid constituents rise to the top. The bleaching process may be repeated two or three times, according to the projected marketable application of the product. The sediment from the agitators is drawn off and boiled down to produce oil-soap. The contents of the bags after the oil has been expressed are known as "stearin," and this may be refined in the manner of spermaceti, or it may be sold in its crude condition. Its applications are somewhat limited, since, in the main, it is used as a substitute for tallow. The residue from the agitators finds its principal market as an insecticide in orchards.

While the whale yields immense quantities of oil, there are several other members of this family which are hunted for this product, such as the seal, walrus, sea-elephant, and sea-lion. This fishery is not confined to any one corner of the globe, but is practised from the Atlantic to the Pacific, from Norway, Spitzbergen and the Arctic to the Antarctic; while even the Caspian Sea contributes to the world's supply of seal oil. The blubber, or fat, which is the object of the chase, is that lying between the skin and the muscular tissues. This is stripped and cut into chunks, to expedite the expression of the oil. Three broad methods of winning the oil are practised, the process adopted varying according to the situation, the extent of the catch, and the facilities available; while the intended use of the product also affects the issue to a certain degree. The first and simplest is the sun treatment. Here the mass of blubber is piled in a heap, in capacious tanks, and exposed to solar heat. Putrefaction sets in, breaking down the walls of the cells and releasing the oil. Some two or three months may be occupied in the process, according to the state of the weather; but, while the method is slow, it is inexpensive and simple, as well as being effective. The first "run" of oil is pale in colour, but the hue changes through an orange to a dark brown as decomposition advances, owing to the fact that the products of putrefaction become associated with the liquid. When decomposition has been completed, the pulp is submitted to a boiling process. The oil rises to the surface of the water, and is skimmed off, while the pulp is finally induced to yield the remaining drops of oil by submission to great pressure.

The cooking process is quicker, but more expensive. In this the blubber is minced finely, and placed in a copper over a fire. Gentle heat is applied, and the cells being broken up, the oil escapes to the surface, when it is skimmed off as if it were cream upon milk. This process is imperfect, because, being practised only when the catch is comparatively small and upon the spot, the hunters have not the facilities for increasing the yield by submitting the pulp to a final pressing.

The third, or steam, process is that which is adopted most extensively. It has the advantage of being rapid, while the oil thus obtained is practically odourless, whereas that derived by decomposition is most offensive, as may be imagined. The blubber is minced and placed in large tanks, where it is brought into contact with steam. The latter carries away the oil, which is deposited in receiving-tanks. This oil is of a high grade, and is kept distinct from that which is finally obtained by subjecting the pulp to pressure.

In prosecuting this fishery, the hunters not only have the advantage of securing paying quantities of oil, but the skins

By courtesy of William F. Nye.

A SCHOOL OF PORPOISES LANDED ON THE BEACH.

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ROUNDING-UP A SCHOOL OF PORPOISES.

By courtesy of William F. Nye.

HAULING IN THE SEINE AND THE PORPOISE CATCH.

of the creatures also are marketable for the most part. The pelts of the seal command a ready sale; the sea elephant's hide is also in request among tanners. The grounds for hunting the latter are for the most part off the extreme South American coast, especially around the smaller and unpopulated islands of the Southern Seas. The sea-elephants make their way ashore during the latter part of the year, and the hunters time their arrival to coincide with this movement. The brutes are found in large herds, ranging from 50 to 300, or more. The largest bulls are despatched, the females and young being left unmolested, unless the harvest of bulls should prove indifferent. The thickness of blubber ranges up to 10 inches, and this is cut off in large pieces and towed out to the vessels moored off-shore. The oil is extracted by the method generally practised in connection with whale blubber, and subsequently refined. Ultimately it is classed as whale oil, because it closely resembles the latter article, and as such commands a good price.

The walrus is hunted much upon the same lines as the sea-elephant, but the oil-yield from this creature is considerably less. The layer of blubber is much thinner, the average yield being about 20 gallons from each walrus. Unfortunately, in this case, the wasteful practices followed by the early hunters when the fish were abundant have affected the fishery very seriously. Thirty years ago the walrus-hunt yielded about 2,000,000 gallons of oil, worth £200,000, or $1,000,000, per annum. To-day the hunters consider themselves well favoured by fortune if they bring 2,000 gallons of oil back from the chase. In one day's hunt it is stated that over 1,500 walrus were killed upon a single sand-bar upon which they were discovered disporting themselves. Not one of the carcasses was saved; a high tide washed the whole harvest away. It is not surprising, therefore, that in time the catches depreciated in number and value, and that the hunters are compelled now to penetrate to more distant and lonely seas for their quarry.

While sperm oil is generally considered as one of the finest lubricants for watches, delicate machinery, and mechanism, it is exceeded in these properties by what is known as "fish-jaw oil." This is the oil which is extracted from the jaw of the porpoise. Mr. William F. Nye, of New Bedford, Massachusetts, U.S.A., was one of the first to recognize the peculiar properties and unique value of this oil, and accordingly has specialized in its production. He was persuaded to this effort by the indifferent success which had attended the utilization of nut, bone, seed, and mineral oil in lubricating horological instruments. These latter oils proved fairly efficient for a time, but were susceptible to oxidation, evaporation, and the tendency to "creep" all over the movement, thus reducing the amount of lubrication on a pivot in a jewel. In the case of a chronometer this defect is serious, because it affects the accuracy of the instrument. What is wanted is a lubricating medium which will not oxidize, grow rancid, evaporate, creep, gum, or chill, and which will withstand a high and low temperature with equal success.

In the early days complete dependence had to be placed upon the oil derived from the sperm whale, because there was no alternative; but the quality of the crude deteriorated rapidly as the fishing fleets diminished, and as the whalers were forced to more distant fishing-grounds. The climax came when Mr. Nye placed upon the market a consignment of oil for timepieces, which proved to be sadly wanting in the essential qualities. For some time the cause of this deficiency baffled discovery, but when it was finally ascertained an alarming situation developed. Either a more reliable source of supply than the whale-hunters offered would have to be found, or watch-oil would have to become numbered among things unknown. Mr. Nye embarked upon an elaborate and prolonged series of experiments, which culminated in the discovery that the oil obtained from the jaw of the porpoise and blackfish was vastly superior to the sperm product.

In order to secure reliability in the grade of the crude, he elaborated his own arrangements for hunting down and catching the porpoise and the extraction of the oil. The main idea was to control the issue from one end to the other, and thus be independent of outside supplies.

This industry has now become one of vital importance, and probably is unique. Only the porpoise and blackfish are hunted. Owing to the fact that very few of the latter are seen off the North American coast, and still fewer ever driven ashore, little dependence is placed upon this species. They are larger than the porpoise, but since the oil is precisely the same as that derived from the latter, the porpoise is the fish for which vigilant search is made.

Mr. Nye has established his own station at the lonely, inhospitable spot of Cape Hatteras, North Carolina. Several crews are distributed over a ten-mile stretch of the beach, off which the porpoise is seen in great numbers. Each crew comprises fifteen men, provided with four boats, and a seine, about 1,800 feet in length. Each subsidiary station is equipped with an outlook, and one of the crew is constantly scanning the sea for signs of the fish, which swim in schools parallel with the beach, and relatively close in shore. Directly a school is sighted, the crew are called, and, taking to the boats, proceed to drop the seine, rounding up, or coralling, the fish by drawing the net around them. When this has been accomplished successfully, the men make for the shore with their net, and in a short while the whole school is imprisoned in a small pond or area of the sea. A "sweep-net" is then requisitioned, and with this the porpoises are brought to the water's edge. A rope is passed round the tail of the fish, which is hauled through the surf to a point high and dry upon the beach, where it is despatched.

The carcass is stripped of the blubber or hide from the body, while the jaw is removed separately, carried to a factory, within easy reach of the beach, where kettles, presses, and strainers are installed. Here the jaw oil is rendered immediately. The body or the blubber oil is a cheap grade, approximately of the value of sperm oil, and is sold. The hide itself is also recovered, and finds a ready market among tanners. As it is essential that the jaw oil shall be transferred to the refinery with all speed, in order to preserve its sweet qualities and to avoid rancidity, it is tried out with gentle heat, strained, and despatched to the refinery at New Bedford.

The refining of fish-jaw oil is probably the most protracted refining process in the whole oil industry, the preparation of the oil for its peculiar purpose occupying at least two years. Immediately upon arrival at the factory the gentle cooking process commenced by the fishermen is resumed. When the full yield of oil has been given off, the latter is placed in casks or tanks to await the process of grading. This is the stage at which the greatest care has to be exercised. It is only by leaving the oil stagnant for a prolonged length of time that the trained and skilful eye of the refiner is able to detect to what grade it belongs. Elaborate and delicate tests are made, but greater reliance has to be placed upon trained human skill. The subdivision of the oils into the various classes is extremely delicate, variations of colour, texture, odour, and flavour, as well as other numerous factors, governing the selection. In fact, it is stated that there are barely half a dozen men in the whole world who have acquired the requisite skill to carry out this peculiar task, which conveys some idea of the difficulties attending the production of an efficient clock oil.

By the end of two years the oxygen has united with whatever organic matter or other impurities are contained in the oil. Ordinary straining removes this deleterious matter. The oil now has to be treated so that it may be unaffected by extreme fluctuations in temperature. It is spread out in thin layers and subjected to a temperature far below zero, because it is impossible to advance another step until this is achieved. Moreover, the cooling must be carried out gradually; the process cannot be accelerated, or the properties of the oil undergo destruction.

When it has been chilled to the desired degree, an interesting change takes place. The oil has a beautiful amber hue, but slowly minute spots of translucent material appear. They have an affinity for one another, so they gradually come together. When this development has continued to finality, the liquid is strained through a suitable fabric, which collects these particles, leaving a clear-coloured oil, which fulfils all the requirements of the watch industry. The perfection of this elaborate process may be appreciated when it is stated that oil produced in this manner has successfully resisted congelation when submitted to a temperature as low as 50° below zero. While the finest grades are absorbed by the watch-making and other industries, where a delicate, non-oxidizing, non-creeping, and non-evaporating oil is imperative, the lower grades find a ready market for lubricating other machinery, such as sewing-machines, typewriters, and so forth, where freedom from gumminess is desired.

The body oil-content of numerous other fish, such as the herring, hake, ray, and so forth, is now recovered. In fact, there is no fish which cannot be induced to yield a certain proportion of oil. Those fish which are caught in abundance by means of trawls and seines are treated upon an extensive scale. Huge coppers receive them for the initial heat treatment, while batteries of presses squeeze the cooked pulp to the last drop. The oil finds a ready market, though the prevailing price may be somewhat low, while the residue makes an excellent fish manure, and is in increasing demand. In the British Isles summary disposal of the surplus catches of edible fish is the rule: they are sold direct to the farmers and distributed upon the land. No attempt is made to secure the economical content which, if adequate facilities were available, would reduce the losses inseparable from a glut, while the revenue accruing from the sale of the residue as a fertilizer would be increased, since their speedy disposal would not be imperative, as it is at present. Even the useless parts of the fish, resulting from cleaning, might be profitably submitted to an oil-reducing process.

Fortunately, there are indications that at last this wastage of the sea has been appreciated. One of the latest improvements is the inauguration, by American interests, of a floating oil-factory. This craft has been built and equipped with the latest electrical and mechanical time and labour saving devices, and will primarily be engaged in two industries—the catching of inedible fish for oil-extraction, and the manufacture of fertilizer from the scrap or residue respectively. The menhaden is the fish to be exploited, huge shoals thereof being found in the waters washing the North Atlantic seaboard of the States. This fish resembles a herring, but has no dietetic value. It is rich in oil, however, which finds a ready and profitable sale in the tannery and paint manufacturing industries.

The vessel carries 160 employees, who work in two shifts, thereby enabling manufacture to be carried on day and night continuously. Unlike the majority of fishing-vessels, it is not compelled to return to port frequently, supplies of fuel and rations being carried to suffice for a month at sea. The manufacturing capacity of the floating factory is 800 barrels of oil and 20 tons of fertilizer per day, which, owing to the abundance of the fish, can be maintained without effort.

When a shoal is encountered, huge nets are cast overboard, and are hauled in by means of electrically driven tackle. The nets are emptied into storage-bins, whence, by means of screw conveyors, the fish are carried in an endless stream into small hoppers, and then fed automatically into the steam cookers, where, in the course of a few minutes, they are reduced to a pulp. The oil, rendered by cooking, is drawn off, while the residue is passed into presses, where the last drops of oil are driven out. The oil is conducted to tanks, where it is tested. Being found sweet and pure, it is cooled, and then turned into storage tanks, which have a combined capacity of 20,000 barrels.

The residue, or scrap, is taken from the presses, dried, and packed in bags for market. The vessel is fitted with wireless telegraphy, so that when the storage tanks and other space are fully charged, barges and tugs may proceed out to sea to take off the stocks and transport them to the nearest port. In this way the period of unproductivity, which would arise by returning to port and reputting out to sea, is reduced to the minimum, because the vessel need not return home until it becomes necessary to replenish fuel and food supplies. While the menhaden oil industry has been placed upon a solid foundation in regard to shore oil-reducing plants, this is the first time the idea of establishing a floating factory has been attempted, and, as an illustration of scientific and commercial activity in this particular industry, it is of unusual interest.

The fierce competition offered by petroleum has driven the fish oils almost into oblivion. There is a certain trade in blended oils—combinations of fish and mineral oils—but it is somewhat limited. The trend has been rather to prepare petroleum oils in such a manner as to approach very closely the characteristics and properties of fish oils, while other developments have tended to displace them. A few years ago sperm oil, for instance, comprised the standard illuminant for lighthouses; to-day paraffin, in conjunction with the incandescent gas-burner, or acetylene, is employed.

There are striking evidences of a revival in the fish-oil industry. Science has been busy. The increasing price of dairy butter and the demand for effective substitutes for this comestible, prompted a novel line of research. Fish oils possess certain dietetic qualities; at all events, they are quite as valuable a foodstuff as animal fats. But the peculiar flavour and aroma of the oils derived from this source were a severe drawback, while there was the additional difficulty of inducing the oil to congeal or granulate at a temperature comparable with the setting point of butter. Elaborate experiments were carried out. First the difficulties of aroma and flavour were overcome, and finally the problem of congelation was solved with complete success. The process is comparatively simple and inexpensive. The fish oils are submitted to what is known as a "hydrogenating process." A blast or current of hydrogen is driven through the liquid oil, which is placed in a vessel made from certain metals such as nickel. The action of the gas upon the metallic surface and the chemical composition of the oil completes a startling transformation. The oil is induced to solidify. Thus a new fat base for artificial butter or margarine has been discovered. It is stated to compare favourably with the substitute derived from cocoanut and other vegetable oils, to withstand climatic variations, and to defy detection by the palate.

But this latest conquest of science is not without its alarming features. Applied chemistry in its endeavour to widen the field of foodstuffs has wrought too complete a victory. The dairy interests rose up in arms against the introduction of margarine; but now they are faced with a far more formidable competitor. Fish-oil butter is so closely similar to the dairy product that the character of the oil base cannot be determined. Even the analyst is baffled. The chemical change wrought by hydrogenating is so complete that the resultant margarine assumes every characteristic of dairy butter. As may be imagined, this triumph of scientific effort is being viewed with misgivings. At the moment no means of guarding the consumer against imposition are available. Strenuous efforts have been made, and are still being made, to invent tests to prove whether the fatty base is a fish oil, but they have not been successful.

How this remarkable situation is to be met it is impossible to say. Already factories for the manufacture of this fish-oil butter have been erected and are in operation. The produce has even reached the market. Norway and Japan are the pioneers in this new branch of industry; both countries have an extensive fishing industry upon which to rely, and both have become recognized as large producers of fish oils. Fish-oil butter is assured of a ready and extensive sale throughout Northern Europe and the East; but the product is being placed upon the other big markets of the world. At the moment it is possible to identify the article, since the process of manufacture is not quite perfect, but the butter and margarine industries realize the fact that such defects are merely the inevitable corollary of a new process, and are certain to be overcome as experience is gained and mechanical processes are perfected and improved.

The outlook is certainly disturbing, because fish-oil butter, owing to the low price at which it can be manufactured in countries where labour is cheap, cannot fail to affect the genuine article as well as its recognized substitutes. No objection can be levied against the use of fish oils in this particular direction, inasmuch as they are quite as nutritive as vegetable and animal fats. It will impart a decided stimulus to the fishing industry, and more economical methods of winning the oil from the aquatic animal kingdom are certain to be evolved. Whale oil is the staple oleaginous constituent which is being used in this latest development at present, but, owing to the possibilities of the hydrogenating process, anxiety is being expressed lest oils derived from other and somewhat more doubtful sources be employed. Everything points to another revolution in regard to one article which appears very prominently upon the table, and which enters so intimately into the preparation of comestibles.

CHAPTER XIX

METHODS OF DISTRIBUTING REFINED OILS

ALTHOUGH the transportation of the crude from the field to the refinery offers its peculiar problems, they are insignificant in comparison with those attending the distribution of the products of distillation among the markets of the world. Considerations of cheap movement, expedition, simplicity, and efficiency have to be studied in both instances; but whereas the producer has one substance only to sell—the raw petroleum—the refiner has a diversified assortment of articles of which to dispose, each of which possesses its individual market.

'Twixt well and still the pipe-line meets the situation very completely, but a similar channel of transportation is impossible between refiner and consumer. The distributing issue is rendered additionally complex because local fads and fancies have to be studied and satisfied, otherwise the commodity meets with an indifferent reception. The methods of packing, even the materials employed for the latter, vary considerably. What fulfils the requirements of the British market, for instance, is quite unfitted for the Chinese field, and so on.

Another factor plays a very prominent part in the successful disposal of the products of the refinery. Each country possesses its individual methods of transportation, and close regard must be paid to them. While the railway, the highroad, and motor traction facilitate movement in old-established countries, in the newer territories, where settlement and development are in the embryonic stage, the mediums of transport at command are often of a primitive and uncertain character. In India it may be a bullock-cart; in North Africa the mule; in Egypt the camel; in Uganda the native's head; in China a hand-drawn truck; and so on. Similarly, the artery of communication varies widely in character from an ice-road to a Bush path, from a tortuous, madly rushing river to a winding desert trail. Each demands an individual system of packing in order to meet local conditions effectively.

The problem of distribution may be resolved into two broad groups—wholesale and retail. The former represents the conveyance of the product in bulk from the refinery to a suitable distributing-point in the territory offering a market. The second involves the preparation and sale of the article in small quantities to meet the fluctuating demands of the consumer. The motorist desires his fuel in convenient 2-gallon tins, while the rural cottager, relying upon oil for his table-lamp and cooking-stove, desires it in loose quantities from ½ gallon to a drum or barrel containing 40 gallons or more. Under these circumstances, as may be supposed, distribution represents the most expensive phase of the oil industry, one in which the arts of salesmanship and organization are urgently required. It is a factor which greatly affects the price which the consumer is called upon to pay for the commodity, and the items of expense, efficiency, and elimination of waste, must be studied carefully in order to meet the fierce stress of competition. The perfection of a complete and reliable system of distribution occupies years of labour and involves enormous financial outlay, the return upon which may not become apparent for a prolonged length of time.

During the past few years remarkable improvements have been effected in matters pertaining to distribution. In fact, among the foremost companies of the world it has developed quite into a science. Nowadays the refined oils are transported from the refineries to point of shipment by rail, water, and pipe-lines. The cheapest channel along which the product may be moved is adopted, so long as it is consistent with speedy despatch.

In the early days railways and barges were the sole vehicles for transit. The oil was packed in barrels, and thus shipped to all parts of the world. This was an exceedingly expensive system. The capital invested in the manufacture of the drums, whether made of wood or metal, was enormous, while the item of upkeep, owing to the severe wear and tear, reached a huge figure during the course of the year. But even when barrelling was in vogue, and the railways handled the bulk of the product, the ingenuity of the oil-refiners was revealed in an interesting manner. The ordinary goods waggon or freight car could only receive a strictly limited number of barrels, even when stacked and stowed closely and tightly. To increase the remunerative load per vehicle, a special type of waggon was designed. It was of skeleton form, fitted with racks to receive the barrels. In this manner the load per vehicle was doubled with ease, and consequently the transportation charges were reduced by virtually 50 per cent. Reaching the seaboard, the barrels were slung out by cranes and stowed in the holds of waiting vessels, just as barrels of apples are packed to this day. But no matter how ingeniously the cargo was packed, there was a considerable waste of valuable space, represented by the gaps between the barrels.

The barrel car has practically disappeared. It has been superseded by the bulk tank cars—huge cylindrical vessels lying on their side, and strapped to the deck of the flat truck, provided with a dome through which the oil is discharged into the vessel, and with simple facilities for drawing it off when required. In Great Britain the tank car generally ranges from 8 to 15 tons capacity, but in the New World vehicles carrying 50 or more tons are the standard type.

The tank car has completely revolutionized the system of railway transportation. Packing the barrels, even in the special rack cars, was slow work. To-day a train-load of oil can be made up in a matter of minutes. At the refinery sidings are laid down, and between each track extends a pipe-line, with an adjustable spout, very similar in design to the apparatus employed for charging locomotives with water. The train of cars is backed into the siding, and a dozen or more spouts are connected to as many cars. The taps are turned on, and all the vehicles are charged simultaneously. In this manner a train of oil vehicles half a mile or so in length is ready for movement within an incredibly short period; in fact, a hundred bulk cars may be loaded up in less time than was formerly required for loading a barrel vehicle. The introduction of the bulk tank car and the modern method of loading and discharging have brought about a considerable displacement of labour. Fifty men are able to supervise the loading of one hundred cars or more with ease. It may be pointed out, however, that barrelling has not been superseded entirely. It still prevails to meet the requirements of certain markets, and is practised for the transportation of lubricating oils and waxes.

So far as water transport is concerned, an equally wonderful transformation has taken place. The idea of shipping in bulk by water was tried first with barges. It was not a daring experiment, inasmuch as the load despatched in this manner was somewhat limited. But the advantages accruing from the system, together with the pronounced saving in time and money achieved thereby, prompted further development. The capacity of barges increased rapidly, until now craft of this type capable of carrying from 100 to 300 tons of oil are used extensively.

From the bulk barge to the bulk steamer was not a far cry. The shipbuilder recognized a new and lucrative field for the practice of his craft, and seized the opportunity. The experiment was tried first upon the relatively quiet inland waters. The whaleback, so called from the fact that the hull of the steamer resembles this fish, first attracted attention in this direction. Comparatively small vessels were built at first, because the oil interests move warily when any new or revolutionary idea in transport is advocated. But the simplicity, efficiency, and cheapness of the method could not be gainsaid. The possibility of reducing water-transit charges to an insignificant figure was revealed, and was embraced without further hesitation. The whaleback oil-tanker grew in size rapidly, until to-day vessels of this type are in regular service carrying 10,000 tons—over 2,250,000 gallons—of oil in a single cargo.

Meantime the idea of bulk water transit had spread to the ocean traffic. A special type of vessel, known as the "oil-tanker," had been created. Here again advance was gradual. The first vessels of the type were comparatively small, carrying 1,000 tons or so; but once the advantages of the system were established, a rapid development ensued. To-day the tanker plies the seven seas carrying nothing but oil to feed the hungry markets of the world.

The oil-tanker is an interesting example of shipbuilding handicraft, and incidentally it is one of the safest ships ploughing the ocean. It is divided into three sections; the forepart, or bow, which is reserved to the requirements of the crew; the central section, where the oil is carried; and the stern, in which the propelling machinery is disposed. The central, or oil-carrying, section is insulated at either end by two very strong bulkheads, separated by a space of some 18 inches. The oil section itself is divided into a number of rectangular cells, the walls of which extend from the deck-level to the bottom, while a longitudinal bulkhead extends the full length of the tank. The cells or wells are self-contained, so that various grades of oil may be carried in one cargo. These vessels are of immense strength; disasters among them are very few and far between. During the early weeks of the year 1914 one was caught in a terrible gale off the evil Florida coast, and, under the severe pommelling of the waves, broke in two, and went to the bottom. But this disaster was attributed to individual structural weakness, and to no fault in the type itself. Seeing that the tankers ride the fierce storms of the Atlantic and the unusually tempestuous seas prevailing between the Dutch East Indies and Europe without experiencing the slightest damage, ample evidence is offered of their stability and seaworthiness.

This method of shipping oil by water has reduced the problem of loading and discharging to the acme of simplicity. At the wharves flexible hoses are connected

WATER TRANSPORTATION OF OIL IN 1865.

The petroleum was barrelled and then stacked in barges to be floated or towed along the American waterways. The above scene was familiar upon the oil-fields of the United States during the sixties of the nineteenth century.

THE "SAN FRATERNO," THE LARGEST OIL-TANKER AFLOAT.

The Eagle Oil Transport Company owns ten sister ships, each capable of carrying 15,500 tons—4,500,000 gallons—of oil.

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between the shore tanks and the ship pipes leading to the various wells. The pumps are set to work, and torrents of oil are moved in either direction continuously until the vessel has either been loaded or discharged. One has only to bear in mind the task of loading and unloading a collier to recognize the advantages of oil. There is an absence of dirt, noise, and scurrying mechanical and human labour. Grating and grinding winches, rattling chains and cables, and crunching grabs give way to a low purring of the pumps. A line or two of pipes drooping from the decks to the wharf are the only visible signs that the cargo is under removal. The celerity with which a full load may be taken on board or transferred to shore is equally astonishing. In many instances an 8,000-tonner completes its duty upon a single tide.

The oil-tanker is found in every part of the world. Water distribution is the cheapest means of placing the petroleum products of the Russian Caucasus upon the scattered markets of the Russian Empire. The Nobels, who are to Russia what the Standard Oil Company is to America, have vessels moving to and fro along the great waterways every day and night during the season of navigation, picking up their loads at strategical centres. In this particular development the Russian company is far ahead of its American competitor. Instead of using steam for the propulsion of the vessels, the oil-engine is employed almost exclusively. The advantages are incalculable. Less space is required for the accommodation of the propelling machinery, and more room rendered available for paying cargo, otherwise oil. The oil-engine requires a smaller staff to watch its smooth working, so that there is an appreciable diminution in the labour and wages bill, while the item of maintaining and feeding the crew is reduced correspondingly. The oil-engine can be started up at a moment's notice, and does not consume fuel during periods of inactivity, such as occur while it is shedding a portion of its cargo at a wayside town, as does the steam engine. But for the crude-oil engine it is doubtful whether the Russian company could undertake the delivery and vending of its products in its own market at a price which secures it against competition.

On the Great Lakes of America the tanker driven by the oil-engine has made its appearance, and is challenging the supremacy of its steam-driven rival very seriously. The movement is in its infancy, only two or three vessels of this type being in operation at the moment; but the success so far achieved augurs well for the more extensive application of the idea. In this instance the oil-engine is competing against cheap fuel for steam-raising, but little doubt exists that the oil-driven ship will triumph, in which event the steam-propelled tanker will vanish from the scene. Bulk barging of oil is practised almost exclusively wherever the conditions will not permit power propulsion. It is cheaper than carriage by rail, although it is slower; but the many advantages of this system of conveyance far outweigh the drawbacks. Practically the whole of the oil destined for the storage-tanks scattered throughout London is moved by barges, the Government having prohibited the passage of ocean-going craft engaged in this business beyond the point known as Thames Haven, thirty miles below London Bridge.

The immensity of the fleet engaged in the transportation of oil conveys some intimation of the huge proportions of this industry. The Standard Oil Company has over 120 tankers engaged in its foreign trade alone, ranging up to 9,000 tons, or 3,000,000 gallons, capacity. Parenthetically it may be observed that the greater number of these vessels, certainly the largest, have been built in British shipyards. The company, in accordance with its guiding precept of manufacturing everything possible for its own needs, once essayed the construction of these vessels, but the effort was disastrous. True, this attempt was confined to bulk oil-barges, but this slender experience was sufficient to prove that it could purchase far cheaper in the open market. Incidentally it revealed the salient fact that the design and building of this craft is a highly specialized branch of marine engineering. In addition to this ocean-going fleet, it owns hundreds of barges, tugs, and launches, all of which are engaged exclusively in the movement of oil.

But the most forceful illustration of this phase of activity is revealed by the Eagle Oil Transport Company, a subsidiary concern, controlled by Lord Cowdray, in connection with the exploitation of the oil-fields of Mexico. To meet the situation arising from the prolific yield of Mexican oil, this company placed a single order for twenty tankers to ply between Mexican and British ports. Nine, aggregating 89,000 tons, were ordered from one firm, Messrs. Swan, Hunter, and Wigham Richardson, Ltd., of Wallsend-on-Tyne, who have made a peculiar study of the oil-carrying industry.

Of this big Eagle fleet no less than ten are of 15,500 tons deadweight capacity each. In one stroke the carrying dimensions of the tanker were doubled. An interesting incident in shipbuilding construction may be related in connection with this enterprise. On one day two 15,500-tonners were engaged upon their trials, while two vessels, each of 9,000 tons, were launched the following day, representing no less than 50,000 tons carrying capacity, and this for one company! If the fleet of this organization were placed end to end, it would measure over one and three-quarter miles in length, and if all the vessels were *en route* to Great Britain at one and the same time with full cargoes, over 250,000 tons of oil—75,000,000 gallons—would be afloat. The fact that this one fleet came into being within less than two years conveys a graphic idea of the marvellous growth and vitality of the oil industry.

These 15,500-tonners are the largest vessels yet laid down for this peculiar business. They are virtually sister-ships, so that a description of the one applies broadly to the others. The *San Fraterno*, built at the Wallsend shipyards, was the first of this class to be brought into use. Built upon the Isherwood longitudinal framing system—the latest word in shipbuilding—she measures 548 feet in length. The 15,700 tons—4,710,000 gallons—of oil which she is able to carry are distributed among twelve holds, divided into twenty-four compartments by a longitudinal bulkhead. She is equipped with quadruple expansion engines, fired on the Wallsend-Howden system, capable of developing a speed of 11¼ knots per hour, although upon her trials, under laden conditions, she exceeded the contract by ¾ knot, and with only three of her four boilers in operation. The cargo-tanks are fitted with steam-heating coils, which, rendering the oil more fluid by raising its temperature, facilitates discharging. Her pumps are able to handle 1,200 tons of oil per hour, so that the full load of 15,700 tons may be transferred from ship to shore in less than fourteen hours. The first run under service conditions exceeded all expectations. The round trip between Britain and Mexico was completed at an average speed of over 11 knots, and this for the hourly consumption of about 1½ tons of oil for three out of the four boilers. These results for a ship of these dimensions and tonnage are considered to be highly satisfactory.

Although the construction of a vessel of 15,500 tons carrying capacity indicated a huge step forward, it by no means represents the limits of the shipbuilder in this direction. A few years hence, and we shall have the 30,000-ton tanker, so insistent is the cry for oil, and so imperative the necessity to reduce carrying charges to the minimum. The shipbuilder is ready to supply such a huge vessel, which will exceed in length and size many of the liners afloat to-day, the moment the occasion arises. Such a development is no wild phantasy. When one recalls the huge craft which are employed upon the Great Lakes of America for the conveyance of iron ore and grain, and recollects that the wonderful growth of these vessels is a matter of only a few years, it will be realized that the coming of the 30,000-ton tanker is merely a question of money.

The retail distribution upon land also has undergone radical improvements. Formerly the retail trader was compelled to buy his paraffin—this was the only product in pronounced demand at the time—in large drums ranging up to 52 gallons capacity. Purchases in smaller quantities

DECK OF THE "SAN FRATERNO."

Pipes extend across deck of vessel, to which hoses are connected.

PUMP-ROOM OF THE "SAN FRATERNO."

These pumps move 1,200 tons of oil per hour.

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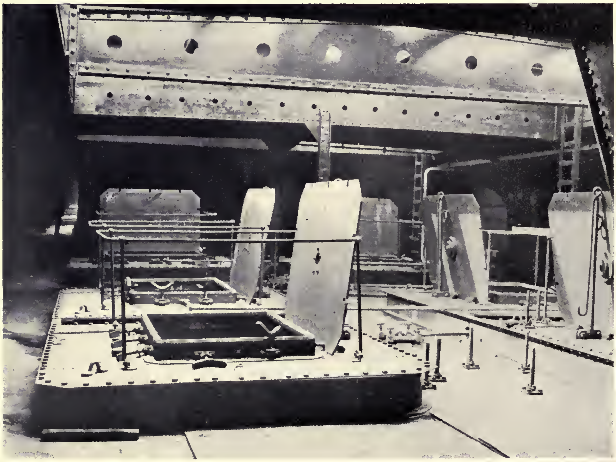
'TWEEN DECKS ON THE "SAN FRATERNO."

Showing hatchways to tanks and pipes through which the oil is pumped.



OIL-TANKS OF THE "SAN FRATERNO."

Hatchways open, showing special oil-tight coverings and hatch-locking devices.

were impossible, owing to the difficulties of transport from the refineries. The consumer had to repair to the shop with his bottle, can, or other vessel, to secure the loose quantity he desired, whether it was a pint, quart, gallon, or more. This system proved disadvantageous. A tradesman having only a limited connection was not in the position to pay for his barrel of oil upon delivery; the vendors were compelled to extend credit, to wait until the shopman had cleared his stock, so that the practice of paying for one upon delivery of the succeeding consignment came into vogue.

To remove this disability, an ingenious individual conceived the idea of retailing the oil in any desired quantity from bulk vehicles. For this purpose he contrived what is now known as the road tank waggon, which is really a diminutive edition of the bulk railway car, adapted to high-road service, and hauled either by animals or power. At first the road tanker was loaded at the railway-station direct from the bulk railway car, which was stored in a siding until emptied. The road tanker was driven from customer to customer, who was able to purchase the exact quantity he desired, instead of the huge barrel which often contained sufficient to last him for months. The distributor received a cash payment upon the transaction, and in many instances he sold paraffin direct to the consumer, especially in country districts. This procedure enabled the unsatisfactory extended credit system to be abolished. The rural dweller appreciated this novel departure, because, by establishing a regular round, he knew exactly when the distributor would call again, and could purchase sufficient stock to carry him over the interval.

Once the advantages of the idea were appreciated, the system extended rapidly. The Standard Oil Company was urged to adopt a similar practice, but hesitated, because the investment in the road tank waggons would be heavy, and because it feared that such a method of distribution might prove more costly than that in vogue, since the expenditure would not be confined to the tank waggons, but would involve the establishment of innumerable storage depots where the road tank waggon could receive supplies. These depots were indispensable; the side-tracking of the laden railway car was satisfactory so far as it went, but this arrangement involved the temporary withdrawal from service of a carrying unit. However, a trial was made upon a small scale in a certain district, and yet upon lines sufficiently comprehensive to test the project completely.

At first the benefits of the movement were somewhat obscured by other factors, so that a certain feeling of doubt prevailed. But when the two systems of distribution were analyzed thoroughly, the company discovered that economies were possible in various directions, while there were the additional advantages accruing from a cash transaction. The factor which stood out most prominently, however, was the saving in the cost of the barrels and transportation charges.

Equipped with this experience, the company embarked upon a systematic rearrangement of its land distribution scheme. The whole country was mapped out upon a comprehensive scale, while the area of each district which could be fed adequately from a central storage-point was determined. This development proved a critical one in the history of the company, one in which the power of capital was illustrated very strikingly. To carry the idea to its logical conclusion involved the investment of millions sterling, but the situation was faced boldly. Depots were established at railway-stations and at suitable points along the waterways accessible by barges. The depot was simple enough, though effective. A cylindrical tank, either of the vertical or horizontal pattern, was erected, its capacity varying according to local exigencies; hose couplings were provided for charging the tanks either from a railway tank car or bulk barge, and to load the road vehicle; while a stable to accommodate the distribution tank waggons and the horses completed the installation.

Each depot was made a complete unit. The distributing agent was given the area of the territory to be covered from that point, and was left to work out his own round and service supply to consumers. Years were occupied in completing the organization of this distribution scheme, but it has proved one of the most successful enterprises ever essayed by the company. To-day there is not a village or a settlement where the familiar tank is not to be seen, while the waggon often makes long trips across the desert, or through the dense forest, to serve some lonely dweller with the "poor man's light." There are a round 3,350 of these subsidiary depots scattered throughout the length and breadth of the United States, while over 5,000 tank waggons ply to and fro between these depots and the local sources of consumption.

The scheme proved so completely satisfactory that, upon the completion of the home network, the company decided to operate its foreign business upon similar lines. Hitherto all foreign sales of oil had been negotiated through commission agents. This system was abolished. The company entered every country, and in Great Britain, France, Germany, Russia, and so on, created subsidiary companies to watch and develop its business. Bulk-stations have been erected at convenient seaboard points in each country, while subsidiary depots have been established at railway-stations and other strategical centres. The half-buried white tank of the "Standard" is a familiar sight at the railway-stations of Great Britain and Continental countries. Fleets of supply waggons were inaugurated to do the same work as in the United States. No country was overlooked, no matter how indifferent the outlook appeared. Trade could be created by the skilful disposition of competent men expert in the art of canvassing, quick to recognize the peculiarities of local conditions, and possessed with the ability to devise ways and means of meeting them successfully.

The seed thus sown so diligently speedily ripened. The missionaries of commerce planted here, there, and everywhere by the company, fulfilled their appointed tasks to perfection. The coolie pushes his small cylindrical tank carried upon a two-wheeled truck to the innermost recesses of China; the Hindu laboriously drives his primitive craft up the backwaters of the India rivers to unload his cargo of oil; the slow-moving bullock-team hitched to the two-wheeled cart carrying the ubiquitous tank penetrates the blistering plains of the Orient; the pack trains of mules and ponies move swiftly, amid clouds of dust, across the African desert, bearing their loads of oil to the dark interior; the camel with its consignment of oil steadily ploughs its way across the sea of sand to the isolated community cut off from all other means of communication. No territory is too far removed from the bounds of civilization, or too inaccessible for the American oil company. In this manner the organization has built up a round 200 stations among the countries of the world where oil may be received in bulk from the tankers, over 5,000 distributing-stations to feed local requirements, and a huge fleet of 4,000 tank waggons to ply the roads, Bush paths, and Indian trails day in and day out. The activity of this company may perhaps be better realized when it is stated that a round 60 per cent. of the oil which it refines finds a market outside the United States. No other oil-producing country in the world extends its tentacles so far, or has woven such an intricate and serviceable system of distribution.

The success of the Standard is not due to waiting for customers to come, but to its wonderful enterprise in creating business. Thus, it not only supplies paraffin among the various nations, but stimulates a demand for the commodity. The tank waggons penetrating to isolated districts carry lamps and stoves. They are strong, serviceable, cheap, and attractive. The agent explains the uses and advantages of these articles, and urges the prospective user to give them a trial. The latter is impressed, acts upon the suggestion, and is gratified by the results. The articles are retained, and the demand for the oil immediately ensues. It may mean the supply only of 1 gallon per week to that one domicile; but when such results are multiplied by thousands, a rich harvest is reaped in the aggregate. The lamps and stoves are sold at cost price, no profit is made

ENGINE-ROOM OF THE "SAN FRATERNO."

The furnaces are fired with oil.

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HOW MEXICAN OILS ARE DELIVERED IN BRITAIN.

Motor traction is adopted. The cylindrical tank carries the products in bulk, enabling any desired quantity to be drawn off.

THE MOTOR DELIVERY OF CASED OIL PRODUCTS.

Motor spirit, certain lubricating oils, and greases, are delivered in cans and tins.

out of them; but each represents a certain outlet for the oil, and this is where the profits are won.

Other companies, with one or two exceptions, have not practised this system with the energy of the American rival. Perhaps the one outstanding exception which eclipses all others is that controlled by Lord Cowdray. When he entered the oil industry by opening up the Mexican fields, he encountered fierce opposition from the forces in possession, which were allied to the Standard Oil Company. The Waters-Pierce Company, to quote its official designation, "held a monopoly"; but such a slight value was placed upon the Mexican petroleum that it virtually confined its energies to the sale of the native crude oil for power purposes. Some highly remunerative contracts had been completed with certain Mexican railways in this connection. But practically all the lighter oils which were required were purchased and shipped from the United States, and the import duty on such products paid.

The British interests changed all this. The lighter products of the oil were distilled upon the spot, to the benefit of Mexican labour and finances, and were exported to Europe. At the same time it was decided to create a market both for refined products and the fuel oil locally. The company in possession construed this movement into an encroachment upon its preserves, and a spirited commercial war broke out. The Mexican Eagle Company accepted the challenge, and startled the American concern by its aggressiveness, tirelessness, energy, and enterprise. The British concern had a refinery at Minatitlan capable of handling 1,400 tons of crude oil daily, and miles of light railways and pipe-lines were in operation. It despatched its drillers and engineers in all directions to search for oil. It was evident that, having planted their feet in the country, the British interests were resolved to leave no stone unturned to secure supremacy.

The foundations of the industry being firmly laid, the British company decided to carry the war into the enemy's camp, and to combat it with its own weapons. An elaborate distribution system was evolved, and put into execution without delay. Contracts were completed with railways for the supply of fuel oil. Tanks were erected at the desired stations where the locomotives could rebunker. Railways which hesitated to adopt liquid fuel were coaxed and tempted to make the experiment upon a limited scale, and, gratified with the success and economies resulting from this system of steam-raising, abandoned coal for oil. One company, in fact, was able to save no less than 40 per cent. upon its daily fuel bill.

The country was also overrun by "live" agents. Within a short space of time no fewer than 160 depots for the sale of oils, lubricants, and other products of the refinery were in thorough working order. The demand, in fact, became so heavy that further refining facilities were required to keep pace with the situation. Accordingly a huge refining plant, capable of treating 4,000 tons of crude oil a day, was set up at Tampico. The bid for trade in Mexico proving so successful, the agents roved farther afield. They penetrated the Southern United States, where the railways, faced with the high price of coal, which had to be hauled over long distances, were driven to oil fuel. The British company assured these railways of an adequate supply of this fuel from the Mexican fields, and, prices being right, long-term contracts for huge quantities were settled. Thus, to-day the British-operated Mexican oil industry not only meets the greater portion of the Mexican demands, but an appreciable volume of the requirements of the Southern United States in this particular line also.

The British market was cultivated similarly. The oil-carrying fleet was inaugurated, but before it came into being reliance had to be placed upon chartered vessels. At Manchester a tract of ground was acquired, and here a tank farm capable of containing 31,000 tons of oil was laid down. Scores of 15-ton railway tank cars were ordered to distribute the commodities throughout these islands, while road tank waggons of the latest type and mechanically driven were purchased. The pace set was so hot that competition was speedily outdistanced; so much so that to-day more fuel oil is imported into these islands from Mexico than from all other oil-producing countries combined.

The enterprise and energy which had achieved such striking results was concentrated upon other countries in turn. The South American railways, which have to import coal from other parts of the world, were attracted to the economies accruing from the use of oil, and substantial contracts were completed. Even Russia was invaded, though she is generally regarded as a difficult country for competitive interests to enter, owing to the power wielded by the Nobels and the heavy import duties. Notwithstanding the huge quantities of fuel oil, or "mashut," as it is called, which are produced from the Caucasian wells, the Mexican product forced an entry, and large quantities of the commodity are being shipped to that country for consumption upon the State railways. The activity and financial strength of the British-Mexican interests to-day make the one rival which the leading American company is compelled to respect.

Although bulk shipment represents the means whereby the greater volume of oil is moved about the world, packing has not been superseded in its entirety. Thus, for instance, China and the neighbouring countries still evince a marked preference for the packed article. The oil is "cased," as it is called. The cans are of 5 gallons capacity, and two comprise a case, which thus contains 10 gallons. The tins and cases are made by machinery, one plant of the Standard Oil Company turning out some 350,000 of these tins every twenty-four hours.

Why, it may be argued, seeing that bulk transportation is so much cheaper, is this method still practised? In the main it is to meet a native weakness. The heathen Chinese and his neighbours are fascinated by that wooden box and tin can. After they have consumed the contents, the cans are utilized for a wide variety of purposes. The native considers the can a useful, if not ornamental, flower-pot. When the can is broken and the metal hammered out flat, it forms an efficient roofing material, and is a serviceable lining for a water-tank, while there are a hundred and one other useful purposes which it can be made to fulfil.

The outer wooden packing-case is neatly fashioned from good, sound, and seasoned timber. It not only forms an excellent firewood, but can be used for a variety of domestic purposes, while it is a first-class foundation for the outer tin covering in roofing operations. The uses to which these materials are put by the ingenious native are astonishing. While they involve a somewhat heavy outlay, they constitute a first-class advertisement. If the attempt were made to sell the oil loosely among such consumers, the custom would speedily disappear. The native appreciates the packing as much as he does the contents. Accordingly, those catering for the remunerative Oriental business pander to the native foible, and in this way have built up an extensive clientele.

CHAPTER XX

THE COMMERCIAL USES OF OIL

THE motor-driven road vehicle undoubtedly represents the most familiar illustration of the application of oil to the generation of power, yet the annual consumption of liquid fuel in the form of motor spirits is relatively insignificant. The strides which have been made by oil in the generation of power, light, and heat during the past few years are amazing. The day of coal's invincible supremacy in the industrial world has passed never to return. Already the yield of oil represents about 10 per cent. of the annual output of coal, while for the purposes of power production the proportion has risen to about 15 per cent.

The advantages of oil are so pronounced that they cannot be ignored. It is cleaner to handle, simpler to control, and offers an effective means of reducing the fuel bill, which, otherwise expressed, signifies a certain reduction in the cost of producing an article. At the present moment oil is being utilized in a round seventy trades and industries which a few years ago were dependent entirely upon coal, and this range of application is extending rapidly.

Oil has revolutionized every form of transportation—road, rail, and sea—while it has also brought human flight within the range of possibility. The startling transformation it has effected in highroad transportation is apparent to everyone. It has driven animal haulage from the field, is threatening electricity, and has been the means of enabling human endeavour to achieve velocities by mechanical propulsion, which a quarter of a century ago would have been regarded as wild dreams. The aeroplane and the automobile represent the fleetest forms of mechanical movement which have been evolved.

But the changes which have been, and still are being, made in connection with movement by rail and water are every whit as wonderful. The motor-ship has appeared upon the scene, and although the development of this type of vessel is exceedingly slow, it is nevertheless exceedingly sure. The Diesel engine is in its infancy: it is a maze of imperfections and defects. But it offers engineering science remarkable scope for activity and inventive ingenuity. Gradually the slow-speed engine burning liquid fuel is undergoing improvement, and, in the course of a few years, will be rendered as simple, reliable, efficient, and as economical as its high-speed contemporary is to-day. Whether the oil-engined vessel will usurp its steam-propelled rival is another question. At the moment this is purely an economic issue. Oil now is virtually as expensive as coal, if not more so, but as new fields are brought into productivity, and the balance between these two factors becomes weighted down in favour of the former, prices must ease.

It is not with the oil-engined ship purely and simply that liquid fuel is making such advances. The true competition is occurring between coal and oil as the steam-raising agent. Coal is dirty, occupies considerable space, and reduces the cargo and passenger-carrying capacity of a vessel very materially. On the other hand, oil may be stored where at present a useless article, from the economic point of view, has to be carried. Vessels, especially those engaged in the passenger-carrying service and the higher branches of merchandise transportation, are provided with double bottoms. The space between the two shells at present is wasted; water is introduced merely for ballasting and trimming purposes. By utilizing oil as the steam-raising agent this space may be turned to profitable account, because the fuel can be carried in the double bottom, and, as it is consumed, the vacant space can be occupied by water to maintain the trim of the craft.

The urgency of some such system of fuel and bunkering is revealed most potently in connection with the high-speed liners which ply the seven seas, as Mr. J. J. Kermode demonstrated before the London Oil Congress of 1912. He took the *Mauretania*, the fastest passenger liner afloat, to illustrate his case. This vessel was built essentially for speed: everything was sacrificed to achieve this end. As is well known, this magnificent vessel, with her engines developing 68,000 horse-power, is able to maintain a speed of twenty-five knots or more between Liverpool and New York. To insure this pace 25 tons of coal have to be fed into the furnaces by hand every hour, which comes to no less than 600 tons per day. Consequently, to cover the distance between the British and American ports 5,500 tons of coal have to be taken on board, while the round trip requires some 11,000 tons. One has only to recall the space which a single ton of coal occupies in the domestic cellar to form some idea of the immense space required to receive several thousand tons. Mr. Kermode pointed out that, if oil were used, 3,300 tons of liquid fuel would perform the same amount of work as is fulfilled by 5,500 tons of coal, so that on the round trip at least 5,000 tons of fuel could be saved. Seeing that the whole of this bulk could be carried in the double bottom, the amount of space which would be released for the reception of cargo may be imagined. Assuming that £1, or $5, could be earned per ton by the carriage of merchandise in what is now the coal bunkers, it is a simple arithmetical sum to calculate how much the earning power of the liner might be increased by the use of liquid fuel.

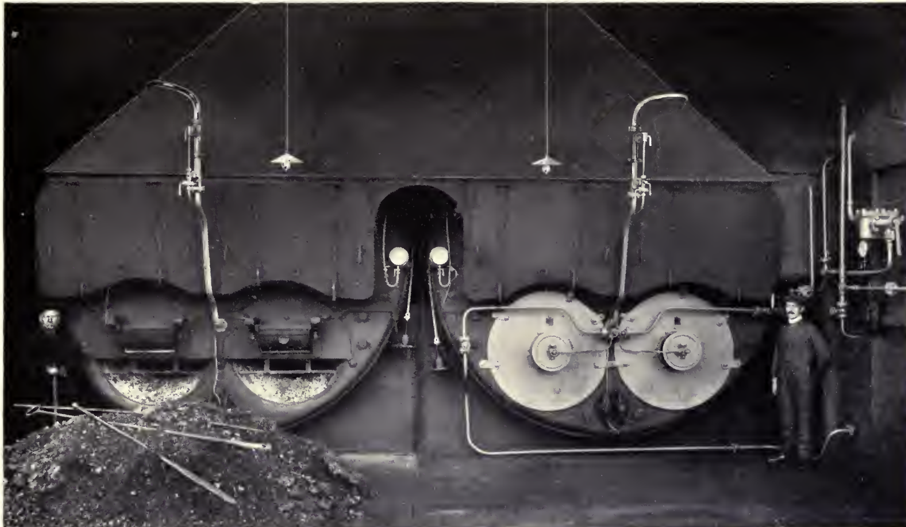
The saving in space is only one phase of the issue. Instead of the furnaces being fed by hand labour, as is now the case in coal-firing, mechanical appliances would be utilized. In this manner it would be possible to reduce the stokehold army from 312 to 30 men. This force would be adequate to attend to the oil burners and to regulate the feed-water to the boilers. This displacement of trimmers and firemen would release sufficient space to accommodate an additional 200 third-class passengers, who would be berthed in the quarters at present occupied by the stokehold crew. Assessing these 200 passengers at £5, or $25, per head, a further addition to the gross revenue of £1,000, or $5,000, would be possible.

Even after allowing for the difference in the prices of the two fuels, it is computed that oil would enable the *Mauretania* to earn at least £10,000, or $50,000, upon a round trip.

There is another point which must not be overlooked. With coal-firing it is incumbent to draw about 32 of the 192 furnaces every watch, to remove clinker, and for general cleaning operations. This means that the aggregate energy of the machinery is reduced from 68,000 to 58,000 horse-power. If oil were used there would be no necessity for drawing the fires; the furnaces could be maintained at full pressure during the voyage from shore to shore. In other words, the steam-raising capacity of the ship would be increased by over 15 per cent., which translated into speed would enable from eight to ten hours in the journey between New York and Queenstown to be saved. Other economies also could be effected. At the moment a large force of men is required to bunker the liner, the task occupying about twenty hours. Were oil fuel used the bunkers could be filled in about three hours, and the operation would entail the employment of only a handful of men. As liquid fuel is moved between ship and shore through pipes, no dust is created, and there is an absence of noise. The saving in cleaning operations arising from coaling, alone would represent a material economy.

With oil it will also be possible to achieve what at present is out of the question. The growing commerce of the world demands the reduction of time spent in travelling to the minimum. Faster ships are required between Europe and South America, and accelerated communication is becoming urgent between the countries of the Northern and Southern Hemispheres. Speedy liners, such as one meets upon the North Atlantic, are impracticable between Europe and the Antipodes, owing to the inability to carry sufficient coal for the whole voyage, and the absence of intermediate bunkering stations upon the longer reaches of the ocean journey. With oil these two disabilities could be overcome successfully.

The shipping world is fully alive to the significance of the issue and to the advantages of oil fuel. There are abundant



By courtesy of the Wallsend Engineering Company, Ltd.

OIL *v.* COAL FOR STEAM-RAISING AT SEA.

The cleanliness and simplicity of the control of the oil-fired furnace at night contrasts vividly with coal-stoking on left.

RUMELY PARAFFIN-DRIVEN OIL TRACTOR HAULING A COMBINED HARVESTER IN MONTANA, U.S.A.

By means of oil-power 65 acres of grain can be cut, threshed, and bagged, per day.

BREAKING VIRGIN LAND BY THE AID OF OIL.

"Rumely" paraffin tractor pulling eight ploughs, drill, and harrow over $2\frac{1}{4}$ acres per hour, upon the plains of North Dakota, U.S.A.

indications that, within a few years, all the crack ships of the North Atlantic, at least, will depend upon liquid fuel. When the White Star liner *Olympic* was reconstructed and fitted with an inner skin, the opportunity was taken to adapt the space between the two shells for bunkering oil. The Hamburg-American line is making preparations to embrace oil fuel when the moment arrives. Substantial contracts for adequate supplies at convenient points have been completed. It only remains for one organization to show the way; the others will be compelled to follow suit in order to maintain their relative positions in the competition for traffic.

The shipping pioneers have been busy in other parts of the world. The liner *Niagara*, belonging to the Union Steam Ship Company, and which plies between Australian ports and Vancouver, burns oil fuel, and, in fact, was the first vessel of this character to receive a certificate from the British Board of Trade for carrying passengers. The Japanese liners running between ports and the Pacific seaboard of the United States are equipped for burning oil. Many cargo boats, exclusive of the oil-tankers, which, of course, depend upon oil fuel, are fired with oil, and the space released thereby accommodates increased paying load. No doubt oil fuel would be used more extensively by freighters but for one drawback. While some bunkering ports have both fuels available, the majority can supply coal only. This uncertainty is met to a certain degree by equipping the boats for either coal or liquid fuel, whichever is obtainable, but many of those running upon oil exclusively, which are engaged upon a scheduled route, take on sufficient supplies at the home port to carry them through the round trip.

Oil fuel is even more vital to ships of war than to those engaged in the mercantile marine; in fact, the very existence of a warship might depend upon oil. In the first place the volume of smoke emitted from an oil-fired vessel is insignificant—merely a light, filmy wreath—even when the vessel is being pushed to its utmost; whereas when stoked with coal, thick trails of dense black smoke are thrown off, particularly when the craft is driven hard, rendering discovery by the enemy, even when the latter is below the horizon, quite an easy matter.

Other advantages accruing from the use of oil render it imperative for naval work. A vessel's radius of action—that is, its mileage and work upon a single fuel charge—is extended considerably. When a coal-fired warship runs short of fuel, it is compelled to make for port to take on fresh supplies. True, ingenious devices have been contrived to enable a vessel to be coaled at sea, but so far they have not proved very successful, and can only be employed in the calmest weather. If a warship were surprised in the act of coaling at sea it would be caught at a serious disadvantage, because it would be hampered by the collier, and the tackle for moving the coal from one to the other, which would take a certain length of time to cut adrift. On the other hand, when bunkering with oil it is only necessary to carry one or two lengths of hose from the tanker to the warship, to couple up the pipes, and to pump the fuel from one to the other. In this instance the warship could not be surprised very effectively. Release of the pipe connections and the warship would be ready to meet its opponent. The facility with which a vessel can be bunkered with oil at sea enhances a warship's value, as there is no need for it to return to port for long intervals.

So far as land transportation is concerned, the past few years have witnessed a wonderful transformation. The self-propelled vehicle fed with oil is making startling conquests in all directions. The tradesman depends upon the motor-driven cycle-car and motor-van to serve his customers more expeditiously, and has been enabled to offer prompt delivery over a wider radius—up to sixty miles. The taxi-cab has ousted the hansom from the streets, and the motor-bus has become established more firmly than ever, as the poor man's automobile. The predominance of this vehicle, and what it means to the community, is revealed more powerfully in the Old, than in the New, World. It is not only regarded as a swift and convenient system of transportation between home and business, but is regarded as a pleasure vehicle as well. It enables the working-man, toiling laboriously in the sweltering city for six days, to reach the distant countryside, fields, woods, and stream with its invigorating sweet pure air cheaply, on the seventh day of the week. The mobility of the vehicle is its outstanding characteristic. Unlike the tramway, it is not condemned to a road provided with a pair of metals: it can proceed over any road or lane sufficiently wide to admit the passage of a four-wheeled vehicle. The fact that in London alone over 3,000,000 people take the motor-bus for a breather in the country upon a Bank Holiday, conveys a striking impression of the popularity of this form of locomotion. In the New World the electric tramway holds predominant sway, but the motor-bus is as far ahead of this form of street locomotion as the tram-car is in advance of the rickshaw. Indeed, in the British Isles it promises to render the electric rival obsolete.

Wherever haulage or mobile power is required, the motor is displacing animal effort, and other systems of power. The enterprising farmer ploughs his land, sows his seed, garners his crops, and carries his harvest to market by motor. Inability to work in the field does not condemn the vehicle to idleness; it is an invaluable handmaid for the performance of other innumerable duties—threshing grain, chopping, and mincing foodstuffs for stock, sawing wood, drawing water, generating electricity for the lighting of the home, and so on. In breaking vast stretches of virgin land, such as the prairies of Canada and the United States, and the Steppes of Russia, the motor-driven vehicle has wrought wonders. By its aid an acre of land has been broken in four minutes! Although steam traction has been employed in this duty, the cost of coal and wood, owing to the long haulage, renders this form of power more expensive than oil fuel; hence the popularity of the motor agricultural tractor. Incidentally the expansion of this movement has created a demand for paraffin, the lighter and more explosive spirit being somewhat too expensive for general farming operations. The perfection of a reliable paraffin vaporizer still remains to become numbered as a triumph of mechanical engineering. The problem is somewhat abstruse and complex, but it is being attacked energetically, with the result that, if present indications offer any reliable criterion, the time is not far distant when the paraffin vaporizer will be as perfect as the carburettor used with the high-speed explosion motor in automobile practice to-day. An efficient means of vaporizing this denser oil will exert a far-reaching influence upon the motor fuel situation, which is admitted to be somewhat critical; the automobile will not be condemned to operation upon the more explosive series of the refined products.

In railway transportation oil is offering a complete solution of many searching problems. Many railways operate in territories where local fuel resources are unknown; all coal has to be hauled immense distances, and, consequently, by the time it reaches the centre of consumption, the transportation charges have inflated the prime cost of the fuel to a very pronounced degree. In 1889 Mr. Urquhart devised a burner which enabled the residue from the Russian petroleums to be used as fuel. Tests emphasized its value, and forthwith 143 Russian locomotives were equipped with it. This was a discovery of far-reaching importance. The quantity of residue or mashut available from the Russian oils is enormous, and it is obtainable cheaply; coal, on the other hand, is expensive.

In Great Britain the late Mr. Holden, while chief locomotive engineer of the Great Eastern Railway, introduced a burner for the atomizing and spraying of heavy oil in the furnaces of locomotives, and it was introduced upon one or two of the crack engines of the system. The consumption of oil in the haulage of an express train weighing 225 tons was practically 50 per cent. less as compared with coal. But in Great Britain, with its huge deposits of coal, oil is faced with a formidable competitor. The cost of the latter rose rapidly until at last it was found to be cheaper to burn coal than liquid fuel, and accordingly the innovation was abandoned.

In other countries, however, such as the Southern United States, Mexico, South America, and certain European railways, there is no such competition. For instance, on the Mexican railway, coal alone was used during the year 1910. In 1911 the company was persuaded to test liquid fuel, abundant quantities of which were readily available. The results were so startling that by the end of 1912 not an ounce of coal was being used for the stoking of locomotives upon the railway. Experience proved that by means of oil the fuel consumption was reduced 32 per cent. per kilometre. Oil fuel has a higher calorific value than the coal generally employed for steaming purposes, and, consequently, a less quantity is required to fulfil a certain task, which means that less weight has to be carried by the locomotives. Oil may be taken on with greater ease, speed, and simplicity. An engine's bunkers can be charged in the same manner as the water-tank; the man performing the latter can carry out the former duty. Waste in loading is reduced to insignificance, while cost of bunkering is likewise negligible. Other economies are noticeable. Oil produces no ash or clinker, so that cleaning operations are avoided.

With oil a locomotive, like a steamship, has a greater radius of action—that is to say, it can cover more miles upon a single charge of fuel; there is enhanced steaming power; the adjustment of the fuel to varying loads is effected instantaneously; steam is raised in less time; there is an absence of smoke; while in tropical and semi-tropical countries there is no risk of setting a forest or standing crops on fire by flying sparks ejected from the chimney—a risk inseparable from coal-firing. Upon the North American continent, and, indeed, in Australasia, and other countries, the damage wrought by fires started from passing locomotives attains huge proportions. The danger has been mitigated to a certain degree by fitting spark arresters to the chimneys of the engines, but this precautionary measure has not overcome the evil entirely. The item of compensation which is disbursed annually under this heading by some railways is heavy. With oil this charge cannot be incurred. In the United States the Government has been urged to enforce oil-firing upon those railways traversing the belts where fires from this cause are too frequent, and where extreme devastation is wrought. Many of the American railways, such as the Southern Pacific, resort extensively to oil for firing purposes, and now that the difficulties of atomizing the fuel, to secure perfect combustion, have been solved, there is no reason, except comparative cost, why oil should not be used.

In Mexico oil-firing upon the railways has progressed astonishingly. About 5,000 miles of railways are now in operation, and the daily consumption of oil fuel exceeds 10,000 barrels, or 420,000 gallons. The Tehuantepec trans-continental railway, 189 miles in length, the reconstruction of which was carried out by Messrs. S. Pearson and Son, the well-known British contractors, of which Lord Cowdray is the presiding spirit, runs entirely upon oil. This road is by no means one of the easiest to operate, seeing that its grades run up to about 112 feet per mile, while the sharpest curves are approximately of 500 feet radius, limiting the train speed to 15 miles per hour. On this line the comparative tests between coal and oil which have been carried out are very illuminating. The time occupied in getting up steam to 180 degrees pressure from cold with coal is 152 minutes; with oil the desired end is achieved in 70 minutes. The consumption per 100 ton-miles is 20·8 pounds of coal and 10·3 pounds of oil. The advantage in both instances represents about 50 per cent. With oil fuel improved speed is about 16 per cent. on the average, while the improved evaporation represents no less than 90 per cent. On the Interoceanic Railway, which connects Vera Cruz on the Gulf of Mexico with Acapulco on the Pacific seaboard, which system has an aggregate of 1,035 miles in operation, equally striking results have been achieved. In raising steam from cold to a pressure of 180 pounds per square inch by means of oil, 28 minutes are saved; the improved speed with oil represents 20 per cent.; and the improved evaporation per pound of oil is no less than 130 per cent. The difference in the fuel consumption is, perhaps, more impressive since, whereas 15·07 pounds of coal are required for 100 ton-miles, 6·85 pounds of oil achieve the same end. These results are reflected upon the railways of the United States. In that country the oil-fired locomotives cover over 120,000,000 miles per annum, while the oil consumption easily exceeds 33,000,000 barrels per year.

There is another aspect of railway operation which oil has influenced very materially. Modern economic conditions demand that the revenue-earning capacity of a train should be raised to the maximum. Reduce train-miles, but increase ton-miles, has become the railway-operating slogan. This means that heavier, larger, and more powerful locomotives must be used. But, unfortunately, the locomotive engineer, depending upon coal fuel, is faced with an insurmountable obstacle—the physical endurance of the fireman. Efforts have been made to overcome this obstacle by the evolution of automatic stoking devices. They have met with success up to a certain point, but they are somewhat complicated in design and operation. With oil, as the whole stoking operation is reduced to automatic action—the oil virtually handles itself—no such difficulty arises. The labours of the fireman are reduced to controlling the burners. This fact has not been ignored by the locomotive engineer, and it has been responsible for the evolution of the mammoth locomotives peculiar to the United States. Take the Mallet articulated compounds which are utilized for heavy duty upon the Southern Pacific, for instance. These locomotives are of the 2—8—8—2 type, and have a total weight, engine and tender, ready for the road, of 277 tons. Oil-firing is adopted: with coal it would be impossible to keep such a giant up to its work; oil alone enables this end to be achieved. Owing to the extreme length of the engine, it is run cab foremost, the tender, carrying 3,120 gallons of oil, being attached to the chimney-end. Other locomotives of even greater size and higher hauling capacity have been designed for the heaviest classes of traffic in the States, in which dependence is reposed upon liquid fuel for steam-raising purposes.

The conquest of oil is indicated equally strikingly in connection with stationary plants. Oil is a far more flexible fuel to handle for steam-raising purposes than coal: a sudden demand can be met with tolerable ease therewith. Under coal-stoking conditions, this fluctuating maximum demand is met as a rule by the installation of what might be termed a supplementary force of boilers. Normally the latter are not required, but when the exigencies of an increased demand arise, they are available. With oil this surplus plant is not necessary: the existing installation can be driven somewhat harder to meet the temporary increased demand. Under coal-firing conditions it is necessary to carry banked fires so as to be ready for any emergency, in which case fuel is consumed wastefully. With oil it is only necessary to carry a pilot gas flame. Then, when the sudden demand arises, the oil-burner is started up instantaneously, and within a few minutes the boilers are carrying a full head of steam.

During the past few years wonderful advances have been made in regard to the application of oil to various manufacturing purposes. Furnaces for case-hardening and annealing, forging, rolling, cloth-singeing, melting metals, are in daily use upon an extensive scale, while it has also been adopted for the making of glass. Oil offers a ready means of raising a fierce heat within a few minutes, while the latter may be maintained at a uniform degree with ease. Moreover, it is possible to vary the temperature in accordance with requirements much more readily and satisfactorily with oil than with coal, and this effective control is of vital importance to many industries.

Another interesting and more recent application is in connection with the heating of buildings upon the radiator system. The general method is to maintain a furnace in the basement or some other convenient point, using coal or coke as fuel. Not only is considerable time required to raise the heat to the desired point, but it is a somewhat difficult matter to regulate the temperature. Under oil-firing, this end may be attained in 50 per cent. less time, while by adjustment of the burner the temperature may be

STEAM SUPERSEDED BY OIL.

In many logging districts the railways are operated by internal combustion locomotives.

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OIL *v.* ANIMAL HAULAGE IN AUSTRALIA.

A Daimler petrol-driven road-train, with fourteen tons up, and a freighting team of thirty donkeys hauling one and a half tons.

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controlled to a nicety. The oil fire requires less attention; so long as there is oil in the fuel reservoir it will continue to work. It can be extinguished at any moment, and should it require to be relighted there is an absence of the fire-kindling preliminaries incidental to firing by solid fuel. Of course, as in all other applications of oil to power and heat, periodical interruption of the plant for cleaning purposes is obviated.

CHAPTER XXI

THE WORLD'S FUTURE OIL-SUPPLIES

ALTHOUGH it is patent to one and all that the annual consumption of petroleum to meet the world's complex requirements must be enormous, it is difficult to grasp how much is used during the twelve months, because it attains such a stupendous figure. In 1911 over 420,000,000 barrels were consumed, and the 500,000,000 barrel mark is being approached rapidly. In other words, no fewer than 21,000,000,000 gallons of oil are being drawn from the earth during the course of the year. To this colossal total the United States contribute over 200,000,000 barrels, or 8,400,000,000 gallons—nearly one-half of the whole world's supply. It is not surprising, therefore, to learn that petroleum ranks as one of the foremost products contributing to the nation's wealth. The annual value of the American petroleum yield is considered to exceed in worth all the gold, silver, lead, and every other metal product—copper and iron excepted—produced in an equal length of time in that country.

How long will the earth be able to meet such an enormous consumption? Is there any danger of these resources becoming exhausted? These are obvious questions, bearing in mind the colossal character of the output. So far as the United States are concerned, little apprehension need be entertained. It is computed that the proved oil deposits in that country represent an immense store of 12,000,000,000,000 barrels, or over 520,000,000,000,000 gallons. And new fields are being discovered and opened up every day. The fact that 300,000,000 barrels of petroleum are being drawn from other parts of the globe offers convincing testimony to the enormous extent of this mineral wealth, and it must be remembered that the commercial exploitation of these sources is of comparatively recent date. The rapidity with which these contributing countries are being opened up for their petroleum wealth is amazing.

Although there are ample indications of the untold abundance of the world's supplies of petroleum, the necessity for husbanding these resources has been revealed. Even to-day temporary shortages and gluts are experienced. The urgency for displaying greater intelligence in the exploitation and the utilization of oil is being emphasized upon every side. In the past the abundance of the product caused carelessness and wastefulness in its handling and consumption. But the stiffening of market prices has wrought a wonderful transformation, far more effective in its purpose than the weighty worded warnings of experts. The community, from the increasing price of the commodity, has been forced to practise more economical methods. Similarly, the producer has been driven, by stern experience, to recognize the salient fact that, while a strike of oil may represent the consummation of ambitions, it is more likely than not to spell ruin, since a glut of oil without a market is like a man being stranded upon a desert isle with bulging pockets of gold.

The refineries, from the dominating position they have attained, are driving home the force of the conservation argument with telling effect. They have made the producer appreciate the fact that the production of more oil than the refineries are able to handle, even when driven at tip-top pressure throughout the round twenty-four hours, is inimical to the former's interests. The retort is that the refiners should alleviate the situation by extending their existing plants, or providing new ones, for treating the petroleum, and provide further storage facilities in order to meet the fluctuating conditions. But the refinery is the most expensive item in the whole field of operations, while a tank farm represents an enormous financial investment, the return upon which is somewhat uncertain, owing to the capriciousness of the oil-field, and the duration of its productivity.

The tank farm, from its very character, is migratory. It has to follow on the heels of the speculating drillers and boomers. The duration of its sojourn at any one point is hypothetical. For instance, in 1884 the Standard Oil Company maintained an immense farm of tanks, each of 35,000 barrels capacity, and covering a tract of 20 acres at Olean, in the heart of the Pennsylvania petroleum district. To-day one searches for that tank farm in vain. It was abandoned, the tanks were demolished, and the farm was re-established several hundred miles distant, in the centre of the Oklahoma oil-fields, where 175,000 barrels per day are received, and tanked pending despatch through the pipe-lines to the refineries.

To-day the losses of oil are diminishing. Fire still claims a certain proportion, but here the adoption of scientific appliances and methods for combating this fiend have reduced, and still are reducing, the ravages under this heading to but a fraction of what they were two decades ago. In the refineries themselves the most complex and elaborate arrangements are in operation to reduce wastage. Some of these details, when regarded individually, appear too trivial to receive consideration: the quantity of oil which is saved thereby seems too insignificant to warrant the measures practised, but in the aggregate a very appreciable saving is effected. When the sea-going tankers, the bulk barges, and the railway tank waggons, return to receive further consignments of oil, they receive a preliminary flushing to remove remaining traces of the previous consignment, because the oil to be shipped on this occasion is of different grade. But the flush is not turned overboard. Instead it is led into large settling tanks. Here the oil in time disassociates itself from the water, is run off, and is carried through the distillation process once more. The same applies to the waste from the refineries. Every effort is taken to save every drop of oil possible. It is an illuminating illustration of the old saying that "many a mickle makes a muckle," and it contributes to the efficiency, and incidentally to the profit, of the refinery.

In this observance of small and trifling sources of revenue the Standard Oil Company excels. Nothing is regarded as waste: the items generally classed as such are defined in the same manner as the scientific explanation of dirt—" Matter in the wrong place." Accordingly, every effort is made to turn the apparent waste into its correct and useful channel. This organization creates as much fuss over the misuse of a few nails in the box-making machine as it does over the loss of a railway tank waggon loaded with oil. It prides itself upon its ability to find a use for everything. The little beads of solder which drop to the floor during the process of making the tin cans are collected and thrown into the melting-pot; the sweepings of the various rooms are sifted; the wooden boxes in which the tin plate is imported are sold to tradesmen who can turn them to advantage. The elimination of waste spells efficiency, and it was the observance of this immutable law which was responsible, in a great measure, for the position which this concern assumes in the oil and industrial kingdom to-day.

Oil is growing more expensive, and it will continue to do so under prevailing conditions. The refineries, by introducing the latest and most up-to-date time and labour saving devices, are reducing the cost of resolving the crude into its many marketable parts. But the cost of winning the crude is rising steadily and persistently. In the proved fields the upper layers of oil have been exhausted. The wells have to be taken to a greater depth; the speculative driller has to toil for a longer period than formerly before he meets fortune; and he draws more blanks than prizes in the gamble. Labour is becoming more expensive. Thus, it is costing more to draw a gallon of oil from Mother Earth to-day than was the case a quarter of a century ago. In the Baku district the drills are being driven to depths which were never contemplated before; in Galicia many of the later wells have had to be carried down 4,000 feet to reach the oil, and as the depth has increased experience has proved that greater difficulties are encountered. Water is one enemy which is harassing the deep-well drillers to an extreme degree; it is not readily and inexpensively mastered. In some instances recently remunerative wells have had to be abandoned because water obtaining and maintaining the upper hand, and defying all efforts to overcome it, has poured forth in greater volume than the oil. In fact, in one or two cases the yield of oil has been superseded by a flow of water.

The prevailing experience of the Burmah fields conveys a very interesting illustration of the current difficulties associated with oil drilling. This is one of the richest territories in the world. But the upper layers of paying sand are becoming exhausted, necessitating the re-drilling of the wells to the succeeding layer of oil sands. This seems a simple task, but it has revealed one disturbing feature, not peculiar to Burmah, but common to other parts of the world. Each succeeding layer of paying sand appears to be of diminishing yield. Many of the Burmese wells have been carried down to 2,600 feet, and have been accompanied by extraordinarily fluctuating results. Some re-drilled wells yield excellently; others are non-productive. As the precise disposition of the petroleum-carrying sands in the earth's crust is merely a matter of conjecture, the speculative character of this probing for oil may be realized. At all events, re-drilling and deeper drilling cannot be continued indefinitely.

Such factors cannot but enhance the cost of winning oil from the earth. One company alone expended a round £50,000, or $250,000, more upon its field operations during 1913 than in the previous year, although the work was by no means abnormal. This item is certain to increase as the years pass. In fact, the foregoing organization set aside a round £100,000, or $500,000, in excess of that allowed for the year 1913, to meet the expenses under this heading during the ensuing twelve months.

The outlook for commerce, unless the production increases more rapidly, is far from being attractive. It is certain that oil fuel will be embraced by the leading powers for naval purposes within a few years. It is estimated that, if this practice is adopted upon a comprehensive scale, a round 200,000,000 barrels of oil will be consumed annually. The mercantile marine likewise is contemplating resort to liquid fuel, and if current expectations are fulfilled, a further 200,000,000 barrels per year will thus be absorbed. Thus the needs of navies and commercial vessels will demand 400,000,000 barrels, which, at the moment, represents four-fifths of the total annual output of the globe. To meet this demand, as well as the existing requirements of commerce, the annual output will have to be increased to a round 1,000,000,000 barrels, or 42,000,000,000 gallons per annum. Can this be fulfilled? Expert testimony is doubtful. It will entail doubling the number of wells at present in operation, as well as the number and capacity of pipe-lines, tank farms, refineries, and transport arrangements.

Should this expected development materialize, the situation can be eased to a certain extent. Petroleum structurally adapted to fulfil the conditions of fuel oil is the more prolific, and its preparation for market is somewhat simplified. The naphthas and illuminating oils, known as "toppings," only require removal. These can be taken out by "skimming," being resolved subsequently into their two respective series by distillation. Unfortunately, however, the fuel oil which is marketed as such contains appreciable fractions of the two series removed by skimming, which, in other words, means that the oil may be forced to release further quantities of inflammable and illuminating oils. The refineries, no doubt, will welcome the movement, as their work will be rendered simpler and cheaper, but those industries depending upon the explosive and illuminating oils will suffer somewhat.

The outlook for the motorist depending upon a volatile spirit for his vehicle is far from being rosy. During the past eight years the price of motor spirit has doubted. In the United States alone the domestic consumption of petrol or gasolene rose from 14,000,000 to 50,000,000 gallons per annum within five years. The self-propelled vehicle, though generally regarded as being responsible for the increased consumption of this light spirit, is but one factor in the situation. In the United States the foregoing increase within such a short time was attributable entirely to the perfection of the gasolene stove. Rural dwellers hailed this invention with enthusiasm, because it placed them virtually upon a level with their friends dwelling in towns and cities where public gas supply facilities are available. The spirit stove is also making considerable headway in China, Japan, and contiguous countries, as well as in India, owing to the persistent canvassing of the emissaries of the oil refiners, who are ever on the lookout for new markets, since this is generally regarded as being one of the most valuable sources of petrol consumption. This spirit, moreover, is as indispensable to isolated communities as the staff of life, because power, heat, and lighting are obtained therewith, a fact which those living in the older and more settled corners of the world fail to appreciate. In such districts industrial endeavour is brought to a complete standstill when the existing supplies of this spirit run out.

At the moment it is impossible for the refineries to meet the world's requirements for what is colloquially known as "motor spirit," and this is responsible for its high price, which is about the same figure from London to San Francisco and from Nome to Hobart. The crude is yielding less and less of the more volatile fractions capable of inclusion in this class, while it is being squeezed more and more in the process of distillation and re-distillation to induce it to release the last drop of the lightest naphthas.

At the dawn of the high-speed internal combustion engine the density of petrol or gasolene ranged between 0·636 and 0·657. In a short while the specific density was raised to 0·680, and for a time the market was so well supplied with this that it became recognized as the standard—the colloquialism, "0·680 spirit," indicating the fuel for automobiles. Then came another movement. The yield of 0·680 spirit becoming less uniform, could not be maintained, or not at a reasonable price. Distillates of high and low gravities were mixed together to yield a product apparently analogous to that desired. The device for vaporizing the spirit naturally drew off the lighter constituents first, leaving the denser ingredients behind. When the former was exhausted, the vaporizer no longer worked smoothly, with the result that innumerable carburettor eccentricities were experienced. When these occurred in an equable temperature, it is not surprising that the wrath of the motorist knew no bounds. This mixture of different distillates continued for a while, and, indeed, is practised by some companies to this day. When such methods are practised, the adulteration—for such it is—baffles detection by means of the hydrometer, which merely gives the specific gravity of the liquid and not its vaporizing properties. It is necessary to submit the spirit to fractional distillation, which alone will reveal the fact that light and heavy distillates have been combined.

So persistently has the specific density of motor fuel been lowered that the spirit of to-day ranges from 0·715 to 0·730. This in reality is the benzine or naphtha "B" of ten years ago. The refiner in his persistent downward movement cannot proceed much farther, because he is already verging upon the line of demarcation between the explosive and the illuminating oils. This division from the vaporizing point of view is very sharply defined, so that, generally speaking, 0·730 spirit, under present conditions, is considered to be the limit to which the refiner may proceed in the provision of a motor fuel.

The critical position of the automobile fuel problem has been responsible for the display of considerable inventive ingenuity in the attempt to discover an efficient substitute for petroleum spirit, and fluctuating ephemeral successes are being achieved. Two or three years ago the synthetic or alternative substitute known as "benzole" attracted considerable attention. This must not be confused with the benzol distilled from petroleum, which is a totally different product. The substitute is derived from a coal base, being one of the light oils which has been dissolved in coal gas. Formerly no attempts to recover this product were made, although its removal does not exercise any deleterious effects whatever upon the illuminating qualities of the gas. The production of benzole has developed into an important industry, and has become one of the staple by-products in the manufacture of coke for metallurgical purposes. But in this particular instance the production of the liquid fuel does not constitute a prime factor. It is merely a by-product, the recovery of which is governed by the demand for the coke; in other words, it would prove unremunerative to regard the spirit as a staple product. Accordingly, if the demand for the coke diminishes, the output of the spirit decreases correspondingly, with this additional drawback—when the price of the leading article falls below a certain figure the recovery of the benzole fails to be profitable.

Benzole has not aroused very enthusiastic interest outside the British Islands, and the activity in this direction in this country has come to be regarded as a passing phase. In Germany it is produced upon a limited scale, while in the United States it is absolutely neglected. One disturbing feature which must react against its vogue is that its price has approached that of petrol, notwithstanding the fact that it is inferior to the latter.

While Great Britain cannot point to any raw petroleum deposits, the country is rich in oil in another form—associated with shales, clays, and cannel coals. The shale-oil industry has been described in a previous chapter, and to-day constitutes Great Britain's solitary commercial representation in the oil-producing industry. The clays, especially the Kimmeridge clays, possess an appreciable oil content, which can be won by destructive distillation. But the commercial exploitation is affected by one serious drawback—the absence of fuel deposits within easy reach of the clays. This deficiency is fatal. Much has been said and written about Great Britain's dormant oil resources in this direction, but the situation in regard to the oil-clays to-day is parallel to that which prevailed three or four centuries ago in relation to iron. Sussex is rich in iron ores, and was the centre of the iron ore industry. But no coal is found within easy reach, and wood had to be used as

By courtesy of the Oil Well Supply Company.

A CORNER OF THE BALACHANI OIL-FIELDS.

In Southern Russia the derricks are built so closely together as to give the appearance of a dense forest when viewed from a short distance.

GENERAL VIEW OF A GALICIAN OIL-FIELD.

What is known as the "Canadian" rig is used in this district.

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a fuel in smelting. When the two minerals were found side by side in the North of England, the iron industry migrated from south to the north, owing to the availability of cheap fuel. For the self-same reason, unless coal or other equally cheap and efficient fuel is found within easy reach of the clay deposits, the extraction of the oil will remain merely a possibility and not a commercial certainty.

The possibility of reviving the British coal-oil industry has received considerable stimulation from the perfection of the Del Monte process. In this instance, as with the shales, crude oil is the staple product derived from cannel coal by destructive distillation, with sulphate of ammonia, the valuable fertilizer, as a by-product. The crude oil is afterwards subjected to distillation in a manner comparable with the treatment of the crude derived from shales, various products, among which motor spirit is said to predominate, being obtained thereby.

Great achievements are promised from this latest development, because Great Britain has enormous deposits of cannel coal and shales, which are also to be exploited. Unfortunately, however, it is to be feared that the high price ruling for motor spirit and the agitation of motorists for a cheaper fuel has been responsible for attracting undue attention to this process. One has only to recall the boom which took place in the process of winning oil from the Scottish shales, and the fact that the seventy firms which were once engaged in this industry have now dwindled into six, to recognize the difficulties of the task. The reason for the strong position of the Scottish shale-oil companies I have explained in another chapter; the new process has still to offer proof of its possibilities and profitable operation.

According to the published achievements of the Del Monte process, about 50 gallons of crude oil are drived from 1 ton of cannel coal. It is quite possible that the coal is less rich in oil than that worked by Young at Bathgate, who obtained an average yield of 120 gallons per ton; but the recovery of the sulphate of ammonia by-product is an additional attraction. Those exploiting the Del Monte process have an initial advantage. It is stated that the price of the raw material is 7s. ($1.75) per ton at the works. When Young commenced operations, his coal cost practically double, namely, 13s. 6d. ($3.25) per ton. Unfortunately for Young, the price of his material increased until it attained £4 10s. ($22.50) per ton, which was too high a figure to support the industry, and accordingly oil distillation from the coal came to an end. It is not impossible that what happened in the fifties of the nineteenth will recur in the tens of the twentieth century.

With the Del Monte process it is claimed that, by distillation and cracking, from 14 to 15 gallons of motor spirit, 32 to 33 pounds of paraffin wax, and about 40 pounds of pitch may be derived from 50 gallons of crude oil extracted from 1 ton of coal. From the residue sulphate of ammonia is extracted in paying quantities. Taking all things into consideration, it is claimed to be possible to produce motor spirit for 1½d. (3 cents) per gallon. Needless to say, such an achievement will not only represent a great scientific triumph, and will offer a means of setting the British oil industry upon its feet, but will be hailed with unalloyed delight by British motoring circles. Unfortunately, precedent is against the dawning of such a millennium. Motor spirit is in such keen demand for twenty or thirty markets, and commercial nature is so frail, it is only natural to suppose that the producers will embrace the opportunity to sell their commodity, not at 10d., or 20 cents, per gallon, but at a price much the same as that of petroleum spirit.

The fact is generally admitted that Great Britain should turn its lower grades of coal, those which at present have no market, to account in the distillation of oil. Such an industry no doubt could be created and established were previous experience not a serious deterrent. The previous attempts to distil oil from coal were by no means successful. The quality of the products did not compare favourably with those derived from petroleum, and accordingly the industry fell upon evil days, languished for a time, and finally died out. The evolution of a simple and profitable process for distilling oil from coal remains an unsolved problem of science. Its perfection will enable those countries possessing vast deposits of low-grade coal, but without petroleum resources, to throw off the shackles of dependence upon nations which have been more favourably blessed by Nature in this respect.

In the attempt to alleviate the existing irksome situation prevailing in Great Britain, numerous other inventions have been duly announced. Among these may be mentioned the derivation of motor spirit from heavy oils by "cracking" and catalytic action. Heavy oils are utilized because they may be purchased cheaply. Cracking and catalysis, however, are by no means new. They are practised in every up-to-date petroleum refinery, where effort is being concentrated upon the maximum yield of the explosive and illuminating fractions, especially with oils having a paraffin base. The present crisis has been responsible for the publication of several processes relating to what may be described as the production of synthetic oil products, and for the derivation of oils from a wide variety of substances. Needless to say, these sensational and revolutionary processes are intended for consumption by, and to extract money from, the gullible. To win oil from any substance oil must be present, and in sufficient quantities to render its extraction financially profitable, otherwise the possibilities of success are comparable with those attending the extraction of gold from sea-water.

The solution to the fuel issue in relation to the traction problem must come from outside the petroleum world. Oil refiners are unanimous in the opinion that alcohol will constitute the motor fuel of the future. It is more abundant and can be extracted more easily and cheaply from the raw materials than its equivalent can be derived from petroleum. Moreover, there is the ability to maintain an abundance of the essential raw material, because the vegetable world is prolific in its yield of alcohol. The one objection to alcohol is its lower working efficiency. One gallon of alcohol will do no more useful work than about half a gallon of petroleum spirit. On the other hand, taking into consideration the cheap price at which alcohol can be distilled, this is not a disadvantage. Unfortunately, throttling legislative action has rendered alcohol production impracticable. Were it freed from these trammellings, it would be possible to create a new and large industry, which within a very short time would be flourishing and prosperous. It would solve the back-to-the-land problem completely, because the culture of potatoes, beet, and other vegetable produce yielding a high percentage of alcohol, would be extremely remunerative. Within less than a single decade this country would be able to produce every gallon of motor fuel which it demands. Undoubtedly the alcohol distilling industry will undergo development the moment the chemist evolves a cheap and completely effective denaturizing agent, so that human consumption of the spirit may be rendered impossible.

Seeing that Great Britain does not yield a drop of petroleum, it is obvious that we must depend upon our own exertions, and work out our own salvation in matters pertaining to the motor spirit problem. The foremost petroleum refining companies are generally assailed for artificially inflating the price of this commodity. The situation can be eased only by introducing a powerful competitor, such as alcohol. The petroleum refining companies are not troubled one whit by the various processes which are constantly being brought before the public for winning motor spirit from petroleum and other products. Each has been, and still is being, tested, and the measure of the competition likely to ensue has been fully taken. Whatever contributions such processes may make to the motor fuel question, they cannot affect the ultimate issue, because of the very wide difference between supply and demand. On the other hand, as alcohol can be produced so cheaply—at about one-eighth of the cost of petroleum spirit—and can be manufactured in unlimited quantities, it would become a serious competitor. In one stroke a remunerative market in the petroleum world would be lost beyond recovery, because the petroleum refiner could never aspire to produce and sell petroleum spirit at a figure below, or even comparable with, the price of alcohol.

The wail is frequently raised that the petroleum industry is controlled by a few organizations, and that they wield autocratic sway. Certainly the most prominent firms are huge concerns, possessed of great capital resources, and earning huge profits. The Standard Oil Company of America is unique; its fabric is of colossal proportions. The capital of the company is $100,000,000, or £20,000,000. But this does not convey an adequate impression of its wealth. This is revealed by its extensive operations and stupendous facilities for purchasing, storing, refining, and marketing petroleum and its products. The value of its plant and equipment of all descriptions is estimated at $700,000,000, or £140,000,000, seven times its capital. In normal times it gives employment to 80,000 men, and distributes over $150,000, or £30,000, among this big army every day in the form of wages, while from the sale of its products it derives a daily income exceeding $250,000, or £50,000. The majority of the employees are shareholders in the concern, this policy having been fostered, while it maintains its own pension scheme, which is conducted upon a liberal scale. It owns forests in different parts of the country, whence it derives the timber required for the manufacture of barrels and boxes, which it makes in its own workshops, with machinery designed by its own men, and made in its own machine shops. It makes its own glue; builds its own railway tank waggons; its road waggons; pumps for driving the oil through the pipe-lines, lamps, wicks—in short, a thousand and one articles which are tributary to the oil trade. At the same time it is a large buyer of these commodities in the open market, because even its extensive facilities are insufficient to comply with the fluctuating and expanding requirements of trade.

This powerful organization was created to consolidate interests, to concentrate manufacturing forces, to reduce manufacturing expenses, to eliminate waste, to maintain the balance between production of the crude and refining, to cope with oil-booms and rushes with their concomitant evils and reckless losses of valuable material, and to prevent suicidal competition. In a word, it set the oil industry upon a solid foundation. The organization, owing to its magnitude and wealth, has been bitterly assailed, but obloquy is the inevitable penalty for enterprise and success. The fact is realized to-day, however, that it is a stable and economic national force, which has contributed in no small degree to the wealth of the country to which it belongs. The Standard no more dominates the oil industry of the United States than the British interests govern that of Russia. It is an insignificant oil producer, because it produces a bare 15 per cent. of the petroleum raised in the States. Its producing activities are confined, for the most part, to pioneering in districts where the conditions and problems are beyond the resources of the speculative individual. The remaining 85 per cent. of the oil raised from the earth is contributed by independent companies, syndicates, and speculators. The company is the largest purchaser of the crude, and this is entirely due to the fact that it is able to take care of the raw material, and because the producer is assured of a fair and steady market, as related in a previous chapter.

Owing to the success of the premier American organization, similar concerns are being built up slowly in other countries. Each is essentially a "miniature Standard," because the methods practised by the American concern, which experience has proved to be successful, are being copied. The advantages of concentration and decentralization have been established; they offer the only means of handling successfully such a capricious undertaking as the winning and selling of oil.

Wealth is imperative in oildom. Money often has to be poured out in an apparently reckless manner. The failures exceed the successes in number. Many of the blanks which are drawn after the expenditure of large sums of money would wreck a small concern. The large organization is able to face reverses without perturbing its shareholders in the slightest. In the transportation of the crude, the refining, and the shipment of the products, substantial financial strength is imperative. To-day a corner in oil is impossible, owing to the conflicting interests engaged in the industry. For many years the United States and Russia were virtually the only oil-producing countries, but they hold this distinction no longer. In Mexico the development of the oil resources has undergone sensational and rapid uplifting; in fact, the progress of development eclipses that of the United States. The British interests associated with the expansion of Mexico's oil commerce have played a prominent part in increasing the annual output from that country from 1,000,000 barrels to 23,000,000 barrels, and that within six years. Similarly rapid expansion is taking place in other countries, notably Roumania, while newer territories, unknown to-day, will become powerful forces in the oil world within two or three years, owing to the remarkable enterprise and strenuous endeavour associated with their development.

What is the future of oil ? It is impossible to prophesy. Notwithstanding the conquests which it has achieved up to the present, they are insignificant in comparison with its coming triumphs. It will exert as far-reaching an influence upon the commercial prominence of a country as it will upon its concrete existence. Coal played a vital part in the welfare and prosperity of the countries of the world during the nineteenth century. Oil will seal the fate of nations during the twentieth century.

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