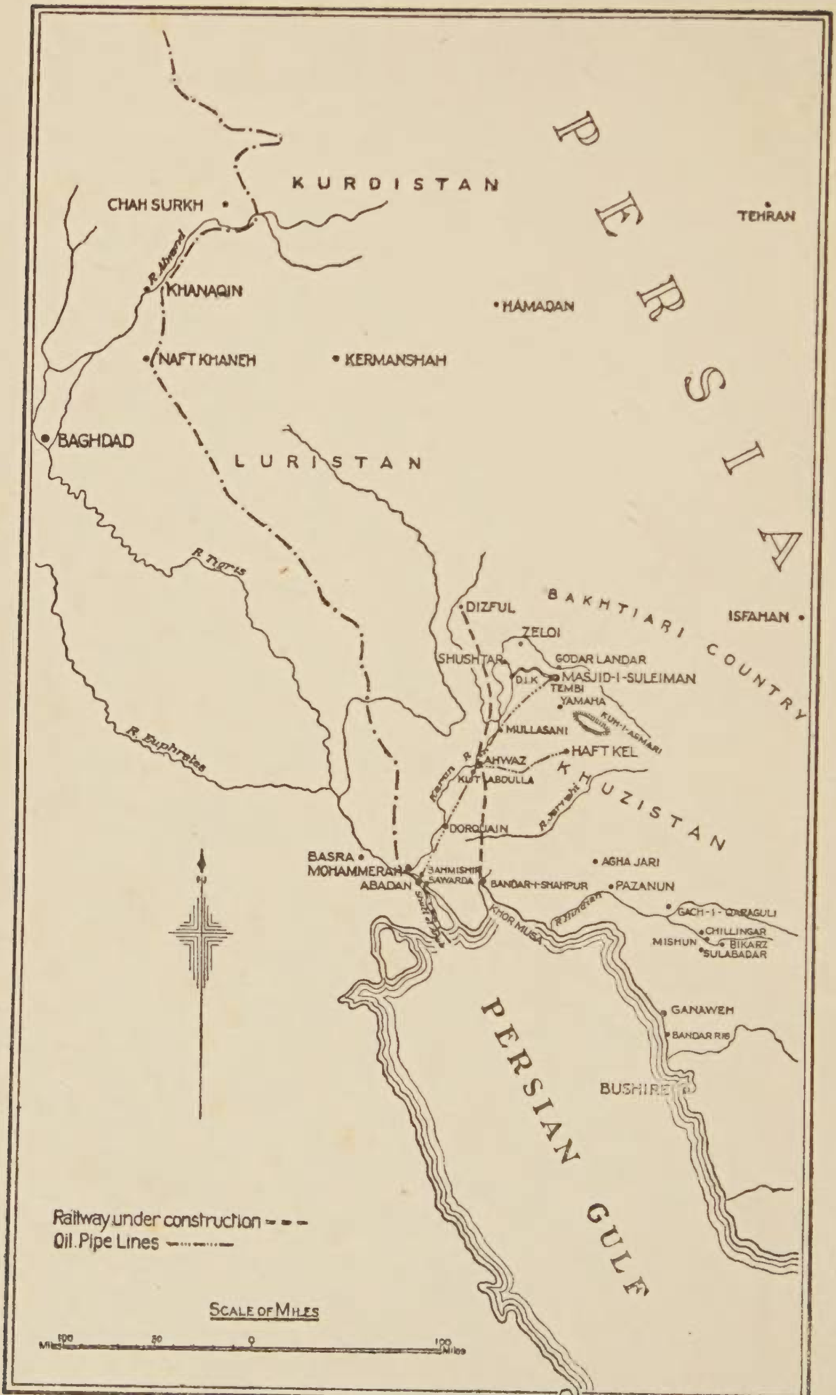
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KUT ABDULLA
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SAWARDA
BANDAR-I-SHAHPUR
PAZANUN
KHOR MUSA
GACH-I-QARAGULI
CHILLINGAR
MISHUN
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SULABADAR
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BANDAR RIG
BUSHIRE
PERSIAN GULF
Railway under construction
Oil Pipe Lines
SCALE OF MILES
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In a Persian Oil Field

IN A PERSIAN OIL FIELD

A Study in Scientific and Industrial Development

BY

J. W. WILLIAMSON, B.Sc.

Barrister-at-Law, of Gray's Inn

Secretary of the British Scientific Instrument Research Association

With a Prefatory Letter from

The Rt. Hon. the EARL of BALFOUR

K.G., O.M., F.R.S.

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Prefatory Letter from the Earl of Balfour to Sir John Cadman, the Chairman of the Anglo-Persian Oil Company.

WHITTINGEHAME HOUSE,
HADDINGTON,
SCOTLAND.

September 26th, 1927.

DEAR SIR JOHN CADMAN,

I am very grateful to you for sending me Mr. Williamson's admirable work, "In a Persian Oil Field." You tell me that this is due in part to what I said at the Mansion House in one of the many speeches which I have made upon the application of science to industry. If this is so, I am indeed to be congratulated; and I am sure that those who share my views on this subject will derive, as I have derived, much satisfaction from reading this lucid exposition of a particular case in which science and industry have successfully co-operated.

Yours sincerely,
BALFOUR.

INTRODUCTION

THE sub-title proclaims this book to be a study in scientific and industrial development. So many publications dealing with science in industry have been issued in recent years that, perhaps, some explanation, if not excuse, is desirable for this addition to the number. Most of the contributions to the subject have approached the question on general lines and reinforced the argument by illustrative examples drawn from several selected industries or from numerous industrial firms. The method adopted in the following study is the reverse of this process; it is to describe, as a concrete illustration of the applications of science to industrial development, the work of one corporation only, the Anglo-Persian Oil Company, in one industry, the oil industry, and to treat the subject in such a way, it is hoped, as to lead to an appreciation of what is implied when we speak of the industrial applications of science.

If practice is better than precept, it may be that the study of how an individual corporation has assimilated scientific knowledge and methods into its industrial organism may be a useful complement to the studies that work down from general considerations to numerous particular instances. The method of presentation here adopted, by enabling the record to take on something of a narrative form, may give to the subject matter an added, because an almost biographical, interest.

The main object of this study, then, is to show, in broad outline only, the extent to which the Anglo-Persian Oil Company has applied and is applying, especially in Persia, scientific knowledge and scientific methods in the oil industry; and also to describe, as integral parts of the same story, though again in outline only, some of the industrial, educational and social developments that have arisen, and have been sedulously cultivated, as natural outgrowths of the Company's work.

It is not the purpose of the writer to tell again the story of the D'Arcy concessions, of the long, indomitable and ultimately triumphant efforts, made in the face of great discouragements, to find the oil which it was suspected was to be found in Persia. That romantic story has been told before. Nor is it the purpose of the writer to describe the initial pioneering difficulties met with in the early years of the Company's work. That story has also been adequately told already. It is with other aspects of the activities and achievements of the Anglo-Persian Oil Company, more particularly in Persia, that this essay is concerned.

The following pages will, it is hoped, show clearly that the financial profits made do not constitute the most important achievements of the Company and that, in any case, the commercial success that has been achieved is due very largely, perhaps predominantly, to the consistent and continuous application of science, in the widest sense of that word, to all, or nearly all, the activities of the Company.

Such an account is especially desirable in these days when statesmen, scientists, captains of industry and others are proclaiming the need for a more extended and more intensive application of science to industrial problems. If the record of what the Anglo-Persian Oil Company has done in Persia can be faithfully and adequately told, it may help, in some measure, to bring about a better and keener appreciation of all that science may do for industry, and must do for British industry if, in the stress of international competition, British industry is to survive.

The writer was invited by the Chairman of the Company to make a visit to Persia, in order to study on the spot this aspect of the Company's work and achievements. The visit, for personal reasons, was necessarily brief, but the writer had an opportunity during a period of nearly a month of visiting the greater part of the active area of the Company's operations in Persia.

It should be understood that what follows is not intended to be a critical review, from a scientific view-point, of the work of the Company. It is, to speak frankly, an appreciation but, the writer hopes and believes, a judicious appreciation.

Nor is it to be taken, in any way, as a technical summary of the operations involved in finding, getting and refining crude oil. The numerous text books published on these subjects contain full information on these points, nor does the writer claim any particular competence to add to their number. What he went out to see was how far the work of the Anglo-Persian Oil Company in Persia was an example of the application of science to industry, interpreting the word science in its widest sense, so as to include the methods of dealing, not only with the raw material obtainable from the crust of the earth, but also with the human and sociological factors necessarily involved whenever and wherever large scale production is carried on.

The genesis of this book was inspired, to a great extent, by some observations made by the Earl of Balfour on the general subject of the application of science to industry. The writer records gratefully his indebtedness to Lord Balfour for the privilege of being permitted to include, by way of preface, the letter that precedes this introduction.

The writer expresses also his thanks to Sir John Cadman, the Chairman of the Anglo-Persian Oil Company, and to many members of the Company's staff for the valuable and willing help given to him. It would take up too much space to name all those to whom he is so indebted, but the writer hopes he will be absolved from the fault of making any invidious distinction if he acknowledges especially his obligations to Mr. J. Jameson, Dr. M. Y. Young and the late Mr. H. Y. V. Jackson, with whom he was brought into frequent contact in Persia. To the Council of the British Scientific Instrument Research Association also the writer expresses his cordial thanks for the leave of absence generously granted to him to enable him to visit Persia.

J. W. Williamson.

3 *Verulam Buildings,*
Gray's Inn, London.
September, 1927.

PREFACE TO THE SECOND EDITION

The first edition of this book being out of print and a new edition having been called for, the opportunity has been taken completely to revise the work and, by considerable additions, to bring it abreast of the latest developments. In particular the geophysical sections have been largely re-written and an entirely new chapter (Chapter XI, "Oil and Ethics") has been added, dealing with the larger, international aspects of the petroleum industry as a whole, so that the reader may be helped to see the Anglo-Persian achievement in proper perspective, as part of the world economic factor popularly summarised under the term "Oil."

The author is again greatly indebted to the kindness of the Chairman of the Anglo-Persian Oil Company and of many members of the Company's staff for valuable advice and assistance in the work of revision.

For the generous appreciation expressed by reviewers and private readers of the work in its first form the author tenders his grateful thanks. He would again emphasise that, although many reviewers have thought well to recommend the book to the attention of petroleum technologists, it is written primarily for the general reader who may have had no scientific or technical training, but who may be interested by such a striking and significant example of the application of science to industry as is here described.

J. W. W.

January, 1930.

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PART I

THE SCIENCE

CHAPTER I

THE PERSIAN OIL FIELD

It may be well at the outset to describe briefly the area covered by the Anglo-Persian Oil Company's present active operations in Persia and in the contiguous territories in north-east Iraq. This area extends generally in a north-west, south-east direction, from Chiah Sourkh and Naft Khaneh in north-east Iraq to Sulabadar in south-west Persia, a total distance in this direction of over 450 miles. From north to south it stretches for 150 miles or so from Gudar-i-Landar on the river Karun to the island of Abadan at the head of the Persian Gulf. The principal oil-field—the original and famous Maidan-i-Naftun field and its extensions—lies in the northern part of this area, in the district having Masjid-i-Sulaiman (Soloman's Temple) for its centre, some thirty-five miles east of the ancient Persian city of Shushtar, the oil being found directly beneath the foothills that give on to the high range of the Bakhtiari Mountains, which form the great barrier between the desert plains to the south and south-west and the great central plateau of Persia. Between the extreme well in the north-west of this Masjid-i-Sulaiman oil-field and the extreme well in the south-east is a distance of about seventeen miles.

At Abadan there is a great refinery for the treatment of the crude oil from this field and also a modern port at which the tankers take in crude oil for shipment to the Company's new refinery at Skewen, Llandarcy, S. Wales, and refined products for other destinations.

Another important oil field has been opened and is in course of rapid development at Naft Khaneh in Iraq, some 100 miles north-east of Baghdad; and a refinery to supply local requirements has been erected to deal with the crude oil from this field, about twenty-five miles north-west of it, on the river Alwand, near Khanaqin, which is the head of a railway from Baghdad and also on the caravan route to Teheran. A third important field is being rapidly developed at Haft Kel, about forty miles S.S.E. of Masjid-i-Sulaiman. Test borings are also being carried out at various places in south Persia.

That, roughly, is the area of the present active operations of the Anglo-Persian Oil Company in the Middle East. The area covered by the concession from the Persian Government is, of course, much greater. It includes practically all Persia except certain provinces in the north and north-west around the Caspian Sea, and covers no less than 500,000 square miles.

The visitor from Abadan who desires to reach "Fields"—the name given "for short" to the main oil field having Masjid-i-Sulaiman for its centre—may proceed by boat up the Shatt al Arab and then up the river Karun, which winds and twists through the desert, as far as Dar-i-Khazineh, some 170 miles by river from Abadan. At Ahwaz, about 114 miles up the river from Abadan, the navigation of the Karun is interrupted by a series of rapids and here the Anglo-Persian Oil Company has important workshops, stores and transhipment equipment, for transferring, by rail and road, materials and persons above and below the rapids. From Dar-i-Khazineh a railway has been constructed to Fields, via the gorge of the Tembi River. This is used mainly for transport of materials. A metalled road for passenger traffic also connects Dar-i-Khazineh with Fields and follows a route further to the north-west, through the foothills.

There is an alternative route to Fields. The desert between Abadan and Dar-i-Khazineh is an excellent natural road for mechanical transport, although, after heavy rains in the winter, it becomes impassable. The introduction of motor cars has reduced the time taken for the journey from Abadan to Fields from five days to eight hours. The river Karun is, however, with modern steamers and barges, still the most economical means of transporting heavy materials. The Company has recently introduced transport by air, and an aeroplane has been provided and pilots engaged, so that members of the staff may now be still more swiftly transported from Abadan to Fields or to and from other areas of the Company's operations. A beginning has thus been made with an air service which is certain in time to be developed extensively.

The work of the Anglo-Persian Oil Company is, of course, to find oil, to get the oil when found to refine it and to distribute the refined products. It may simplify the task of showing to what extent and in what manner science has been and is being applied to the operations of the Company if we take, roughly, this order of presentment and then proceed to describe those social, educational and other developments which have grown with the growth of the Company's industrial operations, and, as will be seen, have been assimilated into the organic whole of the Company's corporate activities.

CHAPTER II

FINDING THE OIL

In most countries where oil has been found indications of the presence of oil-bearing strata are generally, though not always, known before the geologist is called in to play his scientific part. Leakages of gas or of oil or of both—technically known as "seepages" —are often, and perhaps usually, matters of native knowledge and past history. The seepages may be misleading to the oil prospector. They may be evidence, not that oil in any quantity is now there, but that it has been there, the seepage being merely the residue of a once existing great store. Structural indications of the character and conformation of the strata forming the earth's crust often give to the experienced geologist better evidence of the probable presence of oil-bearing strata.

The problem of finding the oil is, therefore, essentially a scientific problem. It is not merely a matter of noticing some oil or gas oozing from the earth, or oil floating on the surface of some stream, and then drilling a well somewhere near by in the hope of striking a hidden oil field. When it is realised that to sink a well may cost upwards of £20,000 it will be understood that "wild cat" drilling is uneconomic. A series of scientific investigations has to be made, and the results have to be co-ordinated and correlated before any prudent and reasonable decision can be taken to sink a test well at any spot. Let us glance at these preliminary scientific investigations as they are conducted by the Anglo-Persian Oil Company.

GEOLOGICAL

The Company's geological headquarters for Persia are situated at Masjid-i-Sulaiman. There is an institute furnished with a complete geological and cartographical equipment and containing also a museum of geological specimens obtained from the various areas of the Company's operations. These specimens, it may be noted by the way, form a valuable and available record for, and contribution to, the science of geology, apart from any applications to the oil industry. A scientific staff of geologists, cartographers, draughtsmen and map-printers constitutes the personnel under the direction of the Principal Geologist. A school for training Persian surveyors has also been added recently to the establishment.

The functions of the Geological Department fall under two headings: Exploration and Exploitation. Geologists engaged on the former are sent out as required, completely equipped with scientific instruments, implements and camping outfits; those engaged on the latter are occupied with development, correlation and research work on the proved fields and on test drilling areas.

The work of the exploration geologists and surveyors is frequently an arduous business in Persia. Many of the areas to be explored have never before been visited by Europeans; in many cases the available maps are inadequate, food and water are scarce or not to be found; and not only roads, but even mule tracks, are non-existent. Apart from the delicate task of getting on good relations with the local inhabitants, the supply of the food and water needed, the transport of the materials and equipment, and the maintenance of communications in such remote areas constitute problems of great difficulty.

The first business of the geologist who is called in to examine a promising area is to make a geological reconnaisance of the area. A rough topographical survey of the surface is made simultaneously, if an adequate topographical map does not exist. Next a more detailed geological survey is carried out over selected portions of the area and a geological map is drawn on a large scale, say, three or six inches to the mile, the scale depending on the complication or simplicity of the structure.

So far we are dealing only with the geology of the surface, though much information of the underlying strata may be given by, and deduced from, the "outcrops" in, or not too distant from, the area under examination—i.e., from those places where the underlying strata have turned so as to come to the surface or have been otherwise exposed, as, for example, in cliffs, gorges or river beds. The various formations so exposed are identified, their thicknesses measured and their direction and the direction of any folds there may be carefully noted. From these data information is obtained as to the character and structure of the underlying strata—the sub-surface geology. This information is supplemented and confirmed or corrected later, as we shall see, from the direct evidence obtained in the process of drilling.

The task of the geologist in the Masjid-i-Sulaiman district was extremely difficult by reason of the character of the earth's crust here. During the period of the folding of the earth's crust in this region, not only were the strata twisted and crumpled in an extraordinary way, but great quantities of certain of the more plastic, underlying strata were squeezed out from between other more rigid strata and thrust forward so as to cover younger beds, with the consequence that the deductions as to the run and character of the underlying strata, which may normally be drawn from outcrops, were utterly untrustworthy here. It was geological chaos.

A GENERAL VIEW OF THE MASJID-I-SULAIMAN OIL FIELDS

As the visitor approaches Fields by rail from Dar-i-Khazineh he climbs gradually through foothills which are mainly masses of smaller or larger detached mounds; then through a gorge cut by the river Tembi through a mass of rock, mainly gypsum, the local name of which is "gach" and which is the plastic material referred to as having been squeezed out; and eventually he comes to a view of hills like nothing so much as the unnumerable ridges, peaks and hillocks, closely packed and apparently all higgledy piggledy, that a child could make by crushing tightly a mass of tissue paper in its hands. It is in this terrain and below such a surface jumble that an oil field has been discovered and tapped which not only may well turn out to be the most productive and extensive oil field in the world, but is unique in the simplicity and "oneness" of its structural character.

It may be as well, perhaps, to describe here and now, in the barest outline, the character of this oil field. The oil is found at depths of from 1,000 to 5,000 feet or so below the surface, in the "Main Limestone," which can be seen to outcrop in the great hog's back of Asmari Mountain, some seventeen miles away to the south-east. Above this oil-bearing limestone rock is, by fortunate circumstance, a hard "cap rock" of anhydrite and above this again are other strata—salt, anhydrite, shales, sandstones and conglomerates—

forming what the geologists call the lower, middle and upper Fars and Bakhtiari formations.

There has been discussion as to how the oil is held in the limestone. Is it contained simply by the porosity of the limestone, or is it in larger cavities in the rock? In the geological department at Fields experimental investigations have been made as to the validity of the porosity theory. All the evidence acquired goes to show that the crude oil occurs, mainly if not wholly, in cracks, fissures and canals within the main limestone, and that the interconnections between these breaks in the continuity of the limestone are such that the oil reservoir in this field is one.

The structure of the Main Limestone is remarkably simple in contrast with the complicated structure of the overlying beds. The limestone is folded into long, narrow, anticlinal structures of great size, separated by deep synclinal depressions. Masjid-i-Sulaiman is situated above one of these great anticlines, the higher part of which is folded into three subsidiary domes—the Naftun, Naftak and Golak domes—all forming part of the one great reservoir of oil.

Within these domes gas from the oil has accumulated in the past and rises continuously, as oil is withdrawn, to the roofs of the domes and the pressure due to this accumulated gas is the most important factor in the recovery of the oil. A visitor standing a little north-west of the ruins of the Masjid-i-Sulaiman, that ancient Zoroastrian fire temple, and looking generally north-west, can see clearly in the broad lines of the strata exposed around him an unmistakable indication of the lateral folding that has given this domed structure to the rocks beneath.

It will be realised, in view of what has been said as to the inherent geological difficulties in this field, that the full knowledge now obtained of the sub-surface structure has come from many lines of investigation and especially from the direct evidence supplied by each new well drilled. The geological information gleaned from the Masjid-i-Sulaiman field has been applied scientifically to the work done in test areas in other parts of Persia, and it has been useful in showing ways in which the usual geological methods and procedure can be suitably modified to meet Persian conditions.

GEO-PHYSICAL

Simultaneously with the geological investigations in any chosen area, or maybe at a later stage, depending on the surface character of the district (more particularly on the presence or absence of mountain masses) the Eötvös Torsion Balance may be called on to give collateral or supplementary evidence. It is essentially an instrument for determining the variation of the gravitational force of the earth at different points of the earth's surface. The balance in its first form was devised nearly forty years ago by Baron Eötvös, professor of Physics at Budapest. Professor Hugo de Böckh, an eminent Hungarian scientist, was the first to draw attention to the geological significance of the varied readings obtained by the Torsion Balance and to the possibilities of the instrument in elucidating sub-surface structure.

The instrument is extremely delicate and sensitive in use, requiring the finest and most careful adjustment, and elaborate precautions have to be taken to exclude effects due to such factors as vibration and changes in temperature. Corrections have also to be made in its indications to allow for the influence of mountains, hills, or even mere undulations in the neighbourhood. For this reason the use of the torsion balance is usually confined to more or less level ground where beds are not exposed and where the geological information is, therefore, scanty, as, for example, in the desert.

The instrument does not and cannot indicate directly the presence or absence of oil below the surface; it merely shows, as a traverse of its indications is taken, how the gravitational force of the earth varies from point to point. From its indications, duly corrected and evaluated by complicated calculations, deductions—probable rather than certain—may be made as to some of the characters of the strata beneath the surface and of their direction and inclination. Such information, correlated with that obtained by the geologist and also with other information obtained in ways presently to be described, is of value to the prospector who is seeking oil. The Company is extending the experimental use of this torsion balance and the experience gained is brought under contribution, not only to the main purpose of finding oil but also to the development of the theory and practical applications of the balance. There is a small corps of trained scientists—the geophysicists—enthusiastically pursuing this two-fold purpose.

This gravimetric method of oil finding, by means of the torsion balance, is, however, only one of the many geophysical methods which the Company is employing or rigorously investigating. These other applications of the growing science of geophysics may be classified conveniently as follows:—electrical methods, depending upon measurements of the electrical conductivity of the rocks forming the crust of the earth; magnetic methods, depending upon measurements of their magnetic susceptibility (a term perhaps sufficiently self-explanatory to the general reader); and seismic methods, depending upon measurements of the elasticity of the rocks. Only the barest indication of some salient features of these investigations, and of the broad scientific principles involved, can be given here, if we are to keep faith with the general reader and avoid trespassing too far into the technical domain.

ELECTRICAL METHODS

Electrical methods of locating ores and minerals have been employed for a number of years, in some cases with great success. It is doubtful, however, if these methods have hitherto proved very successful in oil prospecting. Claims have been made during the past two or three years for detecting oil at depths exceeding two thousand feet, but they have not been substantiated.

There are a number of electrical methods which are used, but all are similar in principle. They depend upon the difference of the electrical conductivity between the body whose position it is required to locate and the surrounding rocks. Electric currents are made to flow in the ground in the region under investigation, and a detailed study is made of the form of the current field (i.e., the shape of the current lines of flow) at the surface of the ground, or of the magnetic field above the ground due to these currents. If a body whose electrical properties differ from those of the surrounding rocks lies buried at not too great a depth within the region under investigation, it causes the current field to become distorted, and a study of this distortion with the aid of suitable apparatus may lead to the location of the body.

The electric current employed is usually alternating, although direct current has also been usefully employed, notably by Professor Schlumberger. When alternating current is used it may be introduced into the ground either by buried electrodes or by inductive methods. In the latter case an alternating current in a closed circuit above the ground causes induced currents within the ground.

In order to determine the shape of the current lines of flow at the surface of the ground two portable metal plates, called electrodes, are employed, which are connected by a cable to a valve amplifier and a pair of telephones. The electrodes are sunk into the soil and set at some distance apart, say 100 feet; and the position of one is varied until the sound heard in the telephones (whose frequency is that of the alternating current employed) is a minimum. Under these conditions the two electrodes are at the same electrical potential, or, to express it in another way, are situated on an equipotential curve; just as, in the familiar Ordnance Survey map, two places at the same height are situated on the same contour line. If, now, one of the electrodes is moved farther away while the other is kept in its original position, another point may be found on this equipotential curve. In this way a series of equipotential curves may be mapped out over the area under investigation, and as these equipotential curves are everywhere at right angles to the current lines of flow, the shape of the latter may be determined.

With regard to the exploration of the magnetic field, it may be explained that when an electric current flows, for example, through a wire, there are produced, in the neighbourhood of the wire, magnetic effects which can be rendered evident by means of a freely suspended magnetic needle. The region round about the wire is, therefore, called a magnetic field. In the same way, when electric currents are made to flow through the ground, there is a magnetic field, due to these currents, in the regions of current flow.

The form of the magnetic field above the surface of the ground is determined by means of a frame aerial connected to a valve amplifier and telephones. The aerial may be rotated about vertical and horizontal axes, and at any given station there is one position for the frame at which the sound heard in the telephones is a minimum. In this position, which may be fixed by means of a compass and circular scales on the instrument, the frame, or, to speak more correctly, the plane of the frame, is parallel to the magnetic lines of force. Thus, if the area being investigated is covered by a network of stations, the shape of the magnetic field over this area may be accurately determined. Any distortion of the current lines of flow set up by a buried mineral or ore-body will result in a corresponding distortion of the magnetic field, and in this way the body may be located.

The possibilities of these electrical methods in their application to the problem of locating oil in Persia have been fully investigated by the Geophysical Staff of the Anglo-Persian Oil Company. It would be premature to pronounce definitely as to their practical value in that country.

MAGNETIC METHODS

The reader knows, in a general way, that the earth behaves as a magnet and that the magnetic force exerted by the earth on a suspended steel magnet—for example, a compass needle—varies at different points on the earth's surface. The measurement of these variations is of great practical importance, not only in navigation, but also in many scientific observations.

The magnetic method of prospecting (which must be distinguished from the method of determining the magnetic field due to electric currents) has been very thoroughly investigated over various parts of the known oil-bearing structure at Masjid-i-Sulaiman, The principle of the method depends on the uneven distribution of the earth's magnetic field in places where changes in the magnetic susceptibility of the material which forms the earth's crust occur. Thus, if measurements of the intensity of the magnetic field be made and tend to give a larger value at a certain place, the presence of some material of higher magnetic susceptibility than its surroundings is suspected.

It was hoped that the crest of the oil-bearing structure would be indicated in this way, as the structure—limestone—is more susceptible than its overburden.

The instruments employed are termed magnetometers, and may be designed to measure either the horizontal or vertical component of the earth's magnetic field. A high degree of sensitiveness and ease of portability are necessary requirements; the instruments used by the Company's Geophysicists were capable of recording a change of one ten-thousandth part in the earth's magnetic field. With instruments of such sensitiveness great care must be exercised that the readings of the instruments refer to the structure upon which observations are being made; such factors as the diurnal variation in the earth's magnetic field, the variation due to change in latitude and the effect of temperature changes on the instruments must all be allowed for.

All that may be said at present is that the method has been of proved value where shallow formations (of the order of 100-200 feet) and large differences in magnetic susceptibility have been present.

SEISMIC METHODS

Lastly, to conclude this brief survey of the geophysical work of the Company an indication must be given of the seismological research being undertaken. It may be said that until comparatively recently the science of seismology has been confined, for the most part, to recording and measuring the earth tremors caused by earthquakes and to deducing from the measurements the locations of the original disturbances. The seismic method of exploration is similar in principle to the other methods described, in so far as it is based on the existence of a difference in certain physical characteristics between the rock-forming structure to be located and the structures above it which form the overburden. In this particular method advantage is taken of the different velocities with which earth tremors—which to the physicist are elastic waves—are transmitted through rocks having different elastic properties and densities. For example, the velocities of compressional waves in sedimentary rocks are of the order of one and a quarter miles per second, whereas in igneous rocks they are from three and a third to five miles per second.

In Persia the reservoir rock is a limestone, and the velocity of the elastic waves in this medium is higher than in the overlying beds. The procedure in seismic exploration is somewhat as follows:

Charges of gelignite are buried several feet below the surface of the ground and exploded. The resulting disturbances or miniature earthquakes—the elastic waves—travel outwards in all directions through the rocks. The arrival of the disturbance at various points on the surface, along traverse lines from the explosion point, is registered on a photographic record by means of sensitive instruments called seismographs. At these stations, by means of suitable apparatus, the instant of the explosion is also recorded. From the records the speed at which the elastic waves travel through the overburden and also through the covered oil rock is deduced. When the difference in velocity is well pronounced and the overburden is fairly homogeneous a reliable estimate of the depth of the oil rock can be obtained from these records. The degree of success of this method depends on obtaining as complete a record as possible of the rock disturbance. The completeness of the record is limited to a great extent by the design of the seismograph, and researches have been carried out with the object of designing a field-worthy instrument, or combination of instruments, which will afford a more complete record of the elastic waves than has hitherto been obtained. With the more detailed information made available by such instruments the method will be applicable to more complicated problems than those which so far have been solved successfully.

An interesting parallel to another physical phenomenon may be noted here. The "wireless" enthusiast knows that there is surrounding the earth, in the upper firmament, an electrified layer known, from the name of its discoverer, as the "Heaviside layer"; and that the radio waves sent out from the world's radio stations are reflected and propagated by this layer, just as in the whispering gallery of St. Paul's Cathedral the sound waves are reflected from the smooth wall, or—to take another illustration—just as the desert mirage is due to the reflection of light rays from certain layers of the atmosphere. Without this reflection from the Heaviside layer, radio communication between the ends of the earth would be impossible and Abadan would be unable, as we shall see later it now is able, to pick up the wireless bulletin broadcast each day from Rugby, in England. The interesting parallel between this Heaviside layer and a highly elastic formation deep down in the earth lies in the fact that the depth of the subterranean structure is deduced from the elastic wave observations in a manner closely related to that employed in calculating the height of the Heaviside layer.

It may be added, for the reader's further interest, that some of the instruments used in seismic methods are of the highest precision and sensitivity, with magnifications of the order of a million, so that movements of almost molecular extent can be detected.

One instrument—to give an illustration—the ultra-micrometer, is capable of registering a movement of one-eighth of a millionth of a centimetre or one-twentieth of a millionth of an inch. It brings a touch of the romantic, if not, indeed, of the fantastic, to realise that the discovery of mighty reservoirs of oil deep down in the earth's crust may be related to the measurement of such infinitesimal movements.

* * * * *

It was said at the beginning of this chapter that the problem of oil finding was essentially a scientific problem. The reader will have realised the comprehensive and the intensive character of the methods—geological and geophysical—by which the Anglo-Persian Oil Company is seeking to put this problem on a sound and broad scientific basis. These methods call not only for the highest scientific knowledge and skill in the individual worker, but also for a correspondingly high degree of staff work to ensure the continuous co-operation and co-ordination of the scientific workers in their common attack on this fundamental problem. It is true that these different geological and geophysical investigations serve to confirm or rebut evidence *inter se*, but their main purpose, it should be noted, is to ascertain the limits of the various methods for elucidating geological sub-structure, so as to facilitate the selection of the method most appropriate to the peculiar conditions of the particular area under exploration.

THE DERRICK FLOOR OF A STANDARD TYPE DRILLING RIG. SHOWING THE HEAVY CABLE BIT WHICH POUNDS ITS WAY THROUGH THE ROCK

CHAPTER III

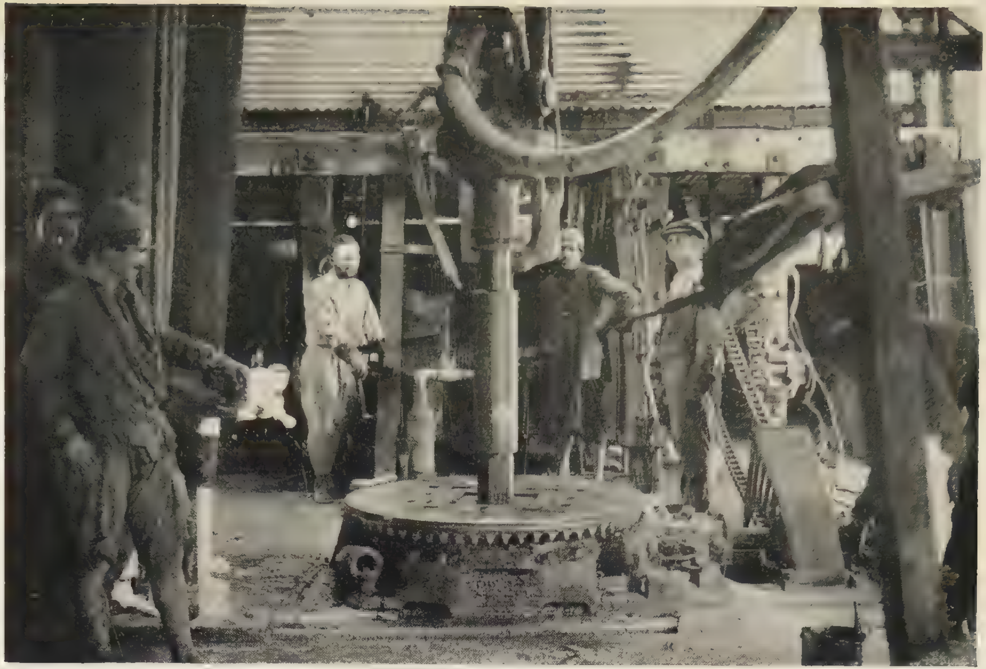
DRILLING THE WELL

FROM the outset the question where to start boring for oil is essentially a scientific problem to be solved by the application of scientific knowledge and methods. We shall see that every subsequent step, from the drilling of the well to the delivery of the refined oil, in the condition and of the character required by the consumer, calls also for the application, in greater measure at some stages, in less measure at others, of scientific knowledge and methods.

Let us now suppose that, from the investigations described, a likely spot has been found for the sinking of a well. The drilling problem is essentially an engineering problem and both engineering in general and the engineering of well drilling in particular have long been developed to a high degree of efficiency. The drilling practice adopted by the Anglo-Persian Oil Company is, therefore, naturally standard practice and it will be sufficient to describe the methods in outline only.

Two systems of drilling are employed—the cable-tool or percussion system and the rotary system. In the first a heavy cutting bit of hard steel at the end of a wire cable is alternately lifted and dropped, by appropriate machinery, so as to produce a succession of blows whereby the hole is literally pounded out, the crushed strata being baled out from time to time. In the rotary system a rigid stem of steel pipe rotates, by the help of machinery, a special type of cutting-bit, which bores through the strata as a gimlet bores through wood. Through the drill pipe a stream of liquid mud is pumped down under hydraulic pressure. This circulating mud flush serves to lubricate the process of drilling, to drive up the cuttings out of the hole and at the same time to "mud up" the formations encountered to prevent them caving. Hence this system is especially adaptable to unconsolidated strata, such as caving sands or silts. The cable-tool system is better suited to harder rocks.

The chief advantage of the rotary system is the rapidity with which a well can be drilled. As much as 450 feet per day has been made under exceptionally good conditions, which is a far greater depth than is possible with the cable-tool in normal circumstances. Other advantages of the rotary system are that, if high gas and oil pressures are encountered, they are more easily controlled; less casing is required for the lining of the well; it is less costly to employ than cable tools and it is more universally adaptable to the normal conditions of modern oil-field development.



TURN TABLE AND DRILL STEM OF A ROTARY DRILLING RIG AT MASJID-I-SULAIMAN

It has, however, three inherent disadvantages: one, the tendency through "mudding" for the driller in charge to miss oil shows; the second, the difficulty of obtaining uncontaminated samples of the strata bored through, to enable the geologist to elucidate the sub-surface geological data; and the third, the tendency for crooked holes to be drilled. The first disadvantage can be minimised, if not avoided, by the skill of the driller. The second has been successfully overcome by the introduction and use of the core-barrel, a device by which satisfactory samples can be regularly obtained. The third, which is an inherent disadvantage of the rotary system at great depths, can be partially overcome by very careful drilling (especially at each change of formation) and by measuring the deflection of the hole at intervals as drilling proceeds, and taking the necessary steps to straighten the hole before it becomes too crooked.

In the Masjid-i-Sulaiman field, however, it has been found that comparatively shallow wells are more economically drilled by cable tools; for the deeper wells the rotary-drill is more advantageously employed. With modern drilling equipment it is now possible to test for structures far deeper than anyone contemplated a few years ago, depths of nearly 10,000 feet having been drilled in the U.S.A. during 1929. For depths of 5,000 feet and over the use of rotary equipment is almost imperative, not only on account of the great saving in time, but because at these great depths the oil, if it be in the crestal region of structures, is usually under very high pressure. Drilling in against these high pressures can be safely carried on, and dangerous blowouts with their attendant fire risks prevented, only by the circulation of mud fluid, which is an inherent feature of the rotary system. Mud fluid can, of course, be used in cable tool wells, but it is difficult to drill through at great depths, and as it cannot be circulated the mud eventually settles out. For these reasons the use of rotary equipment in preference to cable tools has received a certain impetus in Persia during 1929.

When the writer was at Fields, a well was in process of being drilled by the rotary method, for geological information and not for production, which had then reached a depth of 5,000 feet. It was fascinating to watch this rotary drill, roughly a mile long, being turned apparently as easily as one turns a gimlet. This well, it may interest the reader to know, at the end of May, 1927, had reached a depth of 5,809 feet and the casing lining the well ceased at a depth of 2,421 feet, no other casing being required below this.

PETROGRAPHY OF DRILL CUTTINGS

Daily reports of the progress made at each well, of the depth reached, of the strata met with and of other significant features, are made by each driller in charge and copies of these reports are studied by the geologists. Moreover, at intervals of five feet—or oftener if new formations be encountered—samples of borings are taken and sent to the geological department for examination and identification. Here they are washed, dried, examined by the eye and by the microscope and, where it is deemed desirable or necessary, are subjected to chemical analysis.

For example, the cap rock of anhydrite, which covers the oil-bearing limestone, shows under the microscope a peculiar radial structure. If there be any doubt in a given case whether it is the cap rock that has been reached, the microscopic examination of a specimen of the boring reveals the presence or indicates the absence of this radial structure and thus usually resolves the doubt. Similarly, microscopic examination helps to determine whether any limestone met with in drilling is the mother-rock which outcrops in Asmari mountain. If any water be encountered by the driller, samples of it are sent to the chemical laboratories for determinations of its density and composition and from the knowledge thus acquired valuable information can be obtained of any interconnections there may be between distant borings. It is worth notice that all the specimens of borings are carefully kept for reference and are available as contributions to the general science of geology.

There is thus a steady flow into the geological department of information and samples from all the wells being drilled as they are being drilled. From the data thus acquired, duly co-ordinated and correlated, a detailed knowledge is obtained of the sub-surface structure over a wide area. Since some two hundred wells have been drilled in the Masjid-i-Sulaiman field, it will be understood that a thorough and extensive knowledge of the sub-surface geology has now been acquired. Indeed, the "geological chaos," to which reference was made, has now been, in the expressive phrase of the geologists, "all taped out." At the geological headquarters at Masjid-i-Sulaiman and also in the London offices of the Anglo-Persian Oil Company, there are not only large scale maps but also solid models constructed to scale showing the contours of the oil-bearing limestone and the position of each well.

It should be understood that as the well is drilled it is also lined by steel casing. When the drill is nearing the main limestone where the oil is expected, precautions have to be taken against any sudden rush of oil to the detriment of the drillers and the rig. In cable tool wells a long cylindrical steel vessel, called a container, is fastened to the top of the well casing and the cable works, enclosed, through this. A valve is also introduced near the top of the well pipe and controlled by a distant handle, so that in emergency it may be turned off without grave risk to the operator. There is something of a dramatic thrill, in approaching a well, to observe that the "container" is affixed and to read the notice: "No smoking. Drilling in Main Limestone."

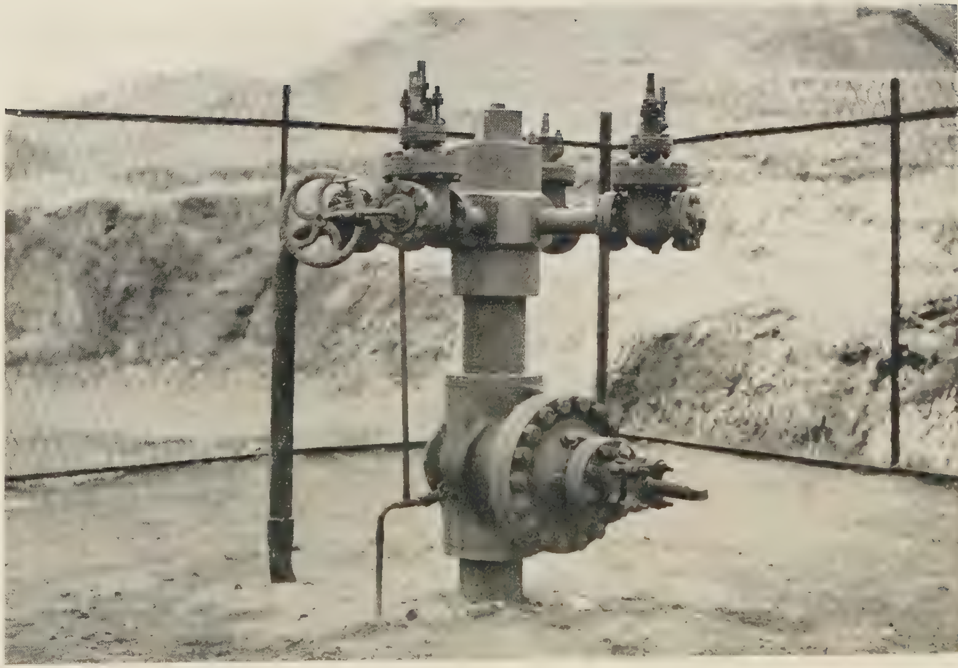
By such devices and precautions a well with a production of as much as 6,000 tons of oil per day can be brought in without any loss of oil, the derrick floor being kept clear of any waste oil. Indeed, the amazing feature to one who vists the Persian oil fields for the first time is the absence of any sight of the crude oil, except for the seepages to be noted here and there in the area. Not until the writer reached the refinery at Abadan, 130 miles away from the oil field, did he see the crude oil which was being drawn from Fields at the rate of some 4,000,000 gallons per day. If one compares this state of things with, for example, pictures of the oil fields of Russia, in Mr. A. Beeby Thompson's elaborate book on the Russian Petroleum Industry, where derricks and rigs are shown drenched in the spouting oil and gas, and where lakes of waste oil surround them, the scientific achievement of the Anglo-Persian Oil Company in avoiding waste and keeping Fields clean of oil can be better appreciated.

CHAPTER IV

STUDY OF PRESSURES AND LEVELS

DRAWING THE OIL

WHEN an oil reservoir is reached the oil may rise in the well pipe and flow under its natural pressure. But there may be difficulties due to excessive flow; on the other hand the oil may have been struck at such a great depth that the natural pressure to which it is subjected is insufficient to start it flowing. Both these difficulties call for the ingenuity of the engineer. Excessive flow has to be checked by appropriate and sufficiently robust well-head fittings. To get the oil to flow from great depths, frequently gas is forced down the well pipe under pressure, so as to aerate the oil, "to make it alive," as the phrase goes. When the pressure is released the mixture of oil and gas usually rises and flows just as soda water gushes from a syphon when the pressure is released. In the Persian oil field there have been hitherto few, if any, difficulties in getting the oil to flow: such difficulties as have been encountered and successfully overcome have been due to high pressures and excessive flow.



FLOWHEAD OF COMPLETED WELL SHOWING MODERN HIGH PRESSURE FITTINGS

We will now suppose that a well has been drilled in and that the oil is flowing under proper control into the pipe line leading to the tanks where, as will be seen, the crude oil is first stored. The well-head fittings include, besides valves for regulating or stopping the flow, pressure gauges for the accurate measurement of the pressures developed at this point. A whole series of scientific investigations into the measurement and implications of these pressures is now undertaken, investigations which are peculiar, in oil-field development, to the Anglo-Persian Oil Company.

When a well "comes in" the gas which rises with the oil, usually at first in great quantity, is allowed to blow off, and is led away to be burnt, until the well pipe is full of oil to the head. The valve is then closed, things are allowed to settle down, and the pressure recorded by the pressure gauge under these steady conditions is carefully noted. This pressure is termed the *Minimum Closed in Pressure.* The reader who has an elementary knowledge of hydrostatics will realise that this pressure is equal to the hydrostatic pressure on the oil at the bottom of the well less the downward pressure due to the weight of oil in the pipe. The purpose of the measurement of this pressure will be explained later.

The oil is now allowed to flow freely into the pipe line and the pressure is measured while the well is flowing. This pressure is termed the *Flowing Pressure.*

Not only is it dependent on the size and conformation of the well that has been tapped but it varies also with the back pressure set up in the pipe line fed by the well. The reader will understand that the flowing pressure of the water in a water main, for example, must vary with the back pressures set up in the various smaller pipes which are fed by the main. The importance of measuring this flowing pressure is that from it reliable calculations may be made of the production of the well, i.e. the number of gallons of oil per day that the well is yielding. In contrast with most oil fields the individual production of wells in this Persian field remains practically constant.

If a freely flowing well be closed, the pressure developed at the well-head will be greater than the minimum closed in pressure; for when a well is flowing freely not only oil but also gas flows and when such a well is closed in the gas collects in the well-head and casing top. The pressure under these conditions, which is termed the *Maximum Closed in Pressure*, is carefully measured. The reader will appreciate that it is equal to the static pressure at the bottom of the well pipe less two back pressures—the back pressure of the column of oil in the well pipe due to its weight, and the back pressure of the column of gas above the oil in the pipe. The function of this measurement of the maximum closed in pressure is to determine the highest pressure to which the flowhead fittings will be subjected—obviously important knowledge to the engineer.

Lastly, a fourth pressure is measured. It will be remembered that above the oil in the present producing area of the Masjid-i-Sulaiman field are domes under the roofs of which gas has accumulated and to which it is constantly rising. Whenever a well is sunk directly into the gas dome overlying the oil reservoir, the pressure of the gas at the well head is measured. This is termed the *Dome Gas Pressure*. Its function will be explained almost immediately.

To recapitulate, there are four distinct and significant pressures periodically measured—the minimum closed in pressure, the flowing pressure, the maximum closed in pressure and the dome gas pressure. In order that all these pressures, measured at different wells and at different ground elevations, shall be comparable one with another, the observations taken are corrected and referred to a common datum level, a presumed sea-level known as Scott's datum level, and thus those inequalities in the observed pressures which are due to some wells being drilled in from a higher point of the earth's surface than are others are eliminated and a common basis of comparison is established.

THE GAS-OIL LEVEL

From the knowledge of the minimum closed in pressure and the dome gas pressure it is possible, by mathematical methods, to determine the gas-oil level, i.e. the level at which the gas in the dome meets the surface of the oil in the reservoir. It would be outside the scope of this essay, which is written for the general reader, to attempt to explain the nature of the mathematics involved. The reader is asked to accept it as fact that reliable determinations can be so calculated.

From the knowledge of the gas-oil level most important conclusions can be drawn, affecting not only the location of new wells, but also the general production policy in the area. It enables decisions to be made as to the location of new wells for production in areas where the contours of the main oil-bearing limestone are known. From it can be deduced with confidence data indicating which wells would, if they were sunk, produce gas only; which wells would, though yielding oil for a time, soon go to gas; and which wells would be likely to have a long flowing life before going to gas. Incidentally, it may be remarked that the problem of the flowing life of wells is a very interesting scientific problem on which much investigation has been done by the Company.

Moreover, and not least important, a knowledge of the gas-oil level, correlated with other data, enables approximate estimates of the total oil reserve to be made.

It will be seen, therefore, that continuous knowledge of the gas-oil level is of great and even vital consequence. In the Physical Research Department at Fields are carefully drawn graphs showing the relation between the dome pressure and the production (i.e. the total quantity of oil withdrawn from below). As oil is withdrawn from below the hydrostatic pressure at the bottom of any given well necessarily falls; the gas within the dome above the oil reservoir expands and hence also the dome gas pressure tends to fall. This reduction in dome pressure allows a portion of the gas dissolved in the great bulk of oil to come out of solution, thereby bringing the system into a new state of equilibrium. The graphs mentioned above show the rate at which the gas-oil level and dome pressure are falling as the production is proceeding.

The Company's production policy aims at keeping the oil-bearing structure as a whole evenly balanced by withdrawing the oil from wells so located that the gas-oil level falls uniformly, as if it were a single surface, throughout the fields. It is interesting to note that, owing to measures having been taken to prevent unnecessary loss of dome gas (for example, by "mudding off" gassy wells that were producing as much as 2,000 tons of oil per day), the rate at which dome pressures and the hydrostatic pressures at the bottoms of the wells have been falling has been sensibly slowed down. The curve showing the relation between the dome pressure and the production will slope the more steeply the more rapidly the dome pressure falls with the production. When observations were first systematically taken, the curve had a slight, but obvious, downward slope; it now shows a distinct tendency to approach the horizontal, indicating that the rate of drop of the dome pressure has become less. That curve is as important in the oil field as is the temperature chart in a fever hospital.

It should be understood that the above description of the scientific work done on the measurement of pressures does not pretend to give a complete picture, even in outline, of all the scientific investigations needed to arrive at definite information as to the gas-oil level, the flowing life of wells or the total reserve. These problems are necessarily related to, and complicated by, such factors as friction, viscosity and the solubility of gas in oil at different temperatures and pressures. A great deal of research work has been and is being prosecuted by the Company's staff on these and other cognate problems.

MIGRATION OF OIL

It may be explained here that outside the present producing area test wells are drilled, not primarily for production but in order to secure vital data. These tests are known as Fields extensions. From the above investigations valuable information has been obtained as to the migration of oil. The evidence points to the conclusion that, with the exception of one extension area recently proved where the porosity of the limestone is definitely low, the oil from the extension areas is migrating to the producing areas and that Fields extensions are being satisfactorily drained by wells at present on production. Intercommunication between wells as far apart as ten miles has been proved by study of the pressures. The excellent migration which exists over the whole field, between area and area, must, therefore, be due to the existence of channel connections in the mother limestone rock, of such number and magnitude, that, at the present rate of production in Fields, and at the consequent velocity of migration of the oil, gravity alone is able to overcome the forces of friction, capillarity and surface tension which tend to impede migration.

THE OIL-WATER LEVEL

There is another important level to be determined. In many oil fields the first hint that the reserves of oil are not inexhaustible is given by a rise in the level of the water, often salt water, usually found beneath the oil. The reader is aware that the oil, being of lighter specific gravity than water and not miscible with it, will float on water. A knowledge of the oil-water level is obviously important as from it the earliest evidence comes as to the rate of exhaustion of the field. It is sufficient to say here that where water has been found beneath the oil horizon in the Persian producing area, careful and systematic measurements over the last six years have shown that the oil-water level is not appreciably rising.

We have seen how important is the maintenance of the underground gas pressure, which is the most important factor in the recovery of the oil from below. Although, as has been stated, the abundant data that have been obtained clearly indicate that this pressure is being well conserved, nevertheless the proposal has been considered to inject into the gas domes the surplus gas, after extracting from it the gasoline. In the next chapter we shall consider in some detail the methods adopted to utilise the enormous volume of gas that is associated with the oil.

*   *   *   *   *

It should be emphasised, what has already been indicated, that all, or nearly all, the scientific work on pressures just described is peculiar to the Anglo-Persian Oil Company, and has no comparable counterpart, as far as the writer knows, in the work done in any other oil field in the world. It is true that these co-ordinated scientific investigations are greatly facilitated by the unique simplicity of the structural conditions of that part of the Persian oil field now under production; and also by the fact that the Company has sole control of the wide area involved. Obviously, it would have been impossible to secure the correlation and the co-ordination necessary for obtaining these scientific data if, in the Persian fields, there had been the chaotic conditions existent in some other parts of the world, where the landscape of the oil-bearing region is crowded with the derricks—"as thick as autumn leaves in Vallambrosa"—of discordant competitors, each feverishly bent on extracting the oil from below, lest his neighbouring rival may be depleting the same common reservoir. There is in this contrast a lesson in rationalisation which we have not space to elaborate. But it would be to miss the real significance of what has been described not to pause and note that the extent and thoroughness of the scientific work done is due mainly to the long and wide view taken by the former Chairman, Lord

Greenway, by the Board of Directors of the Company, and, pre-eminently, by the present Chairman, Sir John Cadman, as to the vital necessity of such scientific data and investigation for ensuring efficient production.

CHAPTER V

THE PROBLEM OF THE GAS

When the oil has been brought to the surface and the well has been connected to the pipe line which is to conduct the crude oil to the refinery, there is a series of operations to be considered before we come to the processes of refining.

The crude oil, as we have seen, contains a good deal of gas. The immediate problem is, what is to be done with this gas?

In the early history of the Company, it will be readily understood, the urgent economic need, after the oil had been drawn from below, was to get the oil refined and to put the refined products on the market for sale. These early days were not favourable times for pausing at each stage of the process of production to consider whether all had been done that could be done at that stage. The gas problem, therefore, was treated summarily at first, because all energies were necessarily concentrated on the adequate production of refined oil.

The gas could not be allowed to escape freely into the air. It is injurious to breathe, and, indeed, poisonous. It was, therefore, led away to convenient spots on the hills around and burnt continuously, night and day, in huge flares, the flames rising frequently to a height of one hundred feet. Photographs of Maidan-i-Naftun in those early days, taken at night, show one of the most wonderful and weird spectacles ever, surely, associated with industrial development. In response to the pathetic plea of one member of the Company's staff the present writer here earns the unique distinction of refraining, though with difficulty, from making a trite reference to Dante's Inferno. But one may be allowed the milder comparison that the blast furnaces of Middlesbrough would have "paled their ineffectual fires" before this field of conflagration. There are still flares in Fields, but the ecstasy of combustion has been greatly allayed, partly by reason of the "mudding off" of gassy wells, to which reference has been made, and also by methods of gas conservation and utilisation to be described.

As the early, urgent needs for the production of refined oil were successfully met, attention was directed to the improvement of each step in the series of operations, and the solution of the gas problem has been, and is being, sought along the lines that will now be explained.

The crude oil in the depths of the earth is in exactly the same condition as soda-water in a syphon; it contains a large amount of dissolved gas held in

GAS SEPARATORS FOR SEPARATING THE GAS FROM THE OIL AS IT FLOWS FROM THE WELL, IN THE OIL-FIELD ON THE MAIDAN solution by the heavy overhead pressure. When the well-head valve is opened the oil issues as a froth, owing to bubbles of the gas which was dissolved at the high underground pressure escaping from solution immediately the pressure is released. One of the main problems is to handle this oil-gas froth in such a way that the oil and gas are effectively separated and the gas is utilised on the spot to the best advantage.

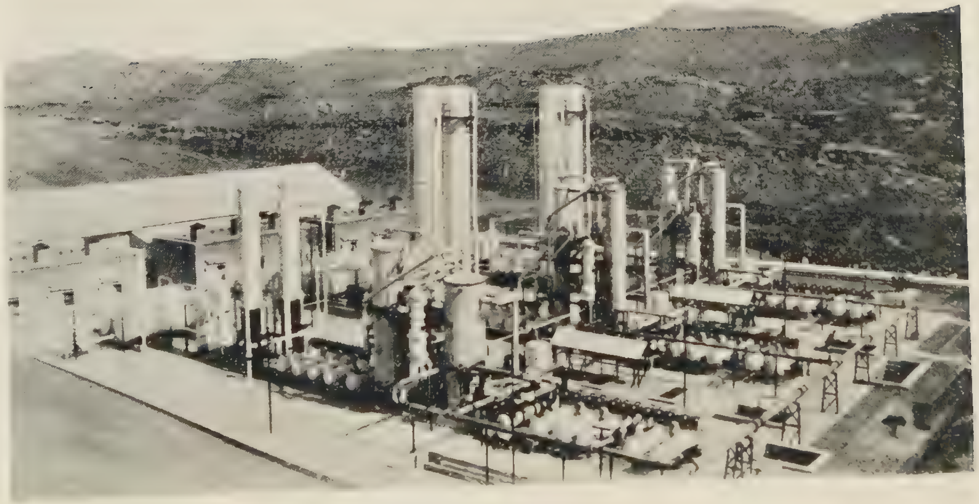
The release of the high pressure oil almost down to atmospheric pressure takes place in two stages. The oil which issues from the well-head at a pressure of about 150 pounds to the square inch is led to "high pressure separators," which consist of long, horizontal, steel cylinders, some two and a half feet in diameter. In these cylinders the pressure is allowed to fall to 30/40 pounds to the square inch, and at this pressure a portion of the total gas content, sufficient to supply the local fuel requirements of the area, is separated. This gas consists mainly of the least soluble hydrocarbon gases, methane and ethane, and contains only an insignificant quantity of petrol vapour.

The gas so separated is purified and conducted through mains to the Fields gas supply for industrial and domestic use. It provides the fuel required for the steam boilers at the electric generating station and the pumping station at Tembi, as well as for other steam-raising plant in the various workshops at or within range of Fields. It is also supplied for heating or cooking purposes to the bungalows, houses, offices and bazaars, including the Persian bakery and the Persian baths. There is thus an abundant—indeed, a super-abundant—supply of natural gas to the whole industrial community in or near Fields. What was at first merely a waste product has thus been turned to industrial and domestic use.

The quantity of the gas so utilised is, however, a very small, almost an infinitesimal, fraction of the total gas available, and other steps are being taken to recover more and more of it for industrial purposes.

To resume the story, the crude oil, with the high pressure gas removed, goes its way to great tanks, called the "flow tanks," where the pressure drops almost to atmospheric pressure. There is still a great deal of gas dissolved in the oil and much of this gas evaporates and rises to the upper parts of the flow tanks. At this lower pressure the fractions evolved are heavier than those leaving the high pressure separators and are laden with petrol vapour. We will call this mixed gas the "low pressure gas."

Before considering what is done with this low pressure gas, it may be as well to see the crude oil a little further on its way. From the flow tanks the crude oil, stripped of its high pressure gas and low pressure gas, goes by the pipe line to the main pumping station at Tembi, whence it is sent on the first stage of its long journey of 130 miles, over hill and



GAS ABSORPTION PLANT AT MASJID-I SULAIMAN desert, to the refinery at Abadan. There is a tank farm at Fields but it comes into operation only as a means of storage in emergency. Thus, in the ordinary course, the oil is delivered to the Tembi pumping station without having suffered, by evaporation in storage, the loss of its light products.

RECOVERY OF GASOLINE

To return to the low pressure gas in the flow tanks, this gas is now led through pipes to the gas absorption and compression plants, in order that there may be recovered from it the valuable product, light spirit or gasoline. Shortly described, the absorption method of recovery is as follows. The low pressure gas is compressed, by rotary compressors, to a pressure of 5 pounds to the square inch; it is then cooled and driven up an absorption tower down which heavy oil is descending. This oil or "lean oil," as it is termed, absorbs from the gas the light fractions, in particular, gasoline or petrol, and becomes, in works phrase, "fat oil." The fat oil is then distilled to yield the gasoline or petrol which it has absorbed. The absorption process is thus a continuous cycle—the low pressure gas flows continuously through the plant; the lean oil absorbs gasoline from the gas and becomes fat oil; the fat oil gives up its gasoline and becomes again lean oil; and the lean oil repeats its former work. The gasoline goes by pipe line to be added to, and enrich, the crude oil destined for the refinery. In the compression method of recovery the gas is compressed by rotary machines to a pressure of 250 pounds per square inch and cooled. This process condenses the gasoline content of the gas and the condensed gasoline then passes into the crude oil pipe line.

The capacity of the gasoline absorption and compression plants now in operation at Masjid-i-Sulaiman is 45,000,000 cubic feet of gas per day, yielding approximately 130,000 gallons of light spirit or gasoline per day. A far better thing, this, than sending the gasoline in flame and smoke to the Persian skies!

It may be incidentally noted that in the absorption process oil has to be cooled at one stage and heated at another. In order to secure economy of fuel, heat interchangers are utilised whereby the heat abstracted from the oil that has to be cooled is made to warm the oil that has to have its temperature raised in distillation. A similar economical use of heat interchangers occurs in many other operations of the Company, notably in the refineries.

The reader may have noticed that at no stage we have yet described is the pressure on the oil completely released. Indeed, as we shall see, all the way from the well-head to the refinery the oil is under pressure. The valuable petrol that escapes with the low pressure gas from the flow tanks is immediately recaptured in the gasoline recovery plants and injected, under pressure, into the crude oil in the pipe line. There it remains under pressure throughout its long journey to Abadan. In this way the crude oil is made to carry, not only the volatile petrol, but also large quantities of gas in solution which constitute a valuable source of fuel for refinery operations that could not otherwise be conveyed to Abadan without great expenditure. The elaborate arrangements adopted for securing this gas immediately it reaches the refinery will be described later.

PYROLYSIS OR CRACKING

We have not yet, however, come to the end of the gas story. Part of the gas which has passed through the absorption plant and given up its gasoline now goes to another plant, called—it is said, not very happily—the pyrolysis plant, where attempts are being made, and on a semi-large scale have been completely successful, to obtain other products of industrial value. It is outside the scope of this essay, and it would try unduly the reader's patience, to enter upon a technical description of the pyrolysis process, which is also known as "cracking." Broadly speaking, it may be said that the process consists essentially in subjecting the gas to high temperatures, in order that the lightest fractions of the gas may combine to form valuable liquid products, of which benzole in particular may be mentioned.

When the writer visited Fields the pyrolysis plant was not in full working order on the commercial scale, but was in the intermediate development stage through which all the discoveries of the research department have to pass before they can be translated to full-scale industrial practice. Both at Fields and at the central research laboratories of the Company at Sunbury-on-Thames systematic researches on this problem have been, and are being, prosecuted with results that are likely to have great scientific and commercial importance.

The gasoline and the benzole thus obtained do not, however, exhaust the list of useful products recoverable from the waste gas.

OTHER BY-PRODUCTS

In the first place, this gas contains a quantity of hydrogen sulphide (sulphuretted hydrogen) which may amount to as much as ten per cent. The hydrogen sulphide itself is a most undesirable constituent, as it has a very unpleasant smell and is highly poisonous. It is for that reason that the high pressure gas is purified before being distributed for domestic and industrial use as fuel. Chemical processes have, however, been devised whereby from the hydrogen sulphide there can be obtained sulphur of an extraordinary degree of purity; and it is possible thus to rid the gas of a noxious constituent and to create a source, not only of pure sulphur, but of sulphur compounds such as carbon bisulphide, all of which are of great value and of wide use in medicine, industry and the arts.

Again, any natural gas, if burnt against a cold metal, or other suitable, surface, deposits carbon in the form of an extremely fine, black soot—"carbon black"—which is much superior to ordinary lampblack as a pigment for the manufacture of printer's ink. Since a thousand cubic feet of gas yield from one to two pounds of carbon black, and it is calculated that one pound of carbon black suffices to print 2,250 copies of a sixteen page newspaper, the potentialities of the Fields gas in this direction alone—whether beneficent or deplorable, the reader must decide—are obvious. Carbon black is also largely used in the rubber industry, being incorporated into the rubber in order to give to it the toughness, elasticity and durability sought after by motor tyre manufacturers. Considerable quantities are also used in the manufacture of stove polishes, Chinese and Indian ink, paper and tarpaulins. Already at Fields a small plant has been established and started for the manufacture of this widely useful by-product.

By varying the conditions of carbonising the gas it is also possible to get the carbon in the form, not of soft black soot, but of a very hard, greyish black solid of close grain, which, on account of its exceptional purity, is of great value for electric arc lamps and for other electrical purposes.

Nor does the tale of useful products obtainable from the gas end here. The gas consists of several, chemically distinct, gases, known generically as hydro-carbons, among which methane and butane may be mentioned. It is possible to separate these constituents by appropriate physical means and to use each one as a raw material for the preparation of other chemical compounds of industrial importance. Thus, by treatment with chlorine, the methane can be converted into chloroform and the butane into butyl chloride and thence into butyl alcohol, which is largely used as a valuable solvent for cellulose lacquer. Fourteen years ago, to take another example, the research chemists of the Anglo-Persian Oil Company showed that the high explosive, trinitrotoluol (T.N.T.), originally produced from coal tar, could be obtained from Persian as well as from other petroleums and large quantities of this explosive were so made during the war.

Indeed the gas and the whole of the petroleum, taken together, constitute a potential raw material for a stupendous chemical industry, as great as, and possibly greater than, the combined synthetic dye and drug industries which have grown out of the once under-valued coal tar.

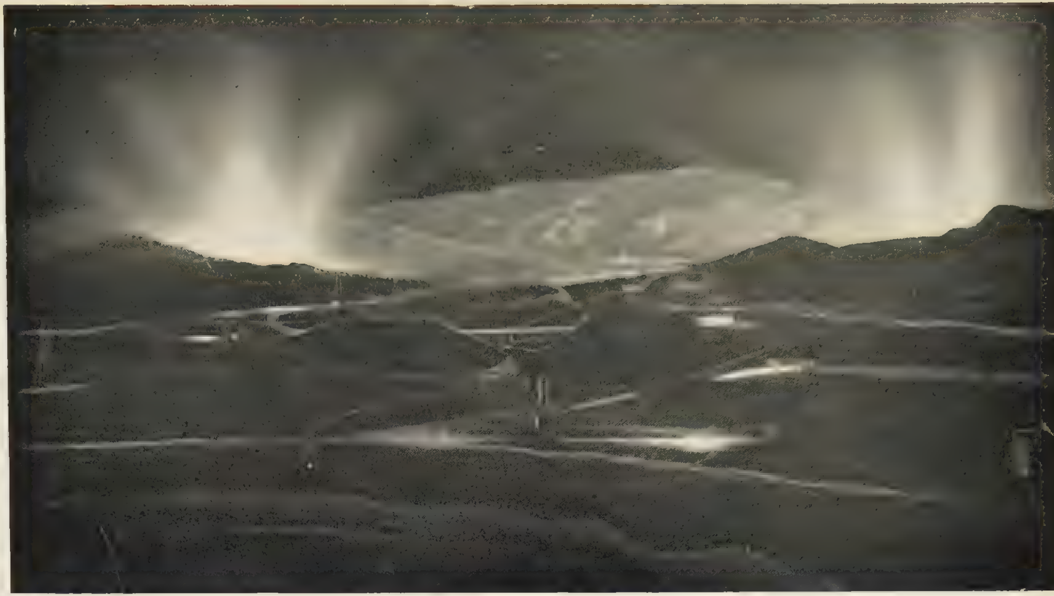
The laboratory 1esearches and the semi-large scale investigations on the preparation from the gas of all these and other industrial by-products have been brought to the point, or nearly to the point, when large scale commercial production can begin.

* * * * *

To summarise this outline of the gas story, as far as it has been told, we have seen that from the gas, which at first was burnt as mere injurious waste, a gaseous fuel, for industrial and domestic use, is obtained, as well as needed by-products, such as gasoline, benzole, carbon black, hard carbon, sulphur and carbon bisulphide. The residue of the gas goes to be burnt in those flares which, for the visitor at least, are still, perhaps, the most fascinating spectacle in Fields. From a daily production of about four to five million gallons of oil it is estimated that, despite all that has been done, some twenty five to thirty million cubic feet of gas per day are so burnt—a stupendous total, enough to supply, for purposes of heat, light and power, the daily needs of Glasgow.

C'est magnifique mais ce n'est pas l'industrie! It is impossible to believe, therefore, that we have got to the end of the gas story. As long as those flares burn, the scientific soul of the Anglo-Persian Oil Company must be disturbed by the question: "What better use can be found for this gas?"

In America natural gas has been conducted through mains to large towns, many miles distant from the source of the gas, and there put to wide industrial and domestic uses. It has also been compressed in cylinders for distribution. There are no large towns, industrial or otherwise, in Persia which are within reach of Fields and to which the gas could be usefully sent. Shushtar, some thirty-five miles away, is the nearest; but who that has visited that romantic Persian city, with its narrow mud streets, its houses and bazaars of sun-baked mud or brick, in picturesque, or other, disarray, can for a moment think of any useful thing to be done with the gas if it were got there? The only power in Shushtar used for industrial purposes is the abundant water flow of the Karun river which turns the wheels of the ancient mills that yield the stone-ground flour. Everything else in Shushtar that can by any stretch be called industrial, and it is but little, is mere handicraft. And even if some bold adventurer were to embark there on industrial manufacture, relying on the gas from Masjid-i-Sulaiman for power, whither would he send his products?



PERSIAN OIL FIELDS BY NIGHT

The problem of those twenty-five to thirty million cubic feet of gas per day remains. It is neither forgotten nor neglected. Attention has already been drawn to the proposal to reinject this gas into the gas domes as a means of re-pressuring the field. In this connection, too, mention may be made of an analogous operation, already adopted, namely, the reinjecting of fuel oil, which is surplus to market requirements, into the oil reservoir, after having saturated it with gas at reservoir pressures. The reason for this last precaution is that, if the fuel oil were returned to the reservoir without its full gas content at reservoir pressures, it would, of course, absorb gas from the crude oil, and so, by reducing the gas pressure, in course of time reduce the flowing lives of the wells. To discover further means of utilising this gas and saving it from total loss to humanity, the writer was assured, is the ultimate goal towards which research at Fields is directed.

CHAPTER VI

RESEARCH AT FIELDS

Before we leave Fields for a time—reluctantly, as every visitor leaves Fields—in order to follow the crude oil through the pipe line to the refinery, something more should be said of the scientific work done, and of the equipment and facilities for experimental research provided there.

The chemical research department at Fields is in charge of the Chief Research Chemist (Persia) who is stationed at Fields and who is also a member of the technical staff of the General Manager. He is assisted by a number of British chemists. In accordance with the general policy of the Company to associate Persians more and more with the development of the Company's operations, a number of Persians who have received a higher school or university education are being trained at Fields as chemical assistants and show great promise of becoming useful members of the Company's personnel.

The primary function of the Fields chemical laboratories, a description of which will follow shortly, is to provide accommodation for research into those problems which are more conveniently investigated on site, such, for example, as depend on ample supplies of raw materials available only in Persia, and which cannot, therefore, be studied at the Company's main Research Station at Sunbury-on-Thames.

A complete liaison has been established ensuring effective co-ordination of all the research work undertaken in Persia and at home. The Chief Research Chemist (Persia) and the Chief Research Chemist at home keep in the closest touch, so that new ideas can be promptly discussed, plans for the investigation of these ideas drafted, and difficulties arising in the course of the research dealt with. In this way needless overlapping or the duplication of investigations is prevented. Moreover, by means of a rotation of staff between the two research stations, the research chemists working at home acquire first-hand acquaintance with the conditions prevailing abroad, while those working in Persia are enabled to keep abreast of the latest developments in apparatus and methods of research. There is thus free diffusion of knowledge and practice between home and Fields, and a corresponding, close partnership between the scientific staffs concerned.

When the writer was at Fields, among the more important gas problems then in course of investigation were: the determination of the ratio between oil and gas and of the gasoline content of the gas, under all flowing conditions; the pyrolysis or cracking of the gas for the production of liquid products; and the elucidation of the conditions under which the oil and gas co-exist underground. In addition to these problems investigations were proceeding on the making of carbon black, hard carbon, the recovery of sulphur and the synthesis of new compounds. The development of all these researches has led already to promising results, and, as was inevitable, has opened out new lines of investigation. The synthesis of new compounds, for example, opens on to an almost illimitable field of research. To take just one illustration: it has been found that olefine gases invariably accompany the thermal decomposition of petroleum hydro-carbons. These olefines are chemically reactive and to the chemist offer a most attractive starting out material. Chlorine can be combined with them, so can hypochlorous acid; the product of the latter reaction is readily converted into glycol, an intermediate product of great importance in industry and a valuable substitute for glycerol. The elements of water (hydrogen and oxygen) can also be attached to olefines, and the resulting products are alcohols. The higher alcohols, such as propyl and butyl, form the basis for valuable solvents and, moreover, solvents that are greatly demanded in the new and growing lacquer industry. Again, these simple derivatives can give rise to further chemical entities

—ethers and esters—which find an ever increasing market in the chemical industry.

It should be noted that, besides these wide and varied problems of research, a great deal of routine work is done in the laboratories, involving the regular, chemical analysis or examination of the various materials produced or consumed at Fields. The milk supply, for example, is tested daily and the water supply periodically. Minor investigations are from time to time undertaken to solve difficulties or doubts arising in the course of the Company's operations, for example, on the geological or the engineering side.

New research laboratories of special design and with modern equipment were built in 1926, in an enclosed area of about five acres, situated at Bibian, not far from the centre of Fields. In the construction of these buildings the maintenance of a cool and uniform temperature during the hot summer months, when the thermometer may rise to 120°F. in the shade, has been the first consideration; and the orientation of the main laboratory, the thickness of the walls, the roofing and the ventilation have all been designed to secure this object.

The main building is 132 feet long by 56 feet wide and is constructed of two steel frames and local stone and gypsum. The roof is of corrugated iron covered with carbolastic. The ceiling throughout is of beaver board with ample air space between it and the roof.

Wide central passages divide the building into four sections. The half of the building that contains all the laboratories is fitted with inlet ducts which supply cool air from a central duct connected to a water-spray air-cooler placed outside. A small refrigerating plant to keep two rooms at temperatures of 0°C. and 15°C. respectively and to make about one cwt. of ice a day is also installed. The other half of the building contains the workshops (fitted with drilling machines, lathe and forge), stores, library and typists' room, and is well provided with electric fans.

Besides the main chemical laboratory and the physical laboratory there are rooms for special purposes, such as a dark room for photography, an oil testing room and a room for high pressure work and combustions. All the laboratories are fitted with a supply of purified natural gas, steam, water, compressed air and vacuum. There are also subsidiary buildings in the grounds for larger scale experimental work, such as the experiments on gas pyrolysis or "cracking." A meteorological station, with a standard screen and instruments, has also been established.

It is true that, as has been well said, the results of research come from men and not from buildings or from apparatus. But in the research buildings at Fields the Company has provided for the men a local habitation for research that will bear comparison with the most modern research laboratories at home.

THE STEEPEST SECTION OF PIPE LINE OVER THE IMAM RAZA

CHAPTER VII

THE PIPE LINE

It will be remembered that we followed the crude oil as far as the first pumping station at Tembi, some five miles from Masjid-i-Sulaiman. We have now to see how this crude oil is transported to the refinery at Abadan.

A few only of the salient features of this stage of the operations will be dealt with here, though the story of the laying of the pipe line in the early days of the Anglo-Persian Oil Company is not the least romantic in its annals. That story has, however, been told before and it lies somewhat outside the purpose of this essay. The distance between Tembi and Abadan along the pipe line is approximately 135 miles. The pipe line has to cross two ridges, the Imam Raza, at a height of 1,366 feet, and Tul Khayaat, at a height of 1,308 feet, above sea level, before it passes through the foothills on to the desert. Tembi, it should be stated, is 618 feet above sea level.

The problems of the pipe line are, as may be expected, mainly engineering problems calling, at times, for the highest skill and ingenuity. The sections of steel pipe are screwed into one another and the most frequent difficulties arise from breakages in the pipe line due to alternate expansion and contraction, caused by the wide variation of temperature from winter to summer. The pipe line is curved at suitable places to enable the line to take up these expansions and contractions without fracture. Valves are introduced at intervals for stopping or regulating the flow.

It may be mentioned that, though the construction of the pipe line is nothing novel in engineering practice, the Company has evolved, for the various parts needed, its own standard specifications, which are markedly high in relation to those generally employed, and the tolerances—i.e. the departures allowed from the standards set—are correspondingly narrow.

Oil, like water, will not climb a hill, and, even on gentle downward slopes of the desert, the viscosity and friction are such that the flow would be too slow for practical purposes. The oil, therefore, has to be driven through the pipe line.

At Tembi there is a pumping station, equipped with modern plant and machinery, which, it is claimed, is not excelled, if equalled, in up-to-date efficiency by any other pumping station in the world. The fuel for steam-raising is the natural gas from Fields and much experimental work is being carried out as to the best types of burner, furnace and boiler for the gas under these industrial conditions. The pumps are powerful centrifugal pumps driven by steam turbines. They discharge the oil at a pressure of 600 pounds to the square inch and drive it as far as the next pumping station, thirty-eight miles away, at Mulla Sani. By the time the oil has arrived at Mulla Sani the pressure, owing to friction and other causes, has dropped to from 20 to 30 pounds to the square inch. At Mulla Sani, therefore, the pressure is "boosted up" again to 600 pounds to the square inch, to drive the oil through another thirty-two odd miles of pipe as far as Kut Abdulla. Here another boosting station sends it to Dorquain, thirty-five miles distant, whence, by a final boost, it is driven thirty miles to the Bahmishir, a tributary of the Shatt al Arab, near to Abadan. Thence it goes to the crude oil storage tanks on the fringe of the refinery.

It should be explained that, in order to secure flexibility and to maintain average "throughput," at each pumping station there are storage tanks of such capacity that, should there be pipe line or station troubles, the next station below can continue for some time to be supplied with oil, while repairs are being effected, and the oil entering the station immediately above can be stored until the disabled station is ready to receive continuous supplies.

There was one problem in connection with the pipe line of sufficient scientific interest to be worth mention here. In the early years serious difficulties arose because of the corrosion of the pipes crossing the desert. Long lengths of the pipe line were put out of action by corrosion after only twelve months' use. The question of finding, by experimental investigation, a suitable protective paint was considered, but it was realised that, assuming that a suitable paint were found, the coating would probably have had to be renewed annually and the cost would have been great, perhaps prohibitive. The solution was found otherwise; it provides an excellent example of the combination of acute observation with common sense—one form of science, it may be hoped.

The desert crossed by the pipe line is, of course, not all flat. It has slight undulations. It was noticed that the pipe line was nearly always most corroded where it rested on the crests of these undulations and least corroded where it touched the lower flanks of the undulations. It was well-known that the soil of much of the desert traversed is impregnated with common salt—the traveller cannot fail to notice the salt as a white incrustation often stretching for miles. The deduction was hazarded that, when rain fell, the crests of the undulations, off which the water ran rapidly, had little of the contained salt washed out; whereas the soil of the lower flanks, through which the water percolated and flowed freely, was probably freed of salt by the mere washing; and that the salt was the primary cause of the corrosion. The fact, also noticed, that a Persian gardener was in the habit of sweetening his garden soil by letting water run freely through it added point to the hypothesis.

Polished pieces of steel tubing were accordingly buried, some in washed soil and others in unwashed soil; the former showed little or no corrosion, the latter the usual corrosion, after the period allowed for this rough test. In this way the deduction as to the cause of the corrosion of the pipe line was held to be confirmed and the cure was sought, and found, by digging a channel in the earth around the pipe line and letting the periodical rains wash out the salt from the soil about the pipe.

Before we leave the pipe line, attention may be drawn to the scientific treatment of another problem arising out of this method of transporting the crude oil. We have seen that pumping stations are required at definite intervals to boost up the pressure sufficiently to maintain a steady flow of oil from Fields to the refinery. The pressure falls between one boosting station and the next, as has been said, from 600 pounds to the square inch to 20 or 30 pounds to the square inch. In order to secure the utmost efficiency of flow and to provide a safe margin for increasing the flow, if needs be, it is necessary that the pressure from station to station should, as far as possible, be graded; that is to say, drop gradually and continuously and not be liable to spasmodic or local rises. Otherwise it might happen that the pressure developed at some point would be the maximum pressure the pipe could withstand. Such a state of things, apart from the risk of breakage, would, of course, give no margin for increased flow. Accordingly a careful survey was made of the distribution of the pressures developed along the whole length of the pipe line and a graph was drawn showing the variations of the pressure along the line. By introducing extra parallel lengths of pipe at places where the graph showed local increases of pressure, the graph showing the fall of pressure was smoothed out; in other words, the pressure drop along the pipe was made gradual instead of being jerky, and, in particular, the development of dangerous pressures at certain points was avoided.

The pipe line is the main artery through which flows the liquid stream on which the very life of the Company depends. At Ahwaz on the river Karun are focussed, under the general direction of the superintendent of the pipe line, all those problems that arise as to the maintenance and improvement of that vital tube. These problems range from difficulties such as those just described to far reaching schemes for ever more efficient and economical transport of the crude oil from Fields to Abadan.

CHAPTER VIII

WATER, ELECTRIC POWER AND LIGHT

THE reader will have appreciated that, for the several large scale industrial operations that have been described, there are four primary needs—water, fuel, light and power. The provision of the fuel required at Fields has been described in the course of the gas story. It is time now to explain whence come the water, light and power.

Until 1926 the main water supply for Fields was obtained from the river Karun at Dar-i-Khazineh. There a pumping plant drew the water from the river and drove it through mains, following generally the road and light railway to Fields, some thirty-eight miles away to the north-east. Now Fields water supply is drawn from a point higher up the Karun river, at Gudar-i-Landar, north of Fields and distant from Maidan-i-Naftun about twelve miles. The change has meant not only a shorter distance for the water to travel, but purer water at less cost. It is estimated that the water is obtained from Gudar-i-Landar at one-fourth of the cost of getting it from Dar-i-Khazineh. The pumping station at Dar-i-

Khazineh is still kept in being, as a standby in case of emergency.

It is rather beside our purpose to describe, in any detail, the engineering side of the Company's operations. The engineering problems are, of course, just as scientific as the other problems that have been or will be discussed, but they constitute a subject too great for the compass of this essay. A visit to Gudar-i-Landar is, however, such a notable excursion from Fields that it deserves a slight digression.

Leaving Maidan-i-Naftun, the centre of Fields, we motor along roads, constructed by the Company, which follow the chosen contours of the innumerable hills, and gradually climb to Tul Bazun. A little beyond this the road ends abruptly on the edge of a plateau, some 2,200 feet above sea level, which is terminated by a steep and rugged mountain side. Nearly a thousand feet below the edge there is a narrow valley, beset by bare hills, the strata of which outcrop vertically in rows upon rows of natural stone walls. Five and a half miles down that valley is the pumping station on the left bank of the Karun river at Gudar-i-Landar.

There is no road down the mountain side: to construct one would be impracticable. Our car is, therefore, left at the top and we proceed to slide down the mountain—with the help of suitable mechanical means. Rails have been laid, on sleepers, down a

"THE SLIDE." TOP OF THE 2,200 FT. INCLINE LEADING TO GUDAR-I-LANDAR shallow cutting in the mountain side, from the top at Sar-i-Gach to the bottom at Par-i-Gach. The drop is about 950 feet and the length of rail 2,158 feet, giving a gradient of nearly 1 in 2. A simple four-wheeled trolley, held by a wire cable paid out from an electrically driven winding engine at the top, takes us down, and, when we return from Gudar-i-Landar, will bring us up. This is what they at Fields call "The Slide" and they are, justifiably, not a little proud of it. At the bottom a waiting car, summoned from Gudar-i-Landar by telephone, takes us down the valley to the pumping station.

The power at Gudar-i-Landar pumping station is electric and is derived from the Tembi power station which will be described shortly. The current is transmitted at 11,300 volts and is transformed to 440 volts for the motors at Gudar-i-Landar. The motors are of 350 horse power and centrifugal pumps send out the water at a pressure of 800 pounds to the square inch. The whole plant is of the latest modern type and has sufficient power to pump a million gallons of water per day.

But perhaps the most interesting feature seen on this fascinating trip is the means adopted to draw the water required from the Karun River. At Gudar-i-Landar the river, flowing over a rocky bed, is subject to great fluctuations of flow. A rise of as much as 45 feet in the level of the water may be expected in flood time. By an ingenious device, provision has been made to cope with a rise of no less than 70 feet. A steep, concrete slipway leads from the top of the high bank to the river bed. The pump house is built on a wheeled bogie, mounted on rails laid along the slipway. From a small house, on the bank above, winches draw in or pay out a cable which raises or lowers the pump house according to the rise or fall of the river, the electric cable transmitting the power to the pump house being drawn in or paid out at the same time.

From this rising and falling pump house the water is pumped into two large storage reservoirs, fitted with sluices and all modern appurtenances, and each capable of discharging half a million gallons of water. From the storage reservoirs the water is drawn, as required, and driven by powerful pumps through an 8-inch water main to the foot of The Slide and thence to the top at Sar-i-Gach, where there are storage tanks with a capacity of 6,4000,000 gallons. From these tanks the water is led by mains to the Fields area for industrial and domestic use.

The whole design, construction and equipment of this new pumping station at Gudar-i-Landar, for which practically all the materials, including the girders and heavy machinery, had to be let down The Slide, leaves on the visitor's mind an abiding impression of efficiency and of triumph over physical difficulties.

To come to the question of the electric power and

PUMP HOUSE ON SLIPWAY AT GUDAR-I-LANDAR

light, there is at Tembi, on the river Tembi, over against the great pumping station which has been described in the section on the Pipe Line, a great power station. It was begun in a modest way, provided with two dynamos, driven by reciprocating engines and yielding 350 kilowatts. As the cry for more power became urgent two steam turbo-alternators were added with an output of 1,500 kilowatts and in December, 1926, another steam turbo-alternator, with an output of 3,000 kilowatts, was installed, as well as the most modern type of switchboard. The fuel used is the natural gas from Fields.

The power is distributed by high tension overhead wires at about 11,000 volts to practically the whole area of Fields, as well as to Tembi itself and Tul Khayaat. Transforming stations, suitably placed, enable the voltage to be stepped down to the appropriate pressure wherever the current is required. The wide distribution over Fields area of the high tension current enables electric power frequently, if not always, to be used for well drilling, which, as compared with steam power, results in economy of cost and accelerated drilling time.

For all these engineering developments, the results of finely directed and organised efforts, spontaneous and admiring tribute was paid in all quarters to Mr. J. Jameson, for so long the General Manager, and now a Deputy Director, of the Company.

CHAPTER IX

REFINING THE CRUDE OIL

THE crude oil, it will be remembered, was left in the Storage Tank Farm on the fringe of the great refinery at Abadan. An attempt must now be made to indicate broadly the general character of the scientific work done by the Anglo-Persian Oil Company in obtaining from the oil the petrol, the kerosene and the other products, to provide which is the primary purpose of the Company's existence.

The reader should be warned afresh that this essay is not to be taken as a technical summary, or even a substitute for such a summary, of the methods of oil production and refining. In dealing with the scientific aspect of the work of the refinery it will necessarily be difficult to keep the narrative within the bounds set, for every step in refining is a scientific process and tempts some comment or explanation. It will be best, therefore, to confine our attention, for the most part, to some salient features of the scientific investigations that are undertaken at Abadan to improve the process of refining, selecting those that illustrate our general theme.

ABADAN REFINERY

We have previously spoken (p. 83) of the crude oil being delivered from the pipe line into the refinery storage tanks, but this is not strictly accurate. It will be remembered that the oil carries in solution large quantities of gas which is required for use as fuel. This precious gas (and with it some even more precious petrol) would evaporate and be lost if the oil were allowed to stand in tanks at atmospheric pressure. The first step, therefore, is to secure and retain the most volatile constituents of the "crude" before they can escape. To effect this the crude is led directly from the pipe line to heaters, which raise its temperature to about 120° F., and thence into large towers which are kept under vacuum. The oil flows down these towers and away to the refinery, but, during the passage through the towers, the gas and some of the gasoline which was injected at Fields are sucked out of the oil by the vacuum and are led away to a gasoline recovery plant. Here the gasoline is separated from the gas and, after stabilisation, is mixed in due course with the rest of the motor spirit, while the dry gas enters the gas main that feeds the boiler furnaces with their fuel.

It should be noted that this process of "degassing" the crude oil immediately on its arrival at the refinery reduces evaporation losses to the minimum, and that the scientific handling of the crude oil, in the manner we have described, so as to maintain it under pressure from the time it leaves the oil rock until it reaches the refinery, is possible only where the whole oil field and the refinery are under one control, such as obtains in the great Persian Field.

The crude oil as it reaches the refinery is, of course, a complex mixture of many compounds. It contains, actually or potentially, such substances, for example, as tar, pitch, paraffin wax, lubricating oil, fuel oil, kerosene or lamp oil, and petrol or motor spirit. Moreover, there is no hard and fast division separating, say, the fuel oil from the kerosene or the kerosene from the petrol. As we pass from the lubricating oil to the petrol, in the order just recited, we pass continuously from heavier to lighter fractions, i.e. from less volatile to more volatile products. The process of refining consists essentially in separating these fractions by distillation and in purifying the distillates by the removal of certain undesired ingredients.

At the Abadan Refinery there is a process chart showing the sequence and connections of all the refining operations. It is perfectly clear and intelligible, not only to the technician, but to the average visitor. Since, however, it looks as formidable as would a composite diagram of a genealogical tree and a railway junction, it is not inserted here. It would be tediously technical to give anything approaching a detailed description of the processes of refining, but the reader who is interested in this aspect of the

Company's work may be glad to have the following summary of some outstanding and fundamental features of refining as carried on at Abadan.

The crude oil, "degassed" in the way we have described, is pumped while still warm to the distillation benches, where it is distilled, in pipe stills and bubble towers of the latest type, into petrol, kerosene, gas oil and fuel oil. There are many advantages, besides that of avoiding evaporation losses, in distilling a crude oil from which the gas has been previously removed. The outstanding advantages are that nearly all the hydrogen sulphide is removed with the gas, so that much of the corrosion of the distillation plant that would otherwise be caused by this constituent is eliminated; and the absence of fixed gases in the vapour evolved from the oil during distillation enables the condensers to operate under very efficient conditions and so reduces the quantity of cooling water required.

Each distillation unit handles approximately a million gallons of crude oil per day and produces distillate of market specification needing no redistillation. Moreover, owing to the efficient design of the furnaces and to the excellent system of heat exchange adopted, the fuel consumption is comparatively low. The yield of products from this pipe-still system of continuous distillation is appreciably higher than that obtainable by the time-honoured, shell-still method of distillation.

The gas oil and the fuel oil as distilled are finished products and are pumped directly to storage tanks, but the petrol and the kerosene require a chemical purification before they are ready for the market. This treatment is primarily one of de-odorisation, as these products contain small quantities of evil-smelling compounds of sulphur which have to be removed.

The treatment of the petrol is carried out in a highly ingenious "washery" plant, invented and designed by the Anglo-Persian Oil Company's chemists and engineers. It operates on the "continuous counter-current" principle, i.e., the oil flows continuously through the plant in one direction and is brought into intimate contact with the purifying chemicals which flow through the plant in the opposite direction. Thus the purified petrol leaves the plant at one end while the exhausted chemicals leave at the other end. Moreover, the application of scientific principles in the whole design of the plant has resulted in its operation being almost automatic, so that a washery, capable of purifying five hundred thousand gallons of petrol per day, can be completely controlled by one man.

The kerosene is desulphurised and purified by means of liquid sulphur dioxide. This treatment is carried out in a continuous counter-current Edeleanu plant of the latest type in which the sulphur dioxide is used over and over again with negligible loss. The refined kerosene is finally further purified by filtration through bauxite.

At the Abadan refinery there are a staff of chemists and chemical laboratories under the charge of a chief chemist. As in the case of the Fields chemical staff so here there is complete liaison and a rotation of staff between Abadan and the research station staff at Sunbury-on-Thames. A good deal of routine work is necessarily carried on, for example, in the daily testing of the various products at each stage of the process. What, however, is more to our purpose is to note the recognition by the Company that there is, and can be, no finality in any of the processes adopted. A sleepless scepticism of the perfection of existing methods is the price of progress. Research is prosecuted continuously into methods of improving every stage of the process and also to secure adjustments and modifications needed to meet special demands or particular difficulties arising out of the nature of the material being treated.

A considerable part of the refinery plant at Abadan, when the writer was there, was being reconstructed, in order to bring it into line with the new knowledge gained, not only from these researches, but also from the co-ordinated investigations undertaken at Sunbury and from the experience acquired in the new refinery at Llandarcy. These reconstructions have since been completed and have brought the Abadan refinery abreast, and in some respects ahead, of the most advanced refineries to be found elsewhere in the world. The whole refining process at Abadan is very flexible, so that the proportions in which the various products—petrol, kerosene, gas oil, fuel oil—are obtained can be varied within wide limits and thus the fluctuating needs of the market for one or another product can be readily met. This desirable flexibility is now being further increased by the installation of cracking equipment which will enable fuel oil to be converted into motor spirit.

There is, too, at Abadan a semi-large scale plant for investigations on the pyrolysis or cracking of the gas, stripped of its gasoline, on lines similar to those followed at Fields, with a view to getting from the lightest fractions of the gas by a sort of synthesis—"polymerisation" is the chemical term we are trying to avoid—heavier liquid fractions, among which benzole may again be mentioned. The introduction of benzole as an ingredient in the motor spirit, it may interest the motorist to learn, is to meet the needs of highly specialised internal combustion engines. When we come to describe the research work done at the research station at Sunbury-on-Thames we shall see that investigations are being undertaken into the varied and extensive problems raised by the use of motor spirit in internal combustion engines.

When, therefore, the pyrolysing or cracking plants, both at Fields and at Abadan, are in full scale working order there will be obtained from otherwise waste gas abundant supplies of useful and needed liquid products.

One feature of the refinery plant is worth mention as an instance, among many, of the adoption of modern efficient machinery. The oil and the various intermediate products travel to and from the numerous units in the refinery plant through an intricate maze of hundreds of miles of pipe—almost as bewildering to the layman as the connections of a telephone exchange. This vast circulatory system is maintained by the use throughout the refinery of electrically driven, centrifugal pumps for all pumping purposes.

The light products of the refinery plant are led away to storage tanks at Bawarda, approximately two and a half miles down the Shatt al Arab from Abadan, there to await shipment in the tankers. The storage of these volatile products is located at such a distance from the refinery in order to minimise the danger of fire during loading. These tanks at Bawarda deserve notice as another example of the application of scientific principles. If the normal type of domed cylindrical storage tank, of fixed capacity, were employed, great waste would be involved, particularly in Persia, where in summer the day temperature rises to 120°F. in the shade. During the day, the summer sun's rays, beating on the roofs of the tanks, would cause expansion, vaporisation and escape of the valuable petrol into the atmosphere. During the cool night contraction and condensation would take place and air be drawn into the tanks. Thus the tanks would behave like enormous lungs, in diastole and systole expiring the needed petrol during the day and inspiring the unwanted air during the night. The company has, therefore, adopted tanks with roofs that float on the surface of the liquid contents, and, by thus eliminating the space between the roof of the tank and the level of the liquid in it, the "carburation" losses during storage are reduced to a minimum.

There is, of course, at Abadan an electric power-station, as well as a pumping station for the industrial water supply drawn from the Shatt al Arab. The fuel used for steam raising is oil, though a certain amount of the stripped gas evolved in the distillation process is also so used.

Nor is artistic amenity forgotten. In front of the chief administration offices at the refinery a great grass plot has been laid for no other purpose than to gladden the eye. It need hardly be said that in a desert land, whose normal colour is that of dry mud, a grass lawn is, indeed, "a thing of beauty and a joy for ever."

CHAPTER X

RESEARCH STATION AT HOME

THE salient features of the scientific work done in finding, getting, transporting and refining the crude oil have now been broadly reviewed. We have seen that both at Fields and at Abadan the chemical staffs and the work they do are brought into co-ordination with the scientific investigators and the research work done at the chief research station at home. Before leaving the more strictly scientific aspects of the Company's activities, in order to describe the not less important or significant work on the educational, health and social sides, it will be well now to describe the general character of the work done at Sunbury-on-Thames.

The decision to establish a research station was taken in 1915. The selection of the site chosen—eighteen miles from London—was determined by the consideration that the research staff must be in the closest personal contact, not only with the nerve-centre of the Company's organisation in London, but also with the most recent developments of scientific thought and activity, the most eminent of scientific societies and the most complete and up-to-date of scientific and technical reference libraries. These latter things, it is needless to say, are centred in London.

In view of the necessarily wide and varied range of the scientific investigations to be undertaken, the Station was laid out as a group of separate buildings, each of which was designed and equipped for a specific type of work, ranging from pure chemical research on the individual chemical substances present in petroleum and pure physical research on the theory of lubrication to long-period tests on Diesel engines and complete refining of crude oil on a scale up to one ton.

The chemical laboratories, with the library, drawing office and engineering shop, constitute the central block of buildings. There are also the experimental refinery, the power house, the boiler house, the experimental house and a large engine test house.

A good deal of analytical work is necessarily done in the regular testing of samples of the crude oil and of the various refinery products, as well as in the examination of specimens of oils, waters and mineral deposits sent home by the Company's geologists and engineers.

Moreover, careful analytical control and record is kept of the quality of such items as refining chemicals, water and water-softening components, building materials, steels and other alloys, paints, enamels and the hundred-and-one miscellaneous articles used in the various activities of the Company. An important phase of this work is the development of improved or new methods of analysis, several of which have been subsequently adopted officially as British standard methods.

In the chemical research laboratories new ideas, new materials and new processes are tried out on the "test-tube scale," i.e., with ounces, or smaller quantities, of material in glass apparatus. In the experimental refinery these experiments can be translated to a larger scale in steel plant which is a replica on a reduced scale of the still larger units of the commercial refineries. Thus it is possible, after a preliminary examination in the laboratory, to distil a relatively large quantity of any new crude oil and to prepare from it all the main derivatives in a refined condition, on a scale which is nearer to refinery conditions and which is of greater guidance, as regards costs and practical, large scale technique, than a laboratory test alone can be.

Before indicating some of the outstanding features of the research problems dealt with at Sunbury (and these range from entomology to boiler insulation and from atomic physics to Schneider Trophy engines) it is worth while to draw attention to one section of the research work, significant of the wide and long views taken by the Company as to the scope of the researches that may legitimately be undertaken.

The petrol and the heavier fuel oils produced are, of course, destined for industrial use in internal combustion engines. The problems of the oil to be used and of the engine that is to use it are regarded as being so closely related that no researches into the one can be complete without correlated and simultaneous researches into the other. An Engine Research Department has, therefore, been created and two large test houses erected. One of these contains a series of typical Diesel engines ranging from eight to sixty horse-power. These are used for experiments on various fuels, on lubricating oils and also on new modifications of engine design. Incidentally they serve another purpose, for at the same time they provide the whole of the electrical power required by the research station.

The other test house is devoted to petrol engines and is divided into two sections. One of these is subdivided into separate cubicles, each of which houses special research engines of a type designed in this Department. These engines are small single cylinder units on which every conceivable variable, including compression ratio and load, can be separately controlled and adjusted while the engine is running. These engines can, therefore, be set to simulate any design of internal combustion motor and any running conditions (for the cubicles can be cooled to arctic, or heated to tropical, temperatures, with adjustable humidity); and, consequently, Persian motor spirit and Persian lubricating oils can be tested under every condition they are liable to meet in the world's markets. A great deal of most important research on fuels and on engine design has been done with these engines and a new method of assaying petrols for anti-knock value has been worked out in this laboratory and published. Incidentally, it is of interest to record that the B.P. fuel used by Sir Henry Segrave in achieving the World's Record Land Speed of 231 m.p.h., at Daytona, was developed by the use of one of these engines and was supplied from Sunbury. Moreover, replicas of these engines are calibrated at Sunbury and then issued to all the Company's refineries, so that each refinery can ensure that the spirit it issues to the markets is of a definite and unvarying quality.

The other section of the petrol engine test house is equipped with typical motor cycle, motor car and motor lorry engines, on which long period tests can be made and measurements of acceleration, power output, fuel and oil consumption, engine wear and similar important factors can be recorded.

It not infrequently happens that in the course of experiments on a particular make of engine some modifications in design are discovered which make a notable improvement in the results which can be achieved. It is easy to see that the friendly co-operation which such work stimulates between motor engine designer and petrol producer cannot but be of great value to both of the great industries involved and also, of course, to the general public.

The research work undertaken at, or directed from, the chief research station at Sunbury goes, however, far beyond the utilitarian aims that have been indicated. It is obviously useful and, indeed, important to discover how to test fuels and to adapt them to give the most efficient service in an engine; or, conversely, how to design or adjust an engine to yield the best service with a given fuel. But the aims and aspirations of the research chemist are not satisfied until answers are obtained to the more profound questions: Why do these adaptations produce the desired results and what is the fundamental mechanism underlying the whole process of combustion or explosion in the cylinder of an engine? Not only the "how" but the "why" has to be known, if the experimental work of the research chemist is to be directed by a logical sequence of thought, founded upon a definite basis of scientific facts, and not be a mere haphazard empiricism, following a "hit or miss" procedure.

We find, therefore, that fundamental research, as distinguished from directly utilitarian investigation, constitutes no small proportion of the activities of the Company's research department. Thus fundamental research on the mechanism of flame propagation in an engine cylinder is being carried out, while other lines of research at present in progress are concerned with the nature and mechanism of lubrication and with the actual chemical entities of which petroleum is composed. Such work is necessarily of an intricate and even recondite character and demands research workers of the highest order, in knowledge, training, skill and experience. The research department of the Anglo-Persian Oil Company, therefore, has wisely sought and maintained close contact with those universities which specialise in the particular type of problem under investigation.

The Company has a scientific advisory council, consisting of Professor Thorpe, Professor Wheeler, Professor Rankine and Professor Lees, on the chemical and physical sides, and of Sir Thomas Holland, Professor de Böckh and Mr. T. Dewhurst, on the geological side, for constant consultation in the initiation, prosecution and correlation of the vital fundamental researches needed.

Nor has such an apparently academic and remote problem as the origin of natural petroleum been ignored. Contributions on this subject have been made to learned Societies by members of the research staff of the Company. The question is not so academic as it seems. As was said by a writer in *Nature*, "the problem of the genesis of petroleum has a distinctly practical significance, for if solved prospectors for mineral oil would be provided with important data and chemists might learn how to produce artificially valuable substances similar to, if not identical with, natural petroleum." The same writer, it may amuse the reader to note by way of diversion, unearthed the following early contribution to this perplexing problem: "A Polish cleric, named Kluk, traced the origin of petroleum to the Garden of Eden, which was so fertile that it must have contained fats: at the Fall this fat partly volatilised and partly sank into the earth, where it was finally transformed into mineral oil by the changes induced by the Flood."

To return to our more serious record, the reader will have already appreciated the vitally important part which the scientific, and perhaps especially the chemical, headquarters must play in a petroleum company of the magnitude of the Anglo-Persian Oil Company. Problems of an essentially scientific character are continually arising in connection with the Fields, the transport and storage of the crude oil, the initial distillation, the refining of the intermediate products, the distribution of the finished article and its ultimate utilisation by the consumer. Some of these problems can be more or less rapidly solved at the central research station at home; sometimes they can be more conveniently investigated at the refineries;

and sometimes, again, Fields research station at Masjid-i-Sulaiman is the most suitable centre for their treatment.

It has already been pointed out that there is complete liaison and co-ordination and a rotation of staff between the various research stations. When occasion demands, a research chemist who has made a special study of the particular problem at Sunbury is sent to deal with it on the spot and, conversely, chemists home on leave from outside areas invariably take, in part, a "busman's holiday" and are attached to the central research department for a period. In this way each chemist in the Company's service is enabled to learn at first hand the lines of thought and of progress in his profession and to discuss his ideas and his problems with his brother chemists. The senior chemists in England visit the refineries and Persia at regular intervals and a general chemical conference, attended by representatives from every chemical centre in the Company's organisation, is held in London each year. The co-ordination of the activities of the Company's chemical staff is one of the most important functions of the central research department and its success is attested by the enthusiasm and *esprit de corps* which, it was evident to the writer, animated the Company's chemical service no less than the other services.

It should be added lastly, in considering the more strictly scientific side of the Company's activities, that the research department, with the full approval and encouragement of the directorate, does not forget its obligations to the cause of science as science. The results of the varied investigations are published to the scientific world, except, obviously, where the work is necessarily of a confidential character. In general, however, the records of the fundamental researches after scientific truth are presented to the Chemical Society and to other learned societies, as the research department's quota to the world's scientific knowledge. Furthermore, the senior members of the chemical and other scientific staff are associated with the activities of advisory, scientific committees of various Government departments and in this way their knowledge and experience are put to the service of a wider circle than that of their own Company. In this connection it is worthy of note that the Chairman of the Company, Sir John Cadman, was for many years a member of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research, which is, in a far from fanciful sense, the scientific senate of the nation, constituted of a chosen few of the country's leaders in science, and charged with the fiduciary duty of promoting the application of science to a wide field of governmental activity and to a broad and diversified area of British industry.

CHAPTER XI

OIL AND ETHICS

Thus far we have described what may be regarded as the more strictly scientific side of the development of a particular oil field. Before we attempt to appreciate what the Anglo-Persian Oil Company has done on the human and sociological side, let us glance at the larger aspects and broader policies of the petroleum industry as a whole, considered as a unit in the world's economy.

It should be acknowledged here that what follows in this chapter is based mainly, indeed, almost wholly, upon an address delivered by Sir John Cadman, before the American Petroleum Institute, at Chicago, in December, 1928. The address was subsequently published under the title, "Petroleum Problems Outside the United States," though it was essentially a pronouncement and an appeal in the higher statesmanship of the oil industry regarded as a world industry. It has seemed to the writer that an outline, at least, of the broad issues raised in that address is a necessary complement to this study of scientific and industrial development in a particular oil field, if the reader is to be helped to see the Anglo-Persian achievement in proper perspective.

What are these larger problems that are engaging the anxious attention of the world's leaders in the petroleum industry? Broadly speaking, they are concerned with the general principles that ought to influence and govern future programmes for control and distribution of the world's oil resources.

The world's reserves of oil are undetermined and perhaps undeterminable; but it is probable that, as in the case of the coal reserves of our own country, successive careful estimates will put the total figure ever higher. For example, whereas in the years 1920 to 1922 some reputable technical and geological opinion in the United States put the virtual exhaustion of the United States' oil resources within a period of twenty or thirty years, an eminent authority at the Fuel and Power Conferences, held in London in 1928, estimated the number of years upon which the world could rely for gasoline as high as 3,000. Still the geologists and the geophysicists go exploring the surface and crust of the earth in quenchless quest for a commodity which has now become one of the essentials of modern civilised life, moulding and modifying our industrial structure and even our social habits, just as coal and steam helped to fashion the industrial and social fabric of the civilisation of the nineteenth century.

If, however, in certain economic reactions, more especially in relation to the laws of supply and demand, we compare, on the one hand, oil with, on the other hand, such common necessaries as food, clothing and houses, some significant differences become apparent. In regard to these latter three commodities increase of supply, whether in home production or in imports, does not increase consumption and enhance demand beyond a certain point. In any given community when the ill-fed, the ill-clad and the homeless have had their needs adequately met in the matters of food, clothing and houses, the mere expansion of supply, accompanied by a fall in price, of these commodities is powerless to increase the demand for them beyond certain narrow limits; for the simple reason that individual human beings cannot extend indefinitely their consumption of food, their use of clothes or their occupation of houses.

There is also another general factor operative in regulating production, namely, the relationship between the value to the user of the thing produced and the expenditure of human energy demanded by its production. The supply of food, clothing and shelter involves a fairly regular cost of human effort for the large as for the small unit. A loaf of bread, a suit of clothes, a house—each represents a fairly definite number of units of human energy spent in its production. Any significant increase in demand for these commodities is necessarily slow; it calls for an approximately corresponding increase in human effort to meet it; and thus a prompt check is imposed upon real over-production.

But in regard to oil the measure of human energy necessary to produce a definite quantity of it varies irregularly within wide limits. For example, the then Chairman of the Anglo-Persian Oil Company in 1926 explained to the shareholders that "to secure the production of crude required for export all that has to be done now is to open the necessary number of valves, by means of which the production of crude can from day to day or from hour to hour be regulated to our requirements to a nicety, just as regularly and accurately as when one turns on the water for one's bath." You call for more wheat and the farmer has to plough, sow and reap correspondingly increased acreage. You call for more crude oil and the engineer opens another valve.

On the one hand, therefore, in regard to the three common necessaries of life we have chosen for comparison, their very nature in relation to human nature, and the fact that to increase the sum of their production needs a regular amount of added human effort, together constitute an automatic check upon really excessive production. On the other hand, when we consider oil, it is, as Sir John Cadman says, "a fact of the first importance that the face of the globe is now drenched with a commodity which, although necessary to life, involves but an irregular and sometimes meagre expenditure of life in its primary production." Furthermore, it exhibits an economic characteristic that is novel—almost unique: the supply not only stimulates the demand, within limits it creates it. New uses spring up for it overnight. There is thus a peculiar economic stimulus to production tending directly to over-production with all its attendant evils—"so resilient appears to be the demand, so far remote the industrial saturation point."

The increase in the world's production is, however, not solely due to this peculiar economic stimulus. Improved geological methods, supplemented by those modern geophysical methods we have outlined in an earlier chapter, have led to the discovery of new oil fields in territories formerly considered to offer little hope. The advance in drilling technique has resulted in a saving of time and the working of strata previously deemed inaccessible, so that there has been an accelerated and more intensive working of the existing oil fields. Improvements in refining methods have resulted in a greater net product from a given quantity of the crude oil. The effects of all these stimuli to production have been most marked in the United States. Taking a survey of the six years 1922 to 1927 in all the producing countries of the world, other than the United States, production increased to the relatively small extent of some seven and a half million tons; whereas the increase in the United States in the same period was no less than forty-seven million tons.

Among the evil consequences of profligate production are premature exhaustion, both material and economic, of discovered fields, and economic instability of the industry as a whole.

With regard to the first consequence, exhaustion, it is worth notice that in the Persian oil field the Company has had sole control and has been able to operate the area as, more or less, a unit field (or, at least, as an area of a few co-ordinated units), undisturbed by the competitive chaos that has characterised certain other oil fields. Furthermore, the comprehensive scientific data that have been obtained by the methods indicated in previous chapters have enabled a far-sighted policy of scientific conservation to be adopted and applied, continuously and systematically. Otherwise, despite the extraordinary richness of the Persian field, exhaustion of an economic, if not of a material, character would have been reached in a comparatively small number of years.

As to the second consequence, economic instability, it affects producer and consumer alike. "In the long run," says Sir John Cadman, "it profits nobody that there should be alternate waves of over-production and under-production, of high prices and low prices, of big profits and of little or no profits." In the Report for 1928 of the Royal Dutch Company for the Working of Petroleum Wells in the Netherlands Indies the ame point is emphasised by Sir Henri Deterding, the Managing Director of the Royal Dutch Shell interests: "During the period of over-production and low prices amounts of capital have to be invested by the industry in order to deal with the large quantities produced; large stocks which cannot be consumed have to be stored in expensive tanks, whereas the earth is a much cheaper and safer storage. When this is followed by a period of small production a great many of the plants become no longer necessary and the capital invested therein is wasted. The same applies to the consumers: first they will adjust themselves to the excessive supply of oil, which necessarily involves capital expenditure also for them, and when the period of low prices is followed by one of high prices they, too, will find that they have expended capital uselessly."

In the United States, too, there is a realistic appreciation of the need to stop the economic waste of world over-production, which, as Sir John Cadman says, "amounts to a robbing of the birthright of future generations." A comprehensive programme for curtailment of crude petroleum production in the Western Hemisphere has been recommended by the General Committee of the American Petroleum Institute on World Production and Consumption of Petroleum and its Products, and has been endorsed by the board of directors of the Institute. With so many interests involved it is obvious that the process of rationalisation of the industry must be a slow business, but an earnest beginning has been made. In April 1929 all parties interested throughout the world were called to a conference in New York to see what can be done to secure a rational, stabilised and economic production in the principal oil-producing countries of the world.

We cannot within the limits of a single chapter, and with regard to the scope of this book, go far into the suggested lines of advance, but certain considerations may be briefly summarised. In the first place there is the need of some recognisable and acceptable policy governing the extent of storage facilities. Sir John Cadman suggests, as a guiding principle, "the desirability of conserving deposits, once discovered, not in imperfect containers constructed on the surface of the earth, but, so far as is practicable, in that great and perfect reservoir which Nature herself has provided." Allied to this is the evil of the unlimited multiplication of facilities for the so-called "service" of the motorist. There is need, economic need, in the interests of producers and consumers alike, to abate the nuisance of excess and to attain some sane equilibrium between service and supply.

Again, in the realm of transportation by sea there are countless instances of waste of strength through lack of co-ordination and by straining against the facts of geography. For example American oil finds its way to India and Persian oil to Iceland. We need "a sane 'economic' of the sea," and this involves the problem of finding for every market the "nearest source of supply"—that is to say, the nearest, taking account of all relevant economic factors, for geographical propinquity is not the only economic factor to be considered here.

Finally, there are the problems having their origin in "the vivid sense of nationalism which, during the last ten years, has acquired acuteness and strength in many countries." It is natural for the government and people of any country in which large deposits of oil have been found to regard their possession jealously and to think of it in merely national terms. But in a country of small consumptive power the mere possession of natural oil is an asset only in so far as a whole complex of external conditions—financial, technical, distributive—makes it so. As Sir John Cadman well says, "without hundreds of investors willing to lose four times out of five in the hope that at the fifth they will make good their losses; without the instruction of a whole faculty of technical resources, founded and developed in other countries—or, it may be, in another hemisphere; without an army of pioneers who have adjusted the needs of man to the character of the product and *vice versa*; without a network of distributive systems having been traced upon the face of the globe—without every one of these things, the oil deposits, priceless as they are potentially, might just as well have been buried deeply in the moon." He, therefore, pleads for "a sane nationalism; regarding oil neither as a heady intoxicant for oneself nor as a deadly drug for one's political competitors, but rather as a store of energy to be conserved, released and applied as part of a concerted operation owing its inception to more than one nation and therefore yielding its tribute to more than one treasury." And this sane nationalism needs as its complement a corresponding policy of "sane and honest internationalism in industry," involving frank co-operation between national and international forces.

Such are some of the leading problems of the petroleum industry which have suggested the challenging title of this chapter: "Oil and Ethics." If it be objected that they savour rather of economics, we may perhaps recall the saying of the cynic: "Show me that a course is economically expedient and I'll soon find you moral sanction for it." There is less of cynicism in the saying than appears on the surface. It is good ethics to instil and practise sound economics. The old gibe at economics as a soulless science has led too frequently to the assumption by ardent propagandists that there is some inherent antagonism between economic and ethical action. It will not be the least valuable service that the world's leaders of the petroleum industry will render if, by their concerted efforts to secure a rational world production of oil, they expose the mischievous fallacy of this assumption.

PART II

THE HUMANITIES

BAKHTIARI CROSSING THE KARUN RIVER ON RAFT OF INFLATED GOAT SKINS

CHAPTER XII

THE HUMAN MATERIAL

It was stated in the introduction that, in considering the application of science to industry we should interpret the word science in its widest sense, so as to include the methods of dealing, not only with the raw material obtained from the crust of the earth, but also with the human and sociological factors necessarily involved in large-scale production. Enough has already been said on the problems flowing from the crude oil. We have now to turn to the ways of dealing with the human material and of building a social structure out of it. If the first part of this essay may be called the science, what follows is the humanities of great industrial undertaking.

It is obvious that for the operations that have been described it was necessary to secure the willing co-operation of the Persians in whose country those operations were to be conducted. In particular large supplies of local labour were essential for the pioneering work, such as the transport of heavy machinery, pipes and other materials; the erection of the derricks, houses and other buildings; and the construction of roads, bridges and railway. The peculiarity of the problem that faced the Anglo-Persian Oil Company from the start lay in the character of the human labour available.

The inhabitants of that part of Persia (Khuzistan) in which the work was to be done were, for the most part, pastoral nomads, consisting mainly of the famous Bakhtiari tribes. The Bakhtiari follow the grass. As summer approaches to scorch the grass on the desert plains, they migrate with their flocks and herds, over the foothills, across the bridgeless rivers and over the snow-clad mountain ranges, to the high lands where grass is then to be found. In the late autumn, when the grass dies down on the high plateau or in the mountain vales, they trek back to the low-lying plains, where, in the mild winter, they can find enough grass on the desert to feed their flocks. They live in tents or in rude shelters constructed of sun-baked mud or of the loose sandstone and shale of the hills Their wants are few and the hardships of such a life are to them scarcely irksome. Of money they have little need and such exchange as they require is done largely by barter.

This part of Persia corresponds roughly to the ancient Kingdom of Elam. There was a time when, as in other parts of Persia to-day, a settled agricultural population dwelt here. Remains of ancient irrigation canals are still to be seen on each side of the Karun river. But the nomadic life of the Bakhtiari is the consequence of successive waves of invasion from the north and west—Babylonian, Greek, Roman, Arab and Turkish—destroying the agricultural resources of this region, which may become yet as fruitful a part of the earth as is, for example, Egypt to-day.

It was from this nomadic human material that the company had to enlist the labour it required. The character and habits of these tribesmen presented human and sociological problems as peculiar and as complex, in their own ways, as the physical and chemical problems raised by the nature of the crude oil obtained from below. It was not sufficient to attract the tribesmen to service with the Company by the prospect of regular pay and the additional comforts that pay could bring; measures had to be taken to keep them when enrolled. The nomadic instinct is not easily extinguished. Gradually they came in increasing numbers into employment and problems immediately arose as to their health, their housing and their training. We will take these problems in this order.

It is not pretended in what follows that the measures adopted were the outcome of some previously elaborated, scientific scheme, embracing in anticipation all the problems to be solved. Something of what was done was necessarily of an emergency character; other steps taken were dictated by the particular need disclosed at the time; and many solutions were found *ambulando*. Nevertheless, the reader will probably gather, as he reads, that, running through the treatment of the varied human and social problems presented, there was a consistent scientific attitude and method, and, be it added, a humanitarian outlook, which it is the aim of the writer, in some measure, to reveal.

CHAPTER XIII

MEDICAL SERVICES

From the outset it was recognised that proper provision for dealing with sickness was at least as important as attractive pay. It is significant that one of the earliest administrators sent out by the Company was a medical man, Dr. M. Y. Young, and it is not less significant that he did not confine his interest to the purely medical sphere, but pushed out into a sympathetic study of this ancient people, of their language, history, customs, habits and ways of thinking. There is now a specially organised department of the Anglo-Persian Oil Company which takes within its province, not only the legal and other formal relationships between the Company on the one hand and the Persian Government, the local officials and individual Persians on the other, but also the study of the human side of the people with whom it has to deal. The gradual growth, from simple beginnings, of the present well-equipped medical, surgical and sanitary services, and the provision of elaborate facilities for the prevention and efficient treatment of disease, deserve to be told in detail. We can attempt here only to picture the state of things to-day.

At Fields, at Ahwaz and at Abadan the Company has built, equipped and staffed hospitals, which it maintains entirely at its own cost and which provide medical and surgical treatment not only for the sick employees of the Company—whether Europeans, Persians, Indians or others—but also for all their families and dependents as well as for others, of whatever race, who are unable otherwise to obtain medical or surgical attention in their need. A general description of the hospitals and of the healing work done, at Fields and at Abadan, may now be given. With a few qualifications, the general features apply also to the hospital at Ahwaz.

FIELDS AREA

The hospital for in-patients at Fields is situated some two miles from Maidan-i-Naftun. In addition to large medical and surgical out-patients' clinics it has indoor accommodation for about a hundred cases, mainly for the salaried staff, but including special wards for women.

There is also an isolation hospital for cases of infectious disease and a camp for the segregation and observation of contacts.

A particularly valuable and rare feature of the Fields

THE OPERATING THEATRE AT THE OIL FIELDS HOSPITAL

Hospital is the section known as the Hyperpyrexia Wing. This was designed originally for the study and treatment of cases of heat stroke, but it has been found that the utility of this building far transcends the original conception of its usefulness. All cases of serious disease accompanied by fever, and, more especially, cases of surgical shock, are greatly benefited by removal to the cool environment of these wards, where a temperature of about 65°F. is maintained by a current of air which has been purified and cooled before being passed in. The system has been extended recently to both the septic and aseptic operating theatres, which are likewise cooled, though to a less degree; and operative surgery, even in the hottest period of the year, is now free from one of the greatest dangers in tropical practice which previously attended it. The walls and floor of the operating theatres are a white mosaic of evenly broken crockery —a brilliant adaptation of waste material to utilitarian ends which has resulted in a marvel of cleanliness.

The hospital stands well back from the road in its own grounds, and is a one-storied building of local stone and gach, with deep verandas giving welcome shade to the several wings. In addition to the two surgical theatres there are a pathological and bacteriological laboratory; an electro-diagnostic department with a complete set of electrically illuminated, diagnostic instruments; an X-ray outfit, which has recently been improved and adapted for pyelography and for the more specialised forms of radiography; and a fast-increasing dental department.

The sanitary and ventilating arrangements throughout the hospital are modern, according to scientific standards. It is proudly claimed, and the writer can well believe it, that Fields Hospital is not only the best equipped hospital in Persia, but that it is also better equipped than are the majority of hospitals of a like size in India.

Facilities for medical treatment in Fields area are afforded also by a number of dispensaries, where the very large number of out-patients are treated and the more serious cases selected for admission to hospital. There are nine of these district dispensaries at distances from the hospital varying from two to fifty odd miles.

It should be pointed out that the medical and surgical service in the Fields area is free of charge for all employees either as "indoor" or "outdoor" patients, and that similar facilities are freely given to the non-employed local inhabitants, as well as to tribesmen who frequently travel long distances to avail themselves of these facilities. Dental treatment is also available for all cases. In this connection it is interesting to note that the local inhabitants and tribesmen have shown a growing confidence in, and an increasing willingness to take advantage of, the facilities offered. At first there was the usual suspicion and timidity in face of the unknown. It has needed tact, sympathy, patience and skill to achieve this result. The value to the Persians of this developing appreciation of modern medical surgical and "preventive" service is obvious, and has already had beneficial reactions reaching beyond the immediate Fields area.

The medical staff comprises a senior medical officer, two resident medical officers and a visiting medical officer. The services of specialists are also available, namely, a consulting surgeon, a pathologist and an ophthalmologist. There is a graded nursing staff of twenty-six under the charge of a European matron, assisted by eight European sisters.

The term "European" employed here and elsewhere in this record, it should be explained, has less reference to what the schoolboy understands by "Europe" than to the British Isles, not excluding the northern part of Britain.

The following figures, representing patients treated in Fields area during the nine months (April-December) of 1928—the period for which the last official medical report was compiled—will give some idea of the extent and variety of the work of the medical, surgical and sanitary staffs:

Hospital in-patients	1,386
Out-patients: (a) new cases	33,212
(b) other cases	64,916
Operations under general anæsthetic..	235
Operations under local or no anæsthetic	1,903
Pathological examinations	7,451
Dental cases	352
Radiograms	423

ABADAN AREA

The medical service in the Abadan area provides, as we saw was done in Fields, free medical and surgical treatment, either in hospital or as "out-door" patients, for all employees of the Company, for their families and dependants, and also for local residents and non-employees who are unable otherwise to secure the necessary medical attention. It co-operates with the local Persian Government Port Health Officials in maintaining the health of the Port of Abadan, by caring for and segregating cases of infectious disease and contacts, by a consistent onslaught on rats and by other practical sanitary measures. All these precautions are of extreme value, though they are rarely adequately appreciated, in the maintenance of the public health. The Port of Abadan is situated at Bawarda, two miles to the south of the refinery, on the Shatt al Arab, where all oil tankers and other merchant shipping are

PERSIAN WARD IN THE ABADAN HOSPITAL

docked, the crews medically inspected and any necessary treatment afforded.

The general hospital for in-patients at Abadan is situated near the refinery and has accommodation for 132 in-patients, out-patients' clinic, operating theatre, X-ray plant and ophthalmic and dental departments, as at Fields. The infectious diseases hospital here has accommodation for 120 cases and 160 contacts. Special accommodation for mental cases has been added and the cooling of the operating theatre and hospital wards is the most recent addition to the amenities which the Company provides for the treatment of sickness.

Dispensaries for the treatment of out-patients and for the selection of the more serious cases for admission to hospital have been established, each under the charge of a medical officer, at Mohammerah, ten miles distant from the general hospital; at Bawarda, two miles away from the hospital; and in the refinery. Another dispensary, in the European residential area, has also been established. It should be added that a medical officer makes visits to quarters when required.

The general observations made in the section dealing with Fields area, as to the growing appreciation of the medical and surgical services by the local Persian inhabitants, apply equally to the Abadan area; and the social benefits to Persia must be similarly diffused.

The Medical Staff and the Nursing Staff of the

Abadan area are fairly comparable, in number and grades, with those in Fields area, though we may note that there are also a medical officer of health and a port health officer. The specialist services of a consulting surgeon, pathologist, an ophthalmic surgeon and a dentist are also freely available.

Some idea of the work carried out by the medical department in the Abadan area is afforded by the figures for nine months in 1928:

Hospital in-patients	1,485
Out-patients (a) New cases	34,842
(b) Attendances	103,060
Operations under general anæsthetic	164
Operations under local or no anæsthetic	612
Pathological examinations	3,136
Dental cases	637
Radiograms	295

In addition, the medical needs of tankers and other vessels are provided for by the Abadan Staff at the rate of some fifty per week.

It may be mentioned that proposals for a new and larger general hospital at Mohammerah, in substitution of the present building at Abadan, are in an advanced stage. The plans have been very fully discussed and the whole scheme for this important replacement exhibits the foresight and comprehensiveness which is characteristic of so many of the Company's undertakings. When built this new hospital will embody all the approved features of modern tropical hospitals, will be equipped with the best of modern appliances in each department and, as the base hospital for non-urgent cases, will allow of the retention of the beds at Fields and Ahwaz for urgent cases.

* * * * *

What is, however, to our main purpose is not so much the scale and equipment of the buildings as the scope and spirit of the medical work proposed to be done. We have already drawn attention to the Hyperpyrexia Ward built at Fields. It is proposed to undertake at Abadan and elsewhere in Persia a comprehensive bacteriological and pathological study of tropical and sub-tropical diseases and also of industrial disease in relation to the particular conditions of the Persian oil industry. For the purpose of these researches the investigators will prepare their own vaccines, their own inoculations and devise their own tests. It is true that much specialised study has been made, for example, in England, of tropical disease and of industrial disease, but the view held by those directing the medical services of the Anglo-Persian Oil Company is that, just as the vital activities of human beings re-act to climatic conditions, so may the causative agents of tropical and industrial diseases be influenced, and possibly profoundly modified, by the local conditions, climatic and otherwise, to which they are subject. In order that such a systematic research may be undertaken in the locality in which these specific diseases are encountered, the new hospital at Mohammerah will provide ample facilities in the way of laboratory accommodation, equipment and the like. It is, of course, impossible to predict what will be the outcome of these investigations, but it is equally impossible not to admire the large and imaginative view that has resulted in this great project.

CHAPTER XIV

PUBLIC HEALTH

To the foregoing account of the medical services provided for individuals we must now add some record of the complementary services conveniently grouped under the heading of public health. To prevent misunderstanding, it should be stated here that what follows applies only to the areas of the Company's operations. Elsewhere the public health department of the Persian Government safeguards the health of the Persian communities, as, for example, at Abadan town and port, adjoining the refinery area.

There is thorough and systematic conservancy work, in order to keep within control the ubiquitous fly and other disease carriers. Anti-malarial work proceeds on scientific lines, and recent observations show that the reduction in mosquitoes is having a marked effect on the occurrence of malaria. The medical report for 1928 states that not only does malaria show a gratifying decrease in incidence, but that there is evidence that the type is less severe. A useful comparison of the figures for 1927 and those for 1928 (worked on a twelve months' basis) shows a decrease of 4,385 malaria cases amongst the hospital and dispensary out-patients, and of 2,177 cases treated in hospitals and quarters.

Anti-plague measures, such as house fumigation, rat trapping and baiting, are regularly carried out and during the nine months of 1928 no less than 34,573 rats were destroyed. It may excite the humorous interest of the reader to be told that this Oil Company has even an official rat catcher. Post-mortem examination is performed in every suspicious case and slides are examined microscopically for B. Pestis. None of these tests, during 1928, proved positive. Strict control is maintained over all cemeteries and no burials are allowed without the authority of the public health department. In this way the special infectious diseases as the cause of death among non-employees can be ascertained or ruled out.

Disinfection of clothing by steam and fumigation of houses by sulphur dioxide are the methods of procedure in all cases of infectious diseases. When smallpox is present to any extent, the clothing of native labourers working on the ships in port is disinfected before they are allowed to proceed on board.

All employees from the United Kingdom are vaccinated and inoculated against enteric group diseases before leaving home. Similar steps are taken with all employees from India on arrival at Mohammerah, the second dose of T.A.B. being given in the area to which

THE VEGETABLE BAZAAR BUILDING PROVIDED BY THE COMPANY AT MASJID-I-SULAIMAN they are posted. Approximately 10,000 vaccinations and inoculations were carried out in Persia during the latter nine months of 1928, in addition to those recorded in the statistical statement below.

The normal sanitary inspection is another feature of the public health work. It is noteworthy that at Abadan, and especially in the Refinery area, a whole series of dry latrines has been converted into a water-borne system. This has enabled a reduction of the sanitary staff to be effected and has done away with the objectionable method of night-soil removal. In this connection it is interesting to note that tact and persuasion were needed before the local labourers could be brought to overcome their natural and habitual prejudices in favour of the superseded system. The traveller in the East will understand the difficulties here. It is enough to say that the design and construction of the water-borne system has ingeniously met the peculiar difficulties, and the labourers, whether Persian or Indian, are now more than satisfied.

There is regular inspection of food and of water supplies and milk supply, with periodic collection of samples for analysis. Four soda water factories are kept under strict observation and control. To take a particular instance, the vegetable bazaar at Fields is inspected daily. It was the proud boast of one officer of the Company that Fields vegetable bazaar is "the cleanest bazaar east of Suez." Without in any way belittling the implications of that boast, the writer, who had seen the bazaars at Damascus and Baghdad, may add that he found the statement easily credible.

An idea of the extent of the varied services performed in a year by the public health departments of the Company may be gathered from the following statistics:—

Fields:

- 307 unauthorised buildings demolished as unsanitary.
- 700 rooms, buildings, etc., limewashed.
- 443 dead animals disposed of by incineration.
- 21,929 carcases of animals killed for food inspected and 3,083 parts condemned as unfit for human consumption.
- 2,481 lbs. of fruit and vegetables condemned and destroyed.
- 15½ tons of condemned provisions from stores incinerated.
- 1,748 vaccinations against smallpox with lymph supplied from the United Kingdom.

Abadan:

- 456 animal carcases, mostly recovered from the river fore-shore, incinerated.
- 3 tons of fruit, fish, meat and vegetables in the bazaars condemned and destroyed.
- 37 portions of animals slaughtered for food found unfit for consumption and incinerated.
- 1,269 vaccinations against smallpox.

Before concluding this survey of the public health services some reference should be made to the provision of a pure water supply and of a modern system of sanitation for Abadan. The river Shatt al Arab provides an abundant supply of water for steam-raising and other refinery purposes but the potable water for domestic supply is drawn from the less contaminated Bahmishir river on the east side of Abadan island. This water is settled in tanks, filtered and treated by a modern chlorination process, in order to purify it, with the result that the tap supply of domestic water in Abadan reaches Western standards and is equal to, if not better than, any other domestic water supply in the East.

As to the sanitation there were inherent difficulties to be overcome, for the level of the land is in many cases below that of the river Shatt al Arab, so that there is no natural fall for effluent. Moreover, because of circumstances that will be known to travellers in the Middle East, there is no "sweeper" class of labourers in Persia available for sanitary services in accordance with, for example, Indian practice. In the bungalow area at Abadan, therefore, the latest form of sanitation has been adapted to meet the peculiar conditions. Septic tanks are provided throughout the area and are periodically cleaned by means of mobile vacuum tanks mounted on motor lorries. The system is a completely closed system so that there is no contact anywhere with the atmosphere. The septicised effluent is collected in concrete wells, 20 feet deep, the level of the liquid in these wells being subject to automatic electrical control, and is pumped thence into the river Shatt al Arab.

The thorough and comprehensive character of the varied public health services that have been summarised will be obvious to the reader. Their primary purpose is, of course, to ensure the efficiency of the productive work of the Company by checking and preventing disease. But they must also have some effect in stimulating the development of similar services in other parts of Persia. If plague spots tend to spread, so do health spots.

GROUP OF STAFF BUNGALOWS AT CHASMEH-I-'ALI

CHAPTER XV

HOUSING

It has already been indicated that neither at Fields nor at Abadan was there any settled community worth mention before the Anglo-Persian Oil Company began its operations there. The large number and the varied types of the buildings now to be seen, for example, at Fields and at Abadan, have practically all been erected by the Company. Broadly speaking, there are three main types of domestic dwellings, designed to provide suitable accommodation for three broad divisions of the Company's employees. There are spacious bungalows (mostly, but not always, one-storied) for the higher staff; smaller bungalows for the clerks; and rows of stone, brick, or gach houses for the Persian labourers and artisans.

It may not be superfluous here to draw attention to two points. In England our domestic architecture is, or professes to be, bent on letting in the sun; in Persia one of the architect's chief concerns is to keep out the sun so as to prevent the dwellings from becoming in the heat of summer veritable ovens. All the bungalows, therefore, are surrounded by deep verandahs and are designed to secure shade rather than light. The other point is in the nature of a *caveat*. The term "bungalow" is apt to sound on English ears as a name for a temporary or diminutive dwelling—a little more than a hut, a little less than a house. It should be understood, then, that the bungalows for the European and higher Persian staff are spacious and solidly built structures of brick or stone, with lofty rooms, ample accommodation, and every modern convenience. Electric light, electric heating and electrically driven fans are installed throughout, and at Fields there is laid on to each bungalow an abundant supply of natural gas. The supply both of electric current and of gas is so abundant, indeed, that no attempt is made to check by meter individual consumption.

Many of the bungalows have gardens. The writer hesitates to whisper it, but here one of his pleasant preconceptions perished. None of the gardens he saw —admittedly at the worst period of the year—gave assured promise of surpassing a typical English garden or of justifying the raptures of Omar Khayyam. It is sad to say it, but it looks as though the beauty of a Persian garden—in Southern Persia, at least—were a literary fiction or a poet's license.

The preceding paragraph has been allowed to stand as it appeared in the first edition, for it is a wretched business to give up a joke, even the mildest. In truth, however, these gardens are now much improved.

Lawns are laid in front of most bungalows and, following the appointment of a Superintendent of Gardens, numbers of varied shrubs and trees have been introduced from Ceylon and India. Moreover, a nursery has been started from which shrubs and flowering plants are gradually going out to stock bungalow gardens, the beauty of which is now, as one authority says with gentle reproof, "a little more than mere 'literary fiction or poet's license'."

The smaller bungalows for the large number of clerks set also a high standard of comfort and are much superior in accommodation and convenience to similar housing provision in, for example, India. The rows of solidly built dwellings for the Persian and other labourers are immeasurably better, in every housing way, than the primitive shelters, with walls of sun-baked mud and flat roofs of mud or reeds or palm leaves, that are the normal type of dwellings to be seen in the adjacent villages. At Fields there is attached to each row of the labourers' houses a common cook house, supplied with natural gas, burning as perennially as the flares. At Abadan a constant supply of fuel oil at present takes the place of the natural gas. Reference has already been made to the sanitation.

On the eastern side of Abadan there is now a model village, rapidly growing in extent, with rows on rows of sanitary well built houses for the numerous Persian artisans and labourers; and a large space of ground has been cleared and a public park has been laid out, for the use of the village, and other, inhabitants.

It should be noted that, whereas at Fields there is abundant local building stone and gach available, at Abadan there is nothing but the alluvial desert, the nearest natural stone being some 130 miles away. One advantage Abadan has over Fields—the river Shatt al Arab, which facilitates the discharge of effluent and assists transport. But practically everything for constructional building at Abadan—earth, lime, sand, cement and bricks—has to be imported. The Company has set up its own brick works, at Kut 'Abdulla, on the river Karun, where rows of great kilns provide the fire-baked bricks needed for the Company's manifold building operations.

Complementary to the provision of dwelling houses was the question of bazaars. It has been indicated that the prospect of regular pay, in the first instance, attracted the nomadic tribesmen to service with the Company. The wages, of themselves, could do little, however, to keep the men in service unless opportunities were provided of purchasing with the wages those commodities and comforts not obtainable in the nomadic life. It was not enough to give money; ways of spending the money had also to be provided. At Masjid-i-Sulaiman therefore, the Company has erected model bazaars, at which the usual

SOME EXAMPLES OF THE HILL-SIDE DWELLINGS AT THE OIL FIELDS

TYPES OF HOUSES BUILT BY THE COMPANY FOR THE PERSIAN WORKMEN AND THEIR FAMILIES
AT MASJID-I-SULAIMAN OIL FIELDS

commodities—food, clothing, utensils, tobacco and ornaments—can be purchased. These bazaars are solidly built rows of shops with open fronts, of the general Persian type, and mark a great advance, in solidity and cleanliness, on the ramshackle, makeshift bazaar buildings frequently to be met with in the East.

Before leaving the subject of housing we may be permitted one reflection. The housing accommodation provided for the Persian labourers is, as has been said, immeasurably better than that to which, before the Anglo-Persian Oil Company came, they were accustomed. It is safe to say that nowhere in Khuzistan, outside the area of the Company's activities, is the dwelling accommodation for the labouring class at all comparable with that provided by the Company. Is it fanciful to think that the example thus set, of a higher housing standard, will inevitably filter outwards and spread a civilising influence beyond the confines of the Company's specific activities?

To the writer, at least, there seemed to be evidence of some such process of diffusion. The journey by launch from Basra to Abadan, a run of some forty miles down the Shatt al Arab, is on a broad river lined on both banks by continuous—or all but continuous—groves of date palms, which stretch inwards for half a mile or more. Among small clearings in these apparently endless groves one sees numerous villages, the dwellings (if such a word be not too dignified for such primitive shelters) being made of mud walls with flat roofs of plaited reeds or matted leaves, and all without doors or even openings for windows. But as the traveller comes off the island of Abadan it is impossible for him, if he be observant, not to be struck by an abrupt change in the character of the villages he sees. The dwellings are larger, they have sloping roofs of straw or reeds, suggestive of the thatched cottage of the English country side, and, what is more significant, they are furnished with doors and windows, though the windows may be unglazed. What is the explanation of this abrupt development if it be not due, in part at least, to some influence spreading outwards from a centre of civilisation in which there has been a marked development of the housing standard? When the traveller arrives eventually at Abadan and sees there the replica of an English port and notes the housing accommodation provided by the Company for its Persian workers he can hardly fail to infer that here is the probable explanation. This impression, which the writer got spontaneously as he reached Abadan for the first time, was confirmed by all the information he acquired afterwards and it strikes the keynote of the social effects in Persia attributable to the enterprise of the Anglo-Persian Oil Company.

CHAPTER XVI

EDUCATION

I. WORKSHOP TRAINING

We have seen that unskilled labour was needed for road-making; for handling and transporting, by mule and ass, the machinery and the varied materials used in constructional work; and for assistance in the elementary operations of rig building and drilling. Beyond that, in order to supplement the European engineers sent out, a demand arose for local inhabitants with some engineering skill, as fitters, machinists, turners and moulders, for example. Some of these more skilled Persians came from Isfahan; others had picked up in other parts of Persia elementary engineering knowledge and skill. They were trained to the more specialised operations of the Company by European engineers.

It is, however, with the training of the young boys, many of them simple nomads, that we are mainly concerned here. The Company has at Masjid-i-Sulaiman, at Ahwaz and at Abadan huge engineering workshops, which, in the multiplicity, variety and magnitude of the work they turn out, are comparable with the works of many a fairly large engineering firm at home. At each of these workshops young Persian boys are being trained, under the supervision of European engineers, in the varied operations of an engineering shop.

The Company has, however, made an attempt at training these young Persians more systematically than by merely putting them under individual supervision in the general workshop. At Fields, at Ahwaz and at Abadan definite Manual Training Centres or Workshop Training Schools—whichever term be preferred—have been established, under the direction of European engineer instructors. At Fields there were about fifty boys under such manual training and at Abadan an approximately similar number. The boys in these workshop Training Schools are trained either as fitters or machinists, and the usual run of elementary operations is followed, namely, chipping, filing, screwing, tapping, turning, etc. It was amusing at Abadan, by the way, to see three Persian boys turned loose on to an old Ford engine, with full leave to pull it to pieces, just to see how it came to be fitted together. No English boy taking his watch to bits could have been more absorbed.

The zest and interest these amenable young Persians take in their work is, however, not more significant than the obvious interest taken in them by their

PERSIAN APPRENTICE SCHOOL AT MASJID-I-SULAIMAN

European instructors. Indeed the writer is fain to confess that, among the many things that impressed him on his visit, to which tribute has been or will be paid in this record, nothing seemed to him more "finely touched to fine issues" than what is being done in these workshop schools at Fields, at Ahwaz and at Abadan. The Company is doing many bigger things but it is doubtful whether it is doing anything of better import than this.

It was soon found that, to make the manual training effective, the boys, who are wholly illiterate, must be taught to read and write. A beginning has been made with such teaching and some small success has already been obtained. All the boys can read the foot-rule, fractions, whole numbers and mixed numbers from English type. Some of them have learnt also to read and write Persian in a moderate way: others are still in the difficulties of word-building. It is proposed to extend this more purely educational work to include arithmetic and general knowledge and, perhaps, also hygiene and games.

To recruit these boys and to keep them when recruited are not matters of mere plain sailing. The recruitment is seasonal, the best period being between the first rains (in December or January) and March. One of the difficulties arose from the influx of bigger boys more suitable for employment as labourers than as learners in the workshop training school.

"They belonged," says one who knows, "to the drifting class who come to the doors of the shop as the sparrows to the doors of houses when the cold weather forces them." From April to June there is apt to be an exodus of nomad types, especially among these bigger boys to whom the wandering life in summer still appeals; and most of the discharges effected at the boys' request take place at this period. This wastage of partly trained human material is not a light matter. To take one illustration: in three years some 390 boys worked periods in the manual training school at Fields and then, at their own convenience, left to follow some "call of the wild" or other lure. The Company is giving anxious thought to the best means of retaining the suitable boys among those enlisted so as to turn them out as more or less skilled craftsmen fit for absorption by the engineering shops. It is obviously to the economic interest of the Company to stop this waste; it is, not less obviously, an economic asset to Persia that the number of indigenous, skilled craftsmen in that country should be increased.

There can be no doubt that the coupling of the simple literary and arithmetical teaching with the manual training will have a steadying effect on the boys enrolled. But the Company has wider and more far-reaching schemes, already initiated or under consideration, for the consolidation and improvement of this training of the young. A system of indentured apprenticeship in co-operation with the local government authorities is being considered, that may involve the housing, feeding and clothing by the Company of the apprentices. Moreover, the Company has already taken steps to extend the more purely educational facilities it provides. Two new elementary schools have been built at Fields and were opened in October, 1927. They will provide, in a less haphazard way, for entry into the manual training centres, boys who are less unstable and who have had some elementary education. These schools are, however, only parts of a much greater educational system established and fostered by the Company, and to this we must now turn our attention.

II. SCHOOLS

It was pointed out that the purely manual workshop training is hampered by the illiteracy of the boys and that, to make the workshop training more effective, steps have been taken to supplement the instruction by teaching the boys to read and write their native language.

There is, however, a further need for a more ambitious scheme of education than that covered by the instruction given in the manual training centres. It is the desire and the policy of the Anglo-Persian Oil

Company to increase progressively the number of skilled Persians employed, whether as engineers, craftsmen or clerks, or in other skilled occupations. For such work there has been hitherto an inadequate supply of sufficiently educated Persians, having a competent, working knowledge of the English language. It is obviously desirable that, in a great industrial enterprise carried on in Persia, as much native skilled labour should be employed as is possible and practicable.

In order, therefore, to render the manual training more effective, and to assist the policy of "Persianising" the personnel, the Company has embarked on a wide and comprehensive scheme of general education, with the approval of, and in co-ordination with, the Persian Government. At Masjid-i-Sulaiman, as we have seen, two elementary schools have been opened. At Ahwaz the Company maintains entirely at its own cost a primary school and a secondary school. There is also an elementary school similarly maintained at Abadan. The writer was privileged to visit both the primary school and the secondary school at Ahwaz, and to see the normal instruction being carried out. As far as the elementary instruction is concerned, it may be taken as typical of that also given at Abadan and at Fields.

The primary or elementary school at Ahwaz had, in 1928, about 162 boys whose ages vary from 9 to

THE COMPANY'S PRIMARY SCHOOL AT AHWAZ

16 years. They are all Persians, drawn from various classes. Entry into the school and the education given are free to all suitable boys, whether they be sons of the Company's employees or not. At Masjid-i-Sulaiman the schools are open to all applicants whose parents are resident in Fields, though preference is given to sons of employees, and a number of places is reserved for the Company's apprentices. To return to the Ahwaz primary school, it should be added that the pupils are also provided with school uniform, including boots and puttees. The medium of instruction is, of course, Persian, and English is also taught. The school is under the charge of the Persian head master, assisted by a staff of six assistant masters, and the whole curriculum conforms to the scheme of the Persian Minister of Education. There is also a physical training instructor, and the school has a fife and drum band, constituted entirely of the boys.

The writer saw the whole school go through their physical exercises, under the direction of the physical training instructor. The smartness, the vim and the discipline shown would have been creditable in an English O.T.C. The exercises, it may be mentioned by the way, are compounded of Russian and German methods of physical training, and are characterised by great rapidity in execution. The instruction in the class rooms covers the usual primary subjects, including the three R's; and many of the boys had made considerable progress in the reading of English. Their pronunciation was more than fair. Indeed, in this respect, they were less afflicted by "vowel complaint" than are the pupils of many a London school.

The secondary school at Ahwaz had been opened only recently in a building acquired by the Company and adapted to educational purposes. There were, in December, 1926, sixteen boys in the school under the charge of a head master, with two assistant masters as his colleagues—a ratio of masters to pupils which must excite the envy of many an English schoolmaster. The number of pupils in the school has since been increased by the passage of suitable boys from the primary school and in 1929 numbered 35-40. The curriculum has been accordingly developed along the normal lines of secondary education. In the initial stage there was necessarily some duplication of the work done in the primary school.

The sanitary arrangements and the equipment of both the primary and the secondary school are good. There is a daily medical inspection and a keen watch is kept on the health of the pupils. In particular, it may be mentioned that there has been a marked improvement in "eye health"—an important benefit in a country where eye troubles are a common infliction, especially among the young.

In addition to maintaining the schools that have been described the Company contributes to the support of others. Moreover, Evening Continuation Classes, giving instruction in such subjects as English, Accountancy, Typewriting, etc., have been started at Fields, Ahwaz and Abadan, and have met with an enthusiastic response. In the realm of higher education, it should be added, six Persian students are now attending courses at Birmingham University, all the expenses involved being borne by the Company. Lastly, while assisting its Persian employees to acquire a knowledge of English the Company encourages its European employees to obtain a good knowledge of the Persian language, and classes have been formed for this purpose.

It must be obvious that, in the character and scope of the educational work just summarised, this Oil Company is performing functions comparable with, though less in extent than, those carried out by, say, a County or Borough Education Authority in England. How far the Company realises the value and importance of this work will be understood when it is added that an English educationist, of distinguished academic qualifications and educational experience, has been appointed and sent to Persia by the Company to direct, co-ordinate and develop these educational activities, in sympathetic co-ordination with the Persian Minister of Education.

To the reader all this educational work must seem, at first impression, a far cry from the business of getting and refining crude oil. And yet the writer has failed in his purpose if he has not already made it clear that it has arisen as a natural—one might almost say, inevitable—outcome of the wide and far-seeing policy already noticed as directing the Company's diversified operations.

WORKSHOP AT FIELDS

CHAPTER XVII

WORKSHOPS AND WORKERS

I. WORKSHOPS AND STORES

FROM a consideration of education and training we are led naturally to say a little of the workshops and stores of the Company and of the measures adopted to give to the workers a conscious and recognised status in the industrial scheme.

It has already been mentioned that at Fields, at Ahwaz and at Abadan the Company has large engineering workshops. It would be wearisome, to author and reader alike, to enter upon a detailed description of each of these workshops, but some of the prominent features of the workshop at Fields may now be given, and be taken, as typical of those also at Ahwaz and Abadan.

Fields workshops are situated at Chashmeh-i-'Ali (the Spring of Ali) which is pretty nearly the geographical centre of the Masjid-i-Sulaiman area. When the Company first came here, by the way, there was nothing but the spring; the rest was wilderness. Fields workshops constitute great general repair shops and are under the charge of a European engineer, assisted by a staff of thirty Europeans, controlling some 420 mixed artisans, of whom some 300 odd are Persians. These workmen include fitters, turners, moulders, blacksmiths, carpenters, armature winders, general repairing electricians, boiler makers, welders (both electric and acetylene) and instrument makers. Among them are seventy-nine Indian engineers, to some of whom young Persians are attached as quasi-apprentices. To mention one instance that may interest the engineering reader, the writer saw a Persian boy, working skilfully at a No. 4 Herbert automatic lathe, whose sole occupation, but two years previously, had been that of a nomad driving the cattle to and from the hills and the desert.

There is a complete installation of the latest modern machinery, from the small instrument maker's bench lathe, weighing 2 lbs., to the huge 45 feet screw-cutting and surfacing lathe, with 14 inch centres. There are also universal milling, spiral gear cutting, automatic machines, operated by native Persians who have been trained by the Company. The operations in these workshops range from the repair of a delicate scientific instrument to the reconstruction of a steam tractor.

As showing the extent to which the Persians are being utilised in these skilled engineering and kindred operations the following table, giving the statistics for December 1926, for various shops at Fields, may be of interest:

	Total No. of Operatives	Persians
Millwright shop	12	9
Boiler shop	57	39
Carpentry and joinery shop	29	26
Fitting and erecting shop	50	31
Electric repair shops	24	24
General ,,	47	47
Machine ,,	57	31
Foundry ,,	24	16
Blacksmith ,,	100	100

It may also interest the reader, as it interested the writer, to be told that the different races show marked characteristic aptitudes for particular branches of the engineering trade—for example, the Persian Arabs excel in pattern making, while the Bakhtiari, Kurds and Lurs are excellent blacksmiths.

Besides the workshops there are also great stores departments distributed at various centres. There are—neglecting sub-stores—three main stores, at Fields, Ahwaz and Abadan respectively. It will be understood that not only the varied materials for the engineering and building operations—the pipes, rails, girders, tractors, engines, well rigs, and the thousand-and-one other articles—but also, to meet the needs of the great number of Europeans employed, vast quantities of food, provisions, furniture, crockery and other domestic utensils have to be imported into the country.

The extensive stores at Fields, Ahwaz and Abadan have been constructed and laid out on modern scientific principles, and are equipped with up-to-date loading and transporting devices, in order to ensure the efficient storage and distribution of these varied products. For example, the stores department at Fields is equipped with a 10 ton electric crane and the railway from Dar-i-Khazineh to Fields runs into the stores yard, bringing approximately three hundred tons of material per month. The provision department distributes no less than £6,000 worth of stores per month. Attached to the stores is an ice factory, with modern refrigerating machinery, which manufactures 3½ tons of ice per day in the summer, and is capable of a daily output of 8 tons. Ample cold storage is provided and there is also a soda water factory turning out, on the average, 700 bottles of soda water per day. A staff of six Europeans, fifty clerks and 120 Persian labourers is needed to work Fields stores alone. The stores at Ahwaz and Abadan perform similar functions on a comparable scale.

It is their boast at stores, as it was Mr. Whiteley's boast, that they can supply anything. The writer accepted a challenge to put it to the test at Ahwaz. It is ungracious to tell the sequel but this is, in part, a

DRILLING STORES AT MASJID-I-SULAIMAN

historical record. The writer asked for a back collar stud, to replace one that had done faithful duty for fifteen years and then broke when he was as far from home as Persia. Alas! the stores failed. It is but fair to add that within an hour the Company provided him with a proper stud, but the source of its supply is still wrapped in mystery. It did not come from stores. The writer has an uneasy suspicion that he is still regarded at Ahwaz as one who did not play fair in asking for such an article.

II. GRADING OF THE WORKERS

We have seen that general education and manual training have been organised, and are to be extended and developed, in order to increase the supply of Persians suitable for employment in the various skilled occupations provided by the Company. There was, however, disclosed a need for further organisation when the workers have been educated and trained. It should be realised that there are no trade unions in Persia ready to receive the workman out of his apprenticeship and to give formal recognition to his status and skill. We may leave aside, as beyond our purpose, all questions of the regulation, by collective bargaining or otherwise, of wages and hours of labour. There still remains, for the skilled worker, the need of a formal appraisement and recognition of the skill he has acquired. The English mechanic who has served his apprenticeship, to take a western example, is "hall marked" as a skilled artisan and his status as such is generally recognised. The Anglo-Persian Oil Company realised that it was not enough to train their Persian employees in the workshops or at the drilling rigs or elsewhere. It was necessary to make the skilled worker conscious of his status and to give him an interest and pride in maintaining and improving it.

A system of grading the workers according to their skill was, therefore, devised and has been in operation for some time. For each grade of workers there are prescribed and definite tests. When the worker has acquired the requisite competence in any one grade and has passed the prescribed tests he is given a corresponding certificate. He can secure promotion to a higher grade only by passing the requisite tests for that grade. These certificates not only testify to the degree of skill reached by the worker but also give him a recognised status, carrying with it a corresponding standard rate of pay. Moreover, a worker retains his certificate and, if he should leave the Company's employment for a time, to taste nomad delights or for other reasons, and then seek re-engagement, he is recognised as eligible for re-employment in his certified grade.

According to the testimony received by the writer, the Persian workers appreciate highly the value of this system of grading and guard it jealously. It is claimed that it fosters their self-respect, it gives them pride in their work and it provides them with incentives for improvement. It is an attempt to do for these initially unorganised, Persian workers something of what the craft guilds did for English workmen from the middle ages down to recent times. The future development of this pregnant scheme will be a matter of great interest and moment. To the writer, and probably also to the reader, its most significant feature is the recognition, implicit in the scheme, that the self-respect of the worker and his pride in his work are of vital concern to the efficiency of any industrial system.

CHAPTER XVIII

SOCIAL AMENITIES

Something should now be said of what is done for the social comfort and even the delight of the employees of the Company. For obvious reasons the need for some provision of this sort is greatest for the European employees, who are far removed from their homes and from the society, games and relaxations to which they may be presumed to have been accustomed. Altogether there are about 1,000 Europeans employed by the Company in Persia. There are communities of about 350 at Fields, 500 at Abadan and seventy at Ahwaz; and smaller groups, widely dispersed, in varying degrees of loneliness, at the pumping stations, the rail-river head, the distant test areas and other outposts. The reader may be reminded that they who are here conveniently termed "European" are mainly British. Of the provision made for their health and housing something has already been said. It is with their gregarious needs that we are now concerned.

In the first place ample provision is made for games—cricket, football, hockey, tennis, squash rac-

A FOOTBALL MATCH ON THE MAIDAN AT MASJID-I-SULAIMAN quets and golf. At Fields, for example, they run a football league and an annual international (England v. Scotland) football match; and they have no less than thirty-nine tennis courts, in the construction of which much ingenuity, not unmixed with science, has been shown. Grass courts are out of the question there; in the summer the grass is scorched up and in the winter it is too scant. The foundations of the tennis courts are made of "Kah-gil," a mixture of straw and mud, frequently used locally for the roofs of dwellings. Over this is a surface of sea shells which, when rolled, provides a durable court that plays fast and requires only systematic rolling to keep it in good condition.

Similar facilities for golf, football, cricket, tennis and squash racquets are provided at Abadan and also, for some of these games, at Ahwaz. Polo is played in Fields, Ahwaz and Mohammerah, the last named embracing Abadan. Most, if not all, of the outlying stations have at least tennis courts. There is even a race course at Fields and the gymkhana clubs holds three or four race meetings a year. The writer attended one meeting held during his visit. It was run entirely by volunteers and was as well organised and furnished, down to the totalisator and the stray dog on the course, as a typical race meeting in England. There is now also a race-course with totalisator at Abadan, and meetings are held twice a year. A boating club has been formed in Abadan and a barge, moored in the Shatt al Arab, has been equipped as a club-house, on which dinners and dances are periodically arranged. Regattas and motor-boat races are held at intervals. Swimming baths have been built in Fields and are in course of construction in Abadan.

At Abadan, Ahwaz and Fields there are clubs; spacious, well-built, and provided with such conveniences as lounge, billard room, card room, reading room and usually, too, dance hall, fitted with stage and dressing rooms for theatrical performances. At Fields, for example, there are eight clubs to meet the social needs of both Europeans and others. At Abadan a central restaurant has been established on the lines adopted by big business houses at home. A manager and a French chef cater for something like 350 employees. Three meals a day are provided, which has proved a great boon to the junior staff. In addition, a private dining-room, accommodating twenty persons, affords members of the staff opportunities of giving dinner parties to their friends. The Anglo-Persian Oil Company, it should be said, provides the buildings, furniture, lighting and heating, and even the periodicals for these clubs, free of charge; for the rest the clubs must be, and are, self-supporting. Each club—and this applies equally to the sports clubs and to the gymkhana club—is run by its own committee. Tennis is free, but the other sports, such as golf, cricket or football, stand on their own financial feet.

A great central hall for Fields area has been built by the Company at Chasmeh-i-'Ali, and was formally opened at Christmas, 1926. It is available for the dances, concerts, theatrical and other entertainments that are organised from time to time by the various clubs in Fields area. In design, construction, accommodation and equipment, the building may well challenge comparison with elaborate halls for similar purposes in London.

Nor have the more serious intellectual interests been overlooked. A lending library has been organised for the service of subscribing readers at Fields, Ahwaz and Abadan; and there are occasional lectures delivered by visitors and others on selected subjects. An attempt is made even to satisfy the modern craving for the daily paper; and a cyclostyled sheet or more of foolscap circulates daily the eclectic budget of news picked up by the wireless station at Abadan from the bulletin broadcast each day from Rugby in England.

The extent and the variety of all these social activities have led to the creation of a special social department, having its own office and its own full-time organiser, who acts also as a combined secretary and liaison officer for many of the club and society doings.

Lest the reader should think that this cursory record of the lighter side of things is beside our main purpose, it should be pointed out that these varied facilities for games, social intercourse and amusement are not merely the bountiful largesse of a munificent corporation. They are essential to the comfort, happiness and *esprit de corps* of the exiled Europeans more especially, on whom the main responsibility for the efficient working of the Company's multifarious operations depends. They help materially to ward off that "staleness" to which every limited community of Europeans, more or less isolated in a foreign country, is liable.

It might seem on first thoughts that there need be no staleness in such a community as, for example, that at Fields, where there are nearly 350 Europeans including some forty ladies. Such a circle may seem big enough to many a Londoner whose acquaintances are few; but, however small a social circle in London may be, each member of it makes fresh contacts every day with wider circles, so that there is a constant social irrigation with fresh ideas, new topics and novel interests. The social circle at Fields, on the other hand, may be larger but it touches no wider circle outside it; the intellectual and social exchanges are confined for the most part to the same members; there is not the same opportunity for cross-fertilisation of ideas and topics. In such circumstances it is easy to see how a feeling of staleness may come to pervade the community and to take some of the zest out of life.

The games, the clubs, the concerts, the dances and other entertainments are valuable specifics against the growth of staleness and social ennui, quite apart from their effect on physical health. From this point of view, therefore, they too may be regarded as properly belonging to a study of the scientific treatment of the human material in industry. They are, no less than the means adopted to minister to health and to provide good housing, direct aids to industrial efficiency.

Before this chapter is closed, however, brief reference should be made to spiritual needs. In Persia Islam not only is held jealously and tenaciously, but permeates and pervades the whole life of the people. To see, as the writer saw, a Persian labourer, in the midst of his work on the pipe line in the desert, step aside and, facing towards Mecca, go through his prayers, devoutly undisturbed by the presence of others, is to get a vivid light on this aspect of Persian life. In all that the Company does, therefore, it is anxious and careful to respect the religious susceptibilities of its Persian employees. At the same time it is significant that the Board of Directors of a great oil company recognizes that its European employees in a distant country do not live by bread alone. Accordingly a chaplain has recently been engaged by the Company and sent to Persia, in order that the spiritual and private needs of the staff may receive sympathetic, personal attention.

CHAPTER XIX

SOME ECONOMIC FACTORS

BEFORE bringing this study in scientific and industrial development to a conclusion, an attempt should be made to summarise briefly some of the conspicuous economic and social benefits that have accrued to Persia through the operations conducted in that country, by the Anglo-Persian Oil Company.

The economic and social advantages ensuing from the provision made, and described in the preceding pages, for the health, housing, education and training of the Persians need no elaboration. It is enough to say that to improve the health, to increase the industrial efficiency and to raise the standard of comfort of a large section of the working population of any country are, perhaps, the most valuable and permanent forms in which contributions can be made to the real wealth of the country.

But there are other economic benefits to Persia, directly attributable to the work of the Company, such as, for example: improved transport facilities by road making and other means; the direct revenue paid to the Persian Government by way of royalties,

ON THE GREAT ROAD FROM GANAWAH TO MISHUN, SHOWING THE TYPE OF COUNTRY THROUGH WHICH THE ROAD HAD TO BE BUILT as well as contributions to local authorities for appropriate services; the creation of increased spending power by the distribution of a large wages fund; and the stimulation of production and the increase in volume and variety of the imports into Persia in order to meet enlarged demands for commodities. All these benefits are the tangible and intangible results of the work of the Anglo-Persian Oil Company in exporting from Persia the crude oil found beneath the surface and the refined products obtained from it. We may glance only cursorily at these factors.

No one who has visited the Middle East and seen the ceaseless caravans of asses, mules or camels, carrying their heavy loads over the desert or through the defiles of the hills, along rough tracks made only by the feet of countless, similar caravans through the ages, can fail to realise what an economic boon is a solid, unquestionable road. The Company has constructed in Persia no less than 1,600 miles of roads. Many, perhaps most, of the Company's roads are among the twisted, crumpled foothills to which reference has been made and the construction of properly graded roads on such a terrain has called for great engineering skill and an enormous use of labour. The roads had to be made fit to bear heavy traffic and this has necessarily involved the building of numerous bridges. The road from Fields to Dar-i-Khazineh, for example, some thirty-six miles long, passes for the greater part of this distance through the Tembi valley, which is for long lengths a deep gorge; and the road has been blasted out of the steep sides of the gorge and crosses the river by several bridges. The Company employs, directly or through contract, some 4,000 Persians who are engaged constantly in making or maintaining roads.

Besides the road from Dar-i-Khazineh to Fields, a railway of 2½ feet gauge was constructed by the Company and opened in 1923. It follows also the Tembi valley and crosses the river by numerous bridges. Along this railway from 3,000 to 4,000 tons of material per month are transported, and the distribution of materials from the rail-river head, by road and railway combined, amounts to no less than 7,000 tons per month. Passengers are carried along the railway by means of a "Drewry" car—a sort of open-sided, single-deck, tram car, driven by a petrol motor built into the chassis.

It is true that the main function of these roads is to serve the transport needs of the Anglo-Persian Oil Company, and that, apart from the employees of the Company, there is no considerable local population, settled near the roads, to which they can be of great use. But they are generally available to all and are used to some extent by Persian non-employees. In any case, they constitute a valuable addition to the material assets of the country, both actually and potentially.

THE DAR-I-KHAZINEH—FIELDS RAILWAY. BRIDGE OVER THE TEMBI RIVER

Not only so, but by their very existence they provide an object lesson and an incentive to other areas, which may lead in time to improved road making and transport facilities in other parts of Persia.

The organisation and the control of the varied traffic along these roads is no light undertaking. For example, the total Fields transport fleet, including lorries and cars, is 467 vehicles; and for the whole of the transport operations in Fields area, taking into account the cars and lorries entering from other areas, approximately, 1,000 vehicles are used. There are similar transport fleets at Ahwaz and Abadan. It is worth notice that the motor lorries are equipped with a special device, called a "Controllograph," whereby there is automatically recorded, on a circular paper dial, the time taken, the speed, the rest periods and the distance covered for each journey of the lorry. The value of such a record for checking waste, loitering, furious driving and misuse is obvious.

The drivers of the cars and motor lorries are mainly Persians, including Arab and Armenian subjects of Persia, and most of them have been trained to their work by the Company. At Ahwaz, which is roughly the half-way house between Fields and Abadan, there is a great motor repair and overhaul shop where the cars and lorries are periodically "vetted" and put into working trim.

Incidentally it may be mentioned that in the busy area of Fields itself and also at Abadan the road traffic is controlled by Atashkaries, after the manner of the City police near the Mansion House in London. These Atashkaries, it should be explained, are Persian firemen, members of the Company's efficient fire brigade, and are trained under a European chief officer who was formerly chief of the fire brigade of an English borough. They wear a khaki uniform, with "shorts," and have a passion for saluting with the smartness of a British guardsman. There is even, in the centre of Maidan-i-Naftun, that most modern development, one-way traffic—maybe along the line of the very mule track that Alexander the Great traversed on his invasion of India. Such is the progress of the centuries.

In connection with transport, mention should also be made of the fleet of shallow-draught, stern-wheel paddle steamers that ply on the Karun river between Abadan and Dar-i-Khazineh and are the main means of transporting the heavy materials imported at Abadan and needed at Fields. It was explained that at Ahwaz, on the river Karun, some 114 miles by river from Abadan, there is a series of rapids. The Company has, therefore, to maintain two fleets of these boats, one to work the lower reach of the Karun river from Abadan to Ahwaz, the other to work the upper reach from above Ahwaz to Dar-i-Khazineh. The navigation of these steamers, which are oilfired and draw only from three to five feet of water, needs care, for the Karun river winds and twists unceasingly through the desert, is subject to great fluctuations of flow, and is beset with mud banks in its course. In times of flood the river frequently overflows its banks into the desert around for miles, and it shifts its course from time to time so that landing stages constructed at chosen points may be rendered useless.

Lastly, to complete this outline of transport facilities, bare reference should be made to the fleet of tankers that come to Abadan to take the crude oil to the Company's refineries at Llandarcy, South Wales, and Grangemouth, Scotland, and refined products to various distributing centres all over the world. The tanker fleet now consists of eighty-six ships (seventy-eight in commission and eight building) of 782,000 dead weight tonnage, which combine all the modern improvements of this type of ship. To enable the largest of these tankers to be fully loaded at Bawarda, the new channel has been dredged, at the Company's expense, through the Bar of the Shatt al Arab on the head of the Persian Gulf.

It may be convenient to interpolate here a brief description of what the Company has done in the way of developing means for the rapid and reliable communication of information between its scattered operating units. With vessels entering and leaving

Abadan at the rate of ten per day, with exploratory tests being conducted in remote parts of Persia, and with the long pipe lines connecting the producing fields with the refinery, it will be obvious to the reader that reliable and speedy means of conveying information is a vital necessity. The Company has, therefore, developed an extensive system of telephones, telegraphy and wireless stations. There are two main wireless stations, one at Masjid-i-Sulaiman and the other at Abadan, supplemented by five wireless installations, of shorter range, at other locations. These smaller stations are in touch with the one or the other of the two main stations and thus a message from any one can reach (by being relayed, if necessary) any other station. There are no less than 375 pole miles of the telephone and telegraph system in constant use, the number of miles of telephone and telegraph wire needed to complete the service being at least six times the pole mileage.

In the case of the pipe lines, for example, that carry continuously, day and night, the crude oil from the wells to the refinery, communication by telephone and telegraph must be maintained between these centres and the pumping stations, for a break in the pipe line or an accident in a pumping station might involve a serious loss of oil, unless instructions could be issued immediately to cease pumping and to effect the necessary repairs. Messages are passing continuously over the telephone and telegraph lines, recording pressures, tank depths, temperatures and a hundred and one technical details, all of the utmost importance to the engineers responsible for the throughput. No patient in a hospital has such attention given to every throb and pulse beat as has this vital line. Without telephone and telegraph systems maintained in a high state of efficiency, the main pipe-line would be really more difficult to operate than would a railway at home without its telephonic and telegraphic signalling systems.

Again, in the course of testing the oil resources of the country, wells are sunk in far distant and almost inaccessible districts, with which continuous communication must be secured. The configuration, and at times the unsettled conditions, of the region between headquarters and these outlying test areas is such that land telegraph lines could be maintained only at prohibitive cost. The Company has taken full advantage of recent developments in radio science and has installed a system of wireless telephones and telegraphs which enables the prospectors in these test areas to communicate their needs to, and to receive instructions from, the principal wireless stations at the oil fields or at Abadan.

Similarly the long distance wireless station at Abadan—the greatest oil port of the East—enables the tankers at sea to communicate their due date at

Abadan; berthing and loading instructions to be passed to the vessels while yet many miles away; and the pilots at the entrance of the Shatt al Arab to be warned in time. Thus, on reaching Abadan, the vessel comes without fuss or delay alongside her appointed wharf, where the shore staff are in readiness to connect the loading lines and hasten the vessel's despatch to distant shores with her cargo of 10,000 tons of oil.

The telephonic, telegraphic and wireless installations are just as essential elements of the Company's equipment as are the pipe-lines, the pumps, the roads and the railway. They constitute, in a very real sense, the nervous system of this great industrial organism, by means of which the most distant parts are brought into instant and intimate touch with headquarters in Persia, and without which it would be impossible to co-ordinate to proper functioning the varied and scattered operations of the Company.

The direct contribution to the revenue of the Persian Government, paid in royalties from 1913 to 31st December, 1928, amounted to just over eight million pounds sterling, the payments for the twenty-one months ended 31st December, 1929, being estimated at about one and three-quarters of a million pounds. Since the total national revenue in 1926-27 amounted to a little more than 6½ million pounds, it is obvious that such substantial payments must relieve the tax-payer in Persia of a considerable part of his tax burden.

In wages and local purchases the Anglo-Persian Oil Company pays out in cash in Persia some 2½ million pounds sterling annually. The economic benefits of such a large wage distribution among the population cannot be confined to the wage receivers; the increased purchasing power spreads prosperity to the traders in the bazaars; it contributes its share to the general purchasing power of the nation as a whole; and it does something to stimulate production and to increase imports in order to meet the enlarged demands so created.

It may be of interest to note here that in order to guard against great fluctuations in the cost of living among the Persian workers, more especially fluctuations caused by wheat shortage, the Anglo-Persian Oil Company holds large reserves of wheat which can be unloaded on to the market when the price of that commodity rises so much as to be a real additional burden to the workers. In this way not only can immediate distress be met but prices and wages are steadied, to the mutual advantage of employer and employed.

It is worthy of remark that the present enlightened Shah of Persia has visited a great part of the area of the Company's active operations in Persia and that, in December, 1926, a number of Cabinet Ministers of the

Persian Government made a similar visit. There is good reason to believe that the Shah and his government are alive to the economic and social benefits accruing to Persia and the Persians from this great industrial enterprise and that, in particular, they welcome the policy of the Company in seeking to increase the co-operation of Persian subjects in the varied operations of the Company.

In this connection it may be mentioned that it is the custom of the Company to issue in Persian the annual general report of the Company as well as Persian translations of other selected publications. In this way an intellectual interest is created and maintained among educated Persians in the progress and development of an industry of vital economic significance to their country. Nor does this intellectual entente, if it may be so called, end here. At home lectures are delivered from time to time before appropriate societies, and articles contributed to magazines and institutional journals, by officials of the Company, and notably by Sir John Cadman and Sir Arnold T. Wilson, on subjects relating to Persia, with the object of familiarising English audiences and readers with Persian achievements, ideas and aspirations. Apart from the inherent interest of lectures and articles of this sort, their psychological effect, there is reason to think, is not negligible.

Much more might be said, of course, were more space available, on the economic results of the activities in Persia of the Anglo-Persian Oil Company. Enough has been said, perhaps, to make it not altogether a wild hope to entertain, that the record here given may help to dispel the notion, sometimes held and expressed at home, that the work of any great industrial undertaking can be dismissed airily under the contemptuous term of exploitation.

CHAPTER XX

CONCLUSION

In the foregoing pages an attempt has been made to show broadly, without too much technical detail, the extent to which the Anglo-Persian Oil Company has applied, and is applying, scientific knowledge, research and methods to its activities, more especially in Persia. There are some outstanding features of this aspect of its work to which attention should now be directed.

In the first place it will have been recognised that the distinction often drawn between pure science and applied science has no practical significance in the determination of the Company's operations. To elucidate the scientific principles involved, to gain the scientific knowledge needed, and to apply the knowledge, in so far as it can be applied, to industrial practice, these aims are regarded as constituting essentially one problem and one purpose.

In the second place, science is not confined, as too often in industry it is, to a strictly limited technical area, nor is it regarded merely as the Hercules standing by to get the industrial waggon out of the rut. There are no limits set to the field in which science, or at least some of the methods of science, may be applied; and the scientist is adopted into the industrial family as a working member of the household, on equal footing with the other members, such as the business man, the financier or the administrator. It follows that the problems presenting themselves successively for solution are seen steadily and seen whole—to borrow Matthew Arnold's phrase—from a standpoint that includes the view of the man with the pick and also the view of the man with the test tube. The merging of these two outlooks and the co-operation of the corresponding personalities provide an example well worth study of how science can be well—perhaps best—assimilated into the industrial organism. It is of more than passing interest to note that this unreserved acceptance of the roles of science and the scientist in industrial development culminated in the appointment to the Chairmanship of this great corporation, by the unanimous vote of his fellow Directors, of Sir John Cadman, whose previous experience combined that of a distinguished university professor with that of a mines manager familiar with the face of the coal seam.

Another notable feature that can hardly have escaped the reader's attention is the comprehensive character of many of the researches undertaken—for example, on the methods of oil finding; the study of pressures and levels; the problem of the gas; the correlation of investigations into engines and engine performances with those into the oil to be used in the engines; and the investigation of tropical and industrial diseases. It may possibly be argued, at first blush, that a company having the large financial resources of the Anglo-Persian Oil Company can well afford to take such a comprehensive view of research needs. Whatever truth there may be in such a contention, the argument fails to take into account how much these large financial resources are due to the general adoption of such a wide and far-seeing policy.

Such are some of the broader considerations that arise on a general survey of the more strictly scientific side of the Company's work. It is, however, impossible fitly to conclude this essay without a wider glance at what in effect the Company has done in Persia.

Before the Company came to Persia the area around Masjid-i-Sulaiman was little else than a wilderness of crumpled hills, the loneliness of which was disturbed only by the wandering nomads or by the prowling hyænas and jackals. There were no roads. There were only mule tracks which the nomadic tribes with their flocks and herds traversed twice a year on their way to the growing grass. A few rude habitations provided shelter for the relatively few Persians that tilled the soil to be found here and there in favourable valleys and, having reaped their meagre crops, then moved on.

To-day, among these same treeless hills, over an area of about 200 square miles, there is a settled industrial population of some 30,000 souls, provided with all, or nearly all, the conveniences and amenities of western civilisation—good roads with motor transport; a light railway; electric light and power supply; pure water supply; natural gas; excellent housing accommodation, from the spacious bungalows for the higher British staff to the rows of solid houses for the Persian labourers; substantially built and sanitary bazaars, including bakery and baths; a more than well equipped hospital; modern sanitation; skilled medical and surgical service; telegraph and telephone services; wireless station; fire brigade; schools and workshop training centres; clubs and a central hall for concerts and other entertainments; playing fields, tennis and racquets courts, golf links and—even—racecourses.

Dotted here and there in Fields are the derricks which mark the spots whence is drawn from below that dark liquor, the crude oil, which is the very life blood and sustenance of this elaborate civilisation and also of the similar and larger community, a hundred and fifty miles away, at Abadan. Round about on the gaunt hills are the ever burning, mighty flares, pillars of cloud by day and gigantic torches by night, that witness to the enormous store of energy beneath this part of the earth's crust and themselves provide fresh problems of the conservation and use of this energy, problems which call for further sustained, scientifically directed, human effort.

A not less remarkable transformation has been effected at Abadan and Bawarda, on the island of Abadan, at the head of the Persian Gulf. Before the Anglo-Persian Oil Company began to construct its refinery here, the land was a waste patch of mud desert, breaking the continuity of the palm groves that line both sides of the Shatt al Arab from above Basra to near the bar of the Persian Gulf.

To-day there is a community of some 50,000 souls at Abadan, which has, excepting the railway, practically everything—and more—to be found at Fields and, when the writer was there in December, 1926, an expert botanist was studying the problem of the most suitable trees, shrubs and plants to be selected for the adornment of a public park already under construction. Abadan and Bawarda, moreover, form a great shipping port—"the Swansea of the East"—with loading jetties, thrust out into the deep water of the Shatt al Arab, to which and from which come and go the great tankers of a mighty fleet, as well as the shallow-draught, river craft that ply on the home waters.

To watch the current of life flow and reflow, day by day, through these varied channels, and to reflect that but a few short years ago there was nothing at Fields but a hilly wilderness and at Abadan only a bare desert, is to realise what a great thing has been done for Persia, for Britain and for civilisation in this area of the Middle East. It is inspiring to remember that all these results have come from British enterprise, industrial organisation and, not least of all, from the steady, persistent application, continuously directed from the head, of scientific knowledge and methods to the whole business of getting and refining a black liquid from the bowels of the earth.

The writer is not disposed to qualify the exalted view expressed to him that what the Anglo-Persian Oil Company has done in Persia is one of the finest achievements associated with the British name. It is a great game finely played, and the spectator must be dull who is not thrilled by it and apathetic if he does not feel, while watching the game, some longing to be a participator in it.

Corporations, it is said, have no souls. One might as well say that schools have no tone or that the spirit of a university is a meaningless phrase. It would be truer and better to say that every corporation has a soul, cramped or spacious, mean or generous, short-sighted or far-sighted, darkened or enlightened. The decisive test, as John Morley pointed out years ago in reference to nations, is the height and amplitude of the issues engaged and whether they are pursued intrepidly or "with creeping foot and blinking eye." The reader must judge how far the Anglo-Persian Oil Company comes to meet this exacting test.