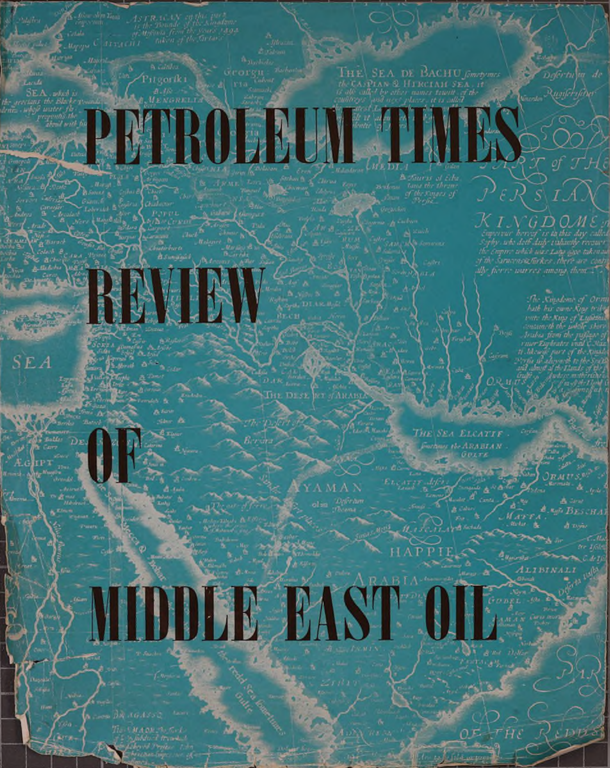
PETROLEUM TIMES

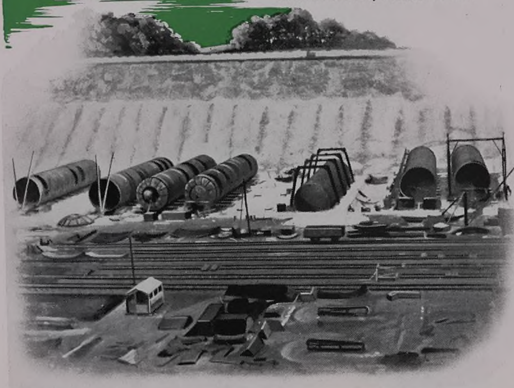
REVIEW

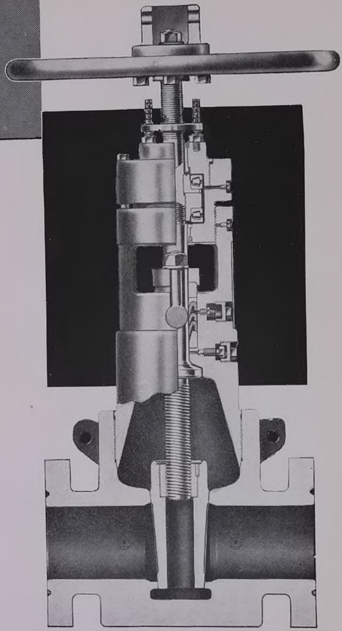
OF

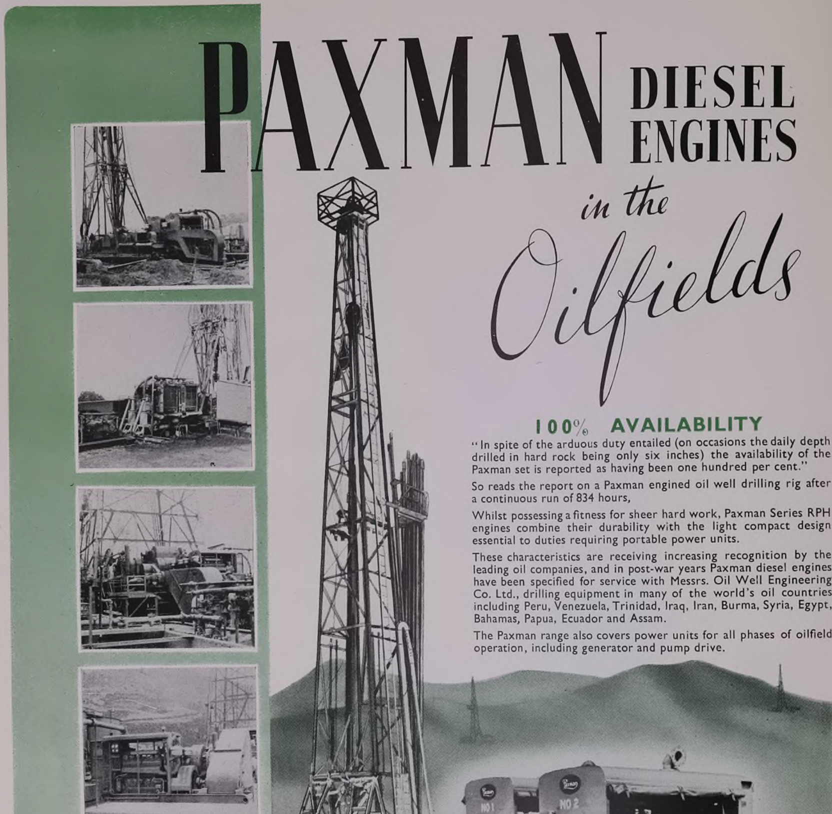
MIDDLE EAST OIL




THE
WORLD'S BEST
FRICTION
LININGS
FERODO
FERODO






PAXMAN DIESEL ENGINES
in the Oilfields
100% AVAILABILITY
"In spite of the arduous duty entailed (on occasions the daily depth drilled in hard rock being only six inches) the availability of the Paxman set is reported as having been one hundred per cent."
So reads the report on a Paxman engined oil well drilling rig after a continuous run of 834 hours,
Whilst possessing a fitness for sheer hard work, Paxman Series RPH engines combine their durability with the light compact design essential to duties requiring portable power units.
These characteristics are receiving increasing recognition by the leading oil companies, and in post-war years Paxman diesel engines have been specified for service with Messrs. Oil Well Engineering Co. Ltd., drilling equipment in many of the world's oil countries including Peru, Venezuela, Trinidad, Iraq, Iran, Burma, Syria, Egypt, Bahamas, Papua, Ecuador and Assam.
The Paxman range also covers power units for all phases of oilfield operation, including generator and pump drive.
NO 1
NO 2
DAVEY, PAXMAN & CO. LTD., COLCHESTER
(ASSOCIATED WITH RUSTON & HORNSBY LTD., LINCOLN)

T.D.

CROFTS *Airflex* CLUTCHES

MADE UNDER FAWICK PATENTS.

FOR OIL DRILLING RIGS, DRAW WORKS, ETC.

Crofts Clutches have the Reliability that gives confidence to the operator under all conditions, and function all the time whatever the load. Upkeep and Maintenance are low. No Lubrication, No Adjustment, No breakage. These Clutches absorb Shock and Vibrations and protect both Driving and Driven Elements. The Confidence given to all Crofts Clutch users is based on the wide experience of the makers in Design, Manufacture and Application and the knowledge that every Clutch is guaranteed.

Designs are Standardised to meet all conditions and for all Powers and Speeds.

We illustrate below Airflex Clutches applied to Model 100 Draw Works and invite inquiries for Clutches for Oil Drilling Rigs, Draw Works, and other Oilfield equipment.

Literature on request.

IMPORTANT.

Airflex Clutches cost less to maintain than other types.

Do not require adjustment.

Need No Lubrication.

Have no arms, levers, pins, etc., to wear or cause trouble.

Act as combined Clutch and Flexible Coupling.

HOW AIRFLEX CLUTCHES OPERATE

Illustration left shows Compressed Air Admitted to Airflex Gland Engaging Clutch.
Illustration right shows Air Released. Note large clearance between Rim and Slippers.

WRITE FOR FOLDERS 4619 & 4621

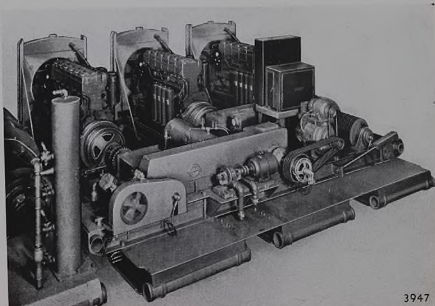


Illustration shows three engines driving oil well Drilling machinery. Each engine is connected to the driven shaft through Airflex Clutches. The illustration also shows Airflex Clutch drive to generator.

CROFTS (ENGINEERS) LTD BRADFORD ENGLAND

Telephone, 65251 - 10 Lines *Telegrams, Crofters, Bradford.*

for drives where maximum strength is essential

These chains have gearing dimensions in conformity with American Standards Association Specification B29a-1930 and are therefore suitable for running on wheels designed for American Standard Chains. They are specially suitable for applications involving extra heavy duty, and are supplied in simple, duplex and triplex forms in a range of pitches from 1·0″ to 2·5″ with riveted or detachable links as required.

Transmission and Conveying Chains, Wheels and Accessories for all mechanical purposes

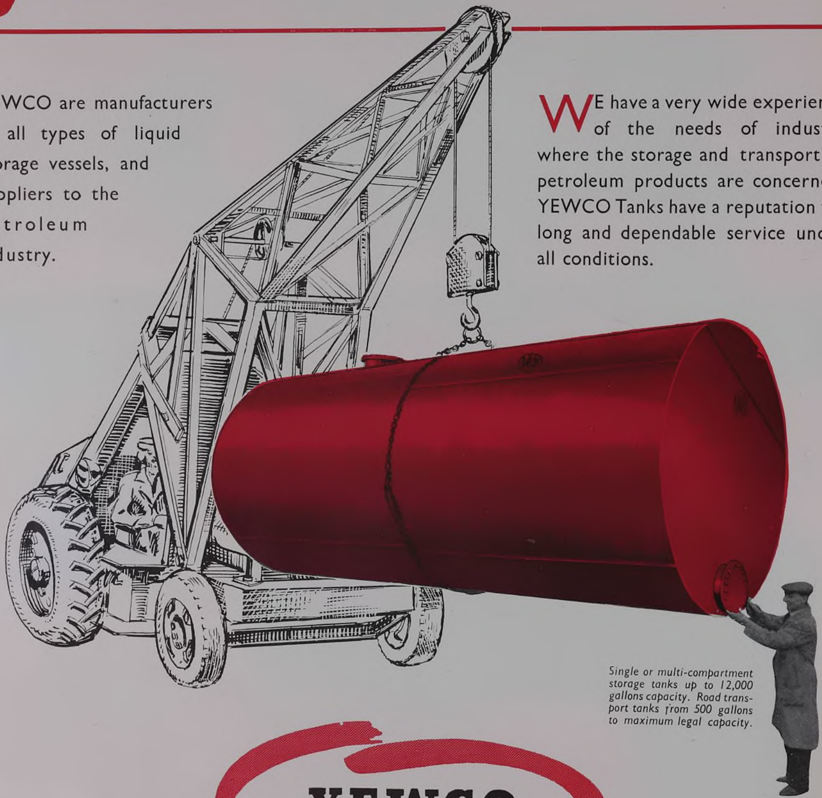
R & C C

THE RENOLD AND COVENTRY CHAIN COMPANY LIMITED · MANCHESTER · ENGLAND

Petroleum TRANSPORTATION AND STORAGE

YEWCO are manufacturers of all types of liquid storage vessels, and suppliers to the Petroleum Industry.

WE have a very wide experience of the needs of industry where the storage and transport of petroleum products are concerned. YEWCO Tanks have a reputation for long and dependable service under all conditions.



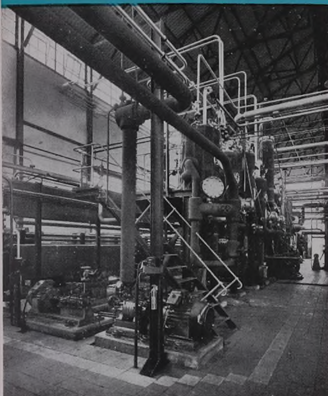
Single or multi-compartment storage tanks up to 12,000 gallons capacity. Road transport tanks from 500 gallons to maximum legal capacity.

YEWCO

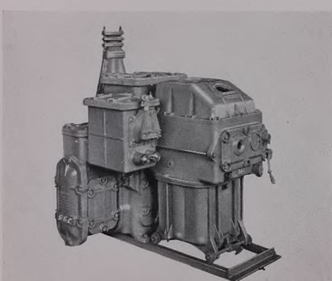
YORKSHIRE ENGINEERING AND WELDING CO (BRADFORD) LTD.
Friar's Works, Bradford Road, Idle, Bradford
***Tel.:* Idle 470-1-2 *Grams:* YEWCO, Bradford**
***Managing Director:* Fred Wood**

QUALITAS NULLI SECUNDUS SERVITAS

G.E.C. ELECTRICAL EQUIPMENT FOR THE PETROLEUM INDUSTRY



G.E.C. Flameproof Squirrel Cage Motors in the treatment section of the refinery of Lobitos Oilfields Ltd., Ellesmere Port, Cheshire.



G.E.C. 3,300 volt Flameproof Oil-circuit Breaker.

The vast experience of the G.E.C., the largest British electrical manufacturing organization in the Empire, in the production of electrical equipment of every kind enables the Company to undertake contracts of the most comprehensive nature for the oil industry.
Some idea of the extensive range of equipment which is produced is afforded by the following brief summary.

GENERATION AND DISTRIBUTION

Turbo-alternators, engine-driven generating plant, transformers, steel-clad air-cooled rectifiers, as well as indoor and outdoor switchgear.

INDUSTRIAL EQUIPMENT FOR WORKSHOPS, Etc.

All types of A.C. and D.C. motors and control gear, cranes and hoists, as well as electronic control apparatus, electric lighting equipment, lifts, ventilation fans, canteen equipment, public address equipment, materials handling plant, etc.

FLAMEPROOF EQUIPMENT BUXTON FLP CERTIFIED

The range includes oil-immersed switchgear, reversing contactors with their master controllers, gate-end panels with the associated plugs, sockets, trailing cable couplers, etc., direct-to-line starters, ironclad switchgear and push buttons for remote control of machines, as well as squirrel cage and slipring motors for outputs from 1 h.p. to 500 h.p., lighting fittings, conduit fittings, signalling equipment, ironclad switchboards, switches with fuses, immersion heaters, etc. All this equipment is covered by Buxton Certificates for Group 2 conditions.

G.E.C. 30 in. A.C. 3-phase Flameproof Propeller Fan.

OILFIELD AND PIPELINE COMMUNICATIONS

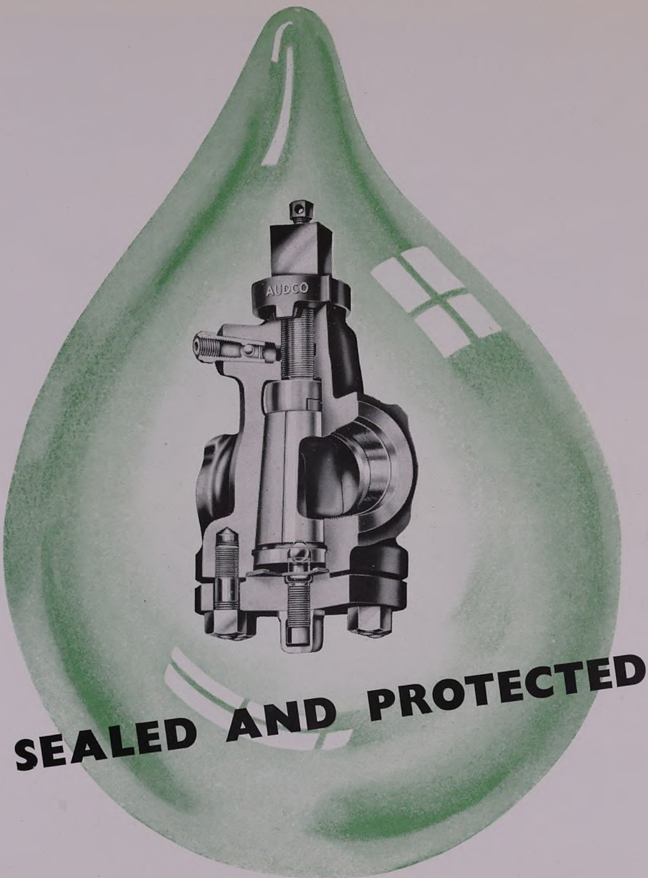
V.H.F. beamed transmitting and receiving stations, high, medium and low transmitting and receiving stations, unattended automatic radio repeater stations, telephone exchanges, mobile H.F. transmitting and receiving stations and "walkie-talkie" equipment. Similar equipment to this is on order for the Anglo-Iranian Oil Co. Ltd.

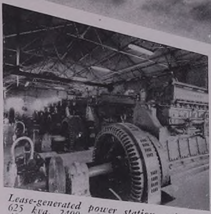
THE GENERAL ELECTRIC CO., LTD., Magnet House, Kingsway, LONDON

OVERSEAS BRANCHES

ARGENTINA: Buenos Aires. AUSTRALIA: Sydney, Adelaide, Brisbane, Melbourne, Newcastle, Perth, Hobart and Launceston. BURMA: Rangoon. CANADA: Fraser & Chalmers of Canada Ltd., Montreal. CHINA: Shanghai, Hong Kong, Tientsin. INDIA & PAKISTAN: Calcutta, Bangalore, Bombay, Cawnpore, Coimbatore, Karachi, Lahore, Madras, New Delhi, Secunderabad. MALAYA: Singapore, Kuala Lumpur, Penang. NEW ZEALAND: Wellington, Auckland, Christchurch, Dunedin. RHODESIA: Salisbury, Bulawayo. SOUTH AFRICA: Johannesburg, Capetown, Durban, Port Elizabeth.

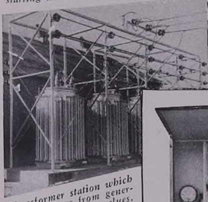
AGENCIES: In Oil-producing areas, and elsewhere throughout the world.


AUDCO



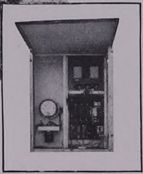
Lease-generated power station, with six 625 kva, 2400-volt, 3-phase, 60 cycle, 400 rpm generators.

Splashproof, weatherproof motor, with high starting torque to assure positive starting under all weather conditions.



Transformer station which raises voltage from generated to distribution values.

Dynagraph



Weatherproof oil well pumping control.

DECADES of close collaboration with the petroleum industry, together with vast manufacturing facilities and unrivalled research and field organizations, enable Westinghouse to supply a complete line of proved electrical and motive equipment for drilling, pumping, transportation, refining and marketing of oil products.

Here, for example, are illustrated a few of the apparatus specifically designed for more efficient pumping, and for lower operating and maintenance cost. The pumping equipment offered by Westinghouse includes complete substations for utility power, generator sets of every size and type for lease-generated power, transformers, distribution apparatus, pumping motors and gearmotor drives, protective and control apparatus for both generating equipment and drives, Dynagraphs for measuring well loads mechanically, and a full range of electrical instruments.

It will be a pleasure to furnish you with full details of Westinghouse equipment for every phase of the petroleum industry. Please consult the Westinghouse distributor in your locality, or write to Department OL-25, Westinghouse Electric International Company, 40 Wall Street, New York 5, U.S.A.

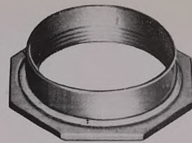
WESTINGHOUSE

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

First in Quality and Service

All 3 parts protect your reputation



Your reputation depends upon the quality of your product at time of delivery. You can ensure delivery of the exact amount and quality you ship, when you use Tri-Sure Closures.

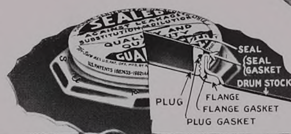
The Tri-Sure flange, plug and seal make shipments completely hazard-proof. They provide safety from seepage, contamination, breathing-in, pilferage and substitution.

Any drum manufacturer can supply you with drums equipped with Tri-Sure Closures. Just specify Tri-Sure Closures to your supplier and he will deliver drums equipped with flanges and plugs. You apply the seal.

1 *Tri-Sure FLANGE is integral with the drum stock. No force can push flange into drum. Octagonal shape prevents turning.*

2 *Tri-Sure PLUG cannot jar loose because threads moulded in die-cast alloy assure perfect engagement with flange.*

3 *Tri-Sure SEAL, tightly crimped around closure, protects contents from seepage, breathing-in or dust. No undetected tampering is possible because seal fits so tightly.*



When you see the letters, TRI-SURE, around a closure, you know that Tri-Sure flange, plug and seal give that drum—and product—a safe trip anywhere.

Tri-Sure Reg. U. S. Pat. Off.

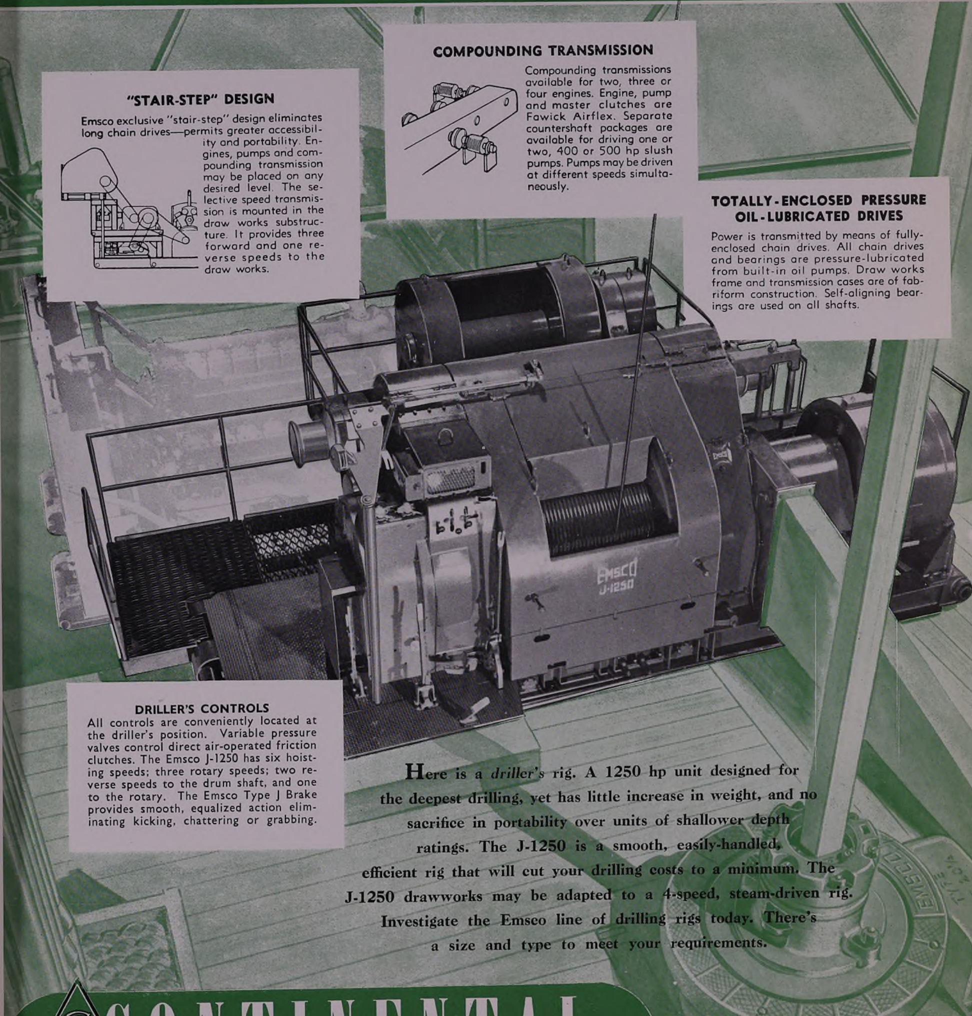
CLOSURES

AMERICAN FLANGE & MANUFACTURING CO. INC.,
30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

TRI-SURE PRODUCTS LIMITED, ST. CATHARINES, ONTARIO, CANADA

The Built-in Features of an

EMSCO J-1250 DRILLING RIG



COMPOUNDING TRANSMISSION

Compounding transmissions available for two, three or four engines. Engine, pump and master clutches are Fawick Airflex. Separate countershaft packages are available for driving one or two, 400 or 500 hp slush pumps. Pumps may be driven at different speeds simultaneously.

"STAIR-STEP" DESIGN

Emsco exclusive "stair-step" design eliminates long chain drives—permits greater accessibility and portability. Engines, pumps and compounding transmission may be placed on any desired level. The selective speed transmission is mounted in the draw works substructure. It provides three forward and one reverse speeds to the draw works.

TOTALLY-ENCLOSED PRESSURE OIL-LUBRICATED DRIVES

Power is transmitted by means of fully-enclosed chain drives. All chain drives and bearings are pressure-lubricated from built-in oil pumps. Draw works frame and transmission cases are of fabriform construction. Self-aligning bearings are used on all shafts.

DRILLER'S CONTROLS

All controls are conveniently located at the driller's position. Variable pressure valves control direct air-operated friction clutches. The Emsco J-1250 has six hoisting speeds; three rotary speeds; two reverse speeds to the drum shaft, and one to the rotary. The Emsco Type J Brake provides smooth, equalized action eliminating kicking, chattering or grabbing.

Here is a *driller's* rig. A 1250 hp unit designed for the deepest drilling, yet has little increase in weight, and no sacrifice in portability over units of shallower depth ratings. The J-1250 is a smooth, easily-handled, efficient rig that will cut your drilling costs to a minimum. The J-1250 drawworks may be adapted to a 4-speed, steam-driven rig. Investigate the Emsco line of drilling rigs today. There's a size and type to meet your requirements.

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PETROLEUM TIMES

Review of Middle East Oil

A COMPREHENSIVE ILLUSTRATED REVIEW OF ALL ASPECTS OF CURRENT DEVELOPMENTS BASED ON A RECENT EXTENDED TOUR BY DR. C. T. BARBER, JOINT EDITOR OF "*PETROLEUM TIMES*," WITH SPECIAL CONTRIBUTIONS FROM OUTSTANDING AUTHORITIES

CONTENTS

So far as practicable an historical sequence has been preserved in the arrangement of the sections of this Review dealing with oil operations in the various Middle East countries.

EXPORT NUMBER — PRICE 7s. 6d. ($1.50) BY POST 8s. 0d. — JUNE 1948

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SUBSIDIARY OF PETROLEUM CONCESSIONS LTD.
OWNERSHIP SAME AS IRAQ PETROLEUM COMPANY

(11) MOSUL PETROLEUM CO. LTD.
CONCESSION :
TERM—75 YEARS FROM JULY 3, 1933.
AREA—ALL OF IRAQ WEST OF TIGRIS RIVER AND NORTH OF 33° LATITUDE APPROXIMATELY 40,000 SQ. MILES
EXPIRES 2008
OWNERSHIP :
SAME AS IRAQ PETROLEUM CO.

(12) IRAQ PETROLEUM CO.
CONCESSION :
TERM—75 YEARS FROM MARCH 14, 1925.
AREA—PROVINCES OF BAGHDAD AND MOSUL, EAST OF TIGRIS RIVER.
EXPIRES 2000
OWNERSHIP :

	Per cent.
" SHELL " GROUP	23.75
ANGLO-IRANIAN OIL CO., LTD.	23.75
C. I. E. FRANCAISE DES PETROLES	23.75
STANDARD OIL CO. (NEW JERSEY)	11.875
SOCONY-VACUUM OIL CO., INC.	11.875
PRIVATE INTEREST (C. S. GULBENKIAN)	5
	100.0

(13) BASRAH PETROLEUM CO., LTD.
CONCESSION :
TERM—75 YEARS FROM DEC. 4, 1938.
AREA—ALL OF IRAQ NOT COVERED BY I. P. C. & M.P.C. CONCESSIONS
EXPIRES 2013
OWNERSHIP :
SAME AS IRAQ PETROLEUM CO.

(14) SINCLAIR PETROLEUM COMPANY
AREA—ALL OF ETHIOPIA

(15) PROPOSED CONCESSION TO SOVIET-IRANIAN OIL CO.
NEGOTIATED APRIL, 1946
REJECTED BY IRANIAN PARLIAMENT OCTOBER, 1947

(16) ANGLO-IRANIAN OIL CO., LTD.
CONCESSION :
TERM—60 YEARS FROM DEC. 31, 1933
AREA—100,000 SQ. MILES
OWNERSHIP :

	Per cent.
BRITISH GOVERNMENT	55.9
BURMAH OIL CO.	26.3
OTHERS (INDIVIDUALS)	17.8
	100.0

(17) KUWAIT OIL CO., LTD.
CONCESSION :
TERM—75 YEARS FROM DEC. 23, 1934.
AREA—ALL OF KUWAIT
EXPIRES 2011
OWNERSHIP :

	Per cent.
ANGLO-IRANIAN OIL CO., LTD.	50
GULF EXPLORATION CO.	50
	100

(18) BAHREIN PETROLEUM CO., LTD.
CONCESSION :
TERM—55 YEARS FROM JUNE 19, 1940.
AREA—ALL OF BAHREIN ISLANDS AND TERRITORIAL WATERS.
OWNERSHIP :

	Per cent.
STANDARD OIL CO. OF CALIFORNIA	50
THE TEXAS COMPANY	50
	100

(19) ARABIAN AMERICAN OIL CO.
CONCESSION :
TERM—ORIGINAL AREA—66 YEARS JULY 15, 1933.
ADDITIONAL AREA—66 YEARS JULY 21, 1939.
AREA—APPROXIMATELY 440,000 SQ. MILES
EXPIRES 1999
OWNERSHIP :
(BASED ON PENDING NEGOTIATIONS)

	Per cent.
STANDARD OIL CO. OF CALIFORNIA	30
THE TEXAS COMPANY	30
STANDARD OIL CO. (NEW JERSEY)	30
SOCONY-VACUUM OIL CO., INC.	10
	100

(20) KHANAQIN OIL CO., LTD.
OWNERSHIP : ANGLO-IRANIAN OIL CO., LTD.


MIDDLE EAST
OIL CONCESSIONS
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Refineries
Pipelines
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PIRSAGAT
NEFTE CHALA
SALIANI
KHAN KISHLAK
CHELEKEN
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(15) PROPOSED CONCESSION TO SOVIET-IRANIAN OIL CO.
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PALKANA
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NAFT-I-SHAH
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(16) ANGLO IRANIAN OIL CO. LTD.
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DAMMAM
BAHREIN
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HOFUF
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DUKHAN
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(7) PETROLEUM DEVELOPMENT (TRUCIAL COAST) LTD.
TRUCIAL OMAN
OMAN
TRANS-ARABIAN PIPELINE CO. HAS CONCESSION FOR CONSTRUCTION & OPERATION OF PIPELINES & ANCILLARY FACILITIES IN SAUDI ARABIA, LEBANON, SYRIA, TRANS-JORDAN AND PALESTINE
CONCESSION ON SAUDI ARABIA'S UNDIVIDED ½ INTEREST IN NEUTRAL ZONE GRANTED TO ARABIAN AMERICAN OIL CO. FOR 66 YRS. FROM JULY 21, 1939
EGYPT
RIYADH
ARAMCO PREFERENTIAL RIGHTS
(19) ARABIAN AMERICAN OIL COMPANY
SAUDI ARABIA
RED SEA
(9) PETROLEUM DEVELOPMENT, LTD.
(6) PETROLEUM DEVELOPMENT, LTD. (OMAN & DHOFAR)
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ADEN
ETHIOPIA
(14) SINCLAIR PETROLEUM COMPANY

The Future of Middle East Oil

"*The centre of gravity of world oil production is shifting from the Gulf-Caribbean area to the Middle East and is likely to continue to shift until it is firmly established in that area.*"

THE PRINCIPAL BASIS for that now famous statement by Dr. Everette de Golyer, leader of the 1944 United States Petroleum Commission to the Middle East, was the spectacular increase in the proved reserves of that area between January, 1936, and December, 1940. In this five-year period, at a cost of less than 100 exploratory wells, Middle East reserves were increased five-fold. The new reserves discovered in that area, estimated at 22,175 million barrels, were equal to the total known world reserves at the beginning of the period.

At the end of 1940, exploration in the Middle East was suspended until the end of the war and there were no further discoveries in that area by the time Dr. de Golyer made his 1944 estimates. Exploration however, had continued in the United States, where between 1936 and 1944 10,925 million barrels of new reserves were proved at a cost of over 40,000 exploratory wells, and 8,355 million barrels in the remainder of the world.

Thus the discoveries of Dammam in Saudi Arabia (1936); Agha Jahri in Iran (1937); Burgan in Kuwait (1938); Abu Hadriya and Abqaiq in Saudi Arabia (1940); and Dukhan in the Qatar Peninsula (1940) completely altered the distribution of world proved reserves. The comparison between 1936 and 1944 is as follows :—

WORLD PROVED OIL RESERVES

	1944 Million barrels	1944 Per cent of world total	1936 Million barrels	1936 Per cent. of world total
Middle East—				
Iran	6,500	..	2,150	..
Saudi Arabia	5,000	..	..	..
Iraq	5,000	..	2,475	..
Kuwait	9,000	..	..	..
Bahrein	300	..	..	..
Qatar	1,000	..	..	..
Total	26,800	42.3	4,625	21.1
United States	21,500	33.9	10,575	48.1
Caribbean*	6,340	10.0	2,136	9.7
U.S.S.R.	5,735	9.0	2,830	12.9
Other	3,045	4.8	1,799	8.2
World total	63,420	100.0	21,965	100.0

* Including Mexico.

Since Dr. de Golyer's estimates of Middle East reserves were made in 1944 the Qatif (1945) and Buqqa (1947) fields have been discovered in Saudi Arabia and the Iraq Petroleum Company group has renewed its exploration programme in Syria, and initiated vigorous exploration programmes in the Lebanon and Palestine and in the Basrah region of Iraq. While the geological conditions in Syria, the Lebanon, and Palestine do not suggest that the oil prospects of these countries are commensurate with those of the Persian Gulf oil province, it will be surprising if continued exploration in Iran, Iraq, and Saudi Arabia does not result in further major discoveries.

Production from the newly discovered fields in Saudi Arabia, Kuwait and Qatar, and plans for increased production from Iraq and Iran were delayed by the war when shortages of materials, equipment and manpower, and above all, strategic considerations, caused the virtual suspension of development work. This tendency was reversed with the United Nations' victory in Europe and vigorous plans were initiated with the object of making increasing quantities of Iranian, Kuwait and Saudi Arabian oil available for the prosecution of the war in the Pacific. Happily this also terminated before these plans came to full fruition, but they are now reflected in increased availability of Middle East crude in a world in which demand bids fair to outstrip other sources of supply. Since 1944, Middle East production has in fact been slightly more than doubled and its percentage contribution to world supply has risen from 5.6 per cent. in 1944 to 9.8 per cent. in 1947.

The world comparison of crude oil production for 1936, 1938, 1944 and 1947 is as follows :—

WORLD OIL PRODUCTION

	1947	1944	1938	1936
	In million barrels			
Middle East—				
Iran	155	102	78	63
Saudi Arabia	92	8	..	..
Iraq	34	30	32	30
Kuwait	16	..	..	..
Bahrein	9	7	8	5
Total	306	147	118	98
Per cent. of world total	*9.8*	*5.6*	*5.9*	*5.4*
United States	1,985	1,685	1,227	1,099
Per cent. of world total	*63.6*	*63.8*	*61.7*	*60.7*
Caribbean*	538	339	263	239
Per cent. of world total	*17.3*	*12.8*	*13.2*	*13.2*
U.S.S.R.	172	275	215	216
Per cent. of world total	*5.5*	*10.4*	*10.8*	*11.9*
Other	117	195	167	159
Per cent. of world total	*3.8*	*7.4*	*8.4*	*8.8*
World total	3,118	2,641	1,990	1,811

* Including Mexico.

The comparison of world production and reserves shows that with 42 per cent. of world reserves, the Middle East is producing 10 per cent. of world production and in 1947 was drawing on its proved reserves at the rate of 1.14 per cent. per annum; the U.S.A. with 33.9 per cent. of world reserves, is producing 64 per cent. of world production and drawing on her proved reserves at the rate of 9.25 per cent. per annum; and the Caribbean, with 10 per cent. of world reserves, is producing 17 per cent. of world production and drawing on its reserves at a rate of 8.5 per cent. per annum.

There is another equally strong contrast between the Middle East and Western Hemisphere production: in 1947 the Middle East production of 306 million barrels was obtained from 223 wells, an average of 1.37 million barrels per well (for Iran the average was 2.15 million); American production of 1,985 million barrels was obtained from over 425,000 wells, an average of 4,660 barrels per well; and 538 million barrels of Caribbean oil from some 9,000 wells, an average of 59,000 barrels per well.

The magnitude of Middle East reserves and the great size and amplitude of the individual fields are natural advantages which are not repeated to the same degree in any other oil province in the world. The great productivity per well is compounded of the natural reservoir conditions and of a production technique which owes as much to the technical acumen and achievements of Middle East oil pioneers as to the absence of competitive drilling. Combined, the natural advantages of great reserves, the exceptional size of individual units, and the technical advantages of unit operation, confer upon Middle East oil a great competitive advantage in comparison with any other major producing area in the world. These advantages have, however, been offset by other factors.

In 1938, 53 per cent. by volume of the oil entering into world trade was imported into Europe, 19 per cent. into the Far East and Oceania, 18 per cent. was absorbed in trade between the Americas, and 10 per cent. imported into Africa. In 1946, the corresponding figures were : 45 per cent. imported into Europe, 26 per cent. absorbed in trade between the Americas, 22 per cent. imported into the Far East and Oceania, and 7 per cent. into Africa. Thus it will be seen that before and since the war, Europe and the industrial countries of North America between them absorbed 71 per cent. of world oil exports. So long as it is tanker-borne Middle East oil is at a disadvantage in comparison with American and Caribbean oil in both these markets. From the Gulf–Caribbean ports it is less than 5,000 miles to Western Europe : from the Persian Gulf it is 7,000 miles via the Suez Canal, involving Canal dues of about 10d. per barrel. In the remaining substantial world market, the Far East and Oceania, Middle East oil was at a similar geographical disadvantage in comparison with the pre-war Netherlands East Indies production. In the pre-war world of oil abundance these economic considerations tended to retard the expansion of Middle East oil in world markets and the distribution of world exports in 1938 was : from the Caribbean, 40 per cent. ; from the U.S.A. 33 per cent. ; from the Middle East 15 per cent. ; and from the rest of the world 12 per cent.

Notwithstanding their unfavourable geographical location with reference to the industrial countries which are the principal consumers of petroleum products, the pressure of the great Middle East reserves, discovered in the quinquennium between 1936 and 1940, was bound, sooner or later, to make itself felt. The post-war oil shortage has hastened that development, and Middle East oil is now a world necessity.

The present world shortage of oil is due to the unprecedented rise in world demand which is brought out by the following comparison of oil consumption in 1938, 1946 and 1947 :—

WORLD OIL DEMAND

	1947 Millions of barrels	1947 Increase since 1946	1947 Increase since 1938	1946	1938
		Per cent.	Per cent.	Million barrels	Million barrels
United States	1,990	8.6	73.1	1,832	1,150
United Kingdom	125	22.5	45.3	102	86
British Commonwealth	230	5.0	109.1	219	110
Other	770	10.5	17.2	697	657
Total	3,115	9.3	55.5	2,850	2,003

The increase in world consumption is dominated by the increase in United States domestic consumption, which in 1947 was within 0.7 per cent. of 1938 total world consumption. The reasons for this increase are : the extraordinary peace-time demands of the military forces which aggregated 91 million barrels in 1947, as compared with 12 million barrels in 1938 ; the increased use of petroleum in agriculture, which employs a million more tractors than in 1941 ; the increased use of fuel oil for domestic heating ; and the increase in motor vehicle registrations, which at the end of 1947 were 6.7 per cent. higher than in 1941. Attention is focussed on this increase in the States because the U.S.A. consumes, as well as produces, 63 per cent. of the world's oil, but the same factors of increased mechanisation of agriculture and use of oil for industrial and domestic heating (due to the world-wide shortage of coal), have operated in varying degrees throughout the world. This world-wide trend to increased utilisation of petroleum is illustrated by the following table of world sources of energy before and after the two world wars :—

WORLD SOURCES OF ENERGY

Year—	From coal	From oil	From natural gas	From water power
	Per cent. of total B.T.U's			
1913	89.8	5.6	1.8	2.8
1919	84.3	8.9	2.5	4.3
1938	65.8	20.9	4.9	8.4
1946	58.6	24.5	7.0	9.9
1947	59.8	23.7	6.7	9.8

What happened in 1947 is now history : what of the future ? C. J. Bauer* of Jersey Standard has estimated that world demand in 1951 will be 3,900 million barrels, a 23.4 per cent. increase over 1947 and requiring an additional production of 2 million barrels per day.

The estimated distribution of this 1951 demand and its comparison with 1947 is as follows :—

ESTIMATED WORLD OIL DEMAND

	Western Hemisphere	Eastern Hemisphere	World total
	In million barrels		
1947	2,325	835	3,160
1951	2,708	1,192	3,900
Increase	383	357	740
Increase, per cent.	*16.4*	*42.8*	*23.4*

It will be seen that the estimated increase in demand is almost equally divided between the Western and Eastern Hemispheres but, with the possibility of recurrent labour troubles and increasing costs in the American coal industry, an increase in Western Hemisphere demand in excess of the 16.4 per cent. catered for, cannot be entirely ruled out.

With the present excessive drain on Western Hemisphere, reserves (9.25 per cent. per annum in the case of the United States and 8.5 per cent. in the case of the Caribbean) it would be imprudent to look to these areas for an appreciable proportion of the required additional 2 million barrels per day. Any substantial increase might well, in fact, be to the detriment of ultimate recovery from them. The optimum rate of production varies with the reservoir characteristics of each field and is dependent on many factors such as the saturation pressure of the crude, the existence, absence, or degree of a natural water drive, etc., but in many fields there are grounds for the suggestion that the optimum rate is in the neighbourhood of 5 per cent. per annum of the recoverable reserves remaining underground. This factor cannot be applied indiscriminately to the determination of the optimum rate of production from such vast and diverse areas as the United States and the Caribbean, since some of the proved reserves are in an advanced stage of depletion while others are barely tapped. This consideration does, however, add technical weight to the cogent economic and strategic arguments against greatly accelerated Western Hemisphere production.

The situation in the Middle East is quite different : here proved reserves are being drawn on at a rate of less than 2 per cent. per annum and in many fields well below the optimum rate for maximum ultimate recovery. It is, therefore, both a world interest that its acute need for more oil should be satisfied by increased Middle East production, and in the interests of the Middle East producing countries and companies that this oil province should make a contribution commensurate with its share of world reserves.

Vigorous plans are under development to enable it to do so, and the world oil budget for 1951 is based on a 100 per cent. increase in Middle East production.

* C. J. Bauer : Paper presented before the American Institute of Mining and Metallurgical Engineers, February, 1948.

Much of the statistical data on world supply and demand has been adapted from this source. It has been modified by more recent information from a variety of sources. In the reconciliation of conflicting data, the author has exercised the prerogative of relying on his own judgment. Any discrepancies which arise from this source, or from the application of conversion factors (tons to barrels, etc.) do not affect the essential aspects of the picture, or the overall conclusion, which is inescapable.

The postulated sources of supply in 1951 in comparison with 1947 are as follows :—

WORLD CRUDE OIL PRODUCTION IN 1947 AND ESTIMATED FOR 1951

	U.S.A.	Caribbean	Middle East	Other	World total
	In million barrels				
1947	1,985	538	308	287	3,118
Per cent. ..	*63.6*	*17.3*	*9.9*	*9.2*	*100*
1951	2,100	675	620	465	3,860
Per cent. ..	*54.4*	*17.5*	*16.1*	*12.0*	*100*
Increase	115	137	312	178	742
Increase per cent.	*5.8*	*25.5*	*101.3*	*62.0*	*23.8*

Past and future supplies to Western Europe (the Marshall Countries) have been analysed in greater detail in the U.S. State Department's report on petroleum requirements under the Marshall Plan, from which the following table is adapted :—

FLOW OF OIL TO WESTERN EUROPE

	1938	1946	Estimates for 1948	1951
	In million barrels			
From—				
United States	88.5	70.5	39.1	15.7
Per cent.	*29.6*	*25.8*	*11.4*	*3.6*
Other Western Hemisphere ..	141.0	135.5	172.4	62.6
Per cent.	*47.1*	*49.6*	*50.0*	*14.3*
Total Western Hemisphere ..	229.5	206.0	211.5	78.3
Per cent.	*76.7*	*75.4*	*61.4*	*17.9*
Middle East	69.7	67.3	133.1	360.5
Per cent.	*23.3*	*24.6*	*38.6*	*82.1*
Grand total	299.2	273.3	344.6	438.8

From the last two tables it will be seen that expansion of Middle East production is vital for the future of European and world supplies. A comparison of the estimated world supply and demand in 1951 also reveals that Western Hemisphere demand will then absorb virtually the whole of the estimated U.S.A. and Caribbean production. Middle East oil is thus a vital domestic issue for the United States which, on balance, is expected by 1951 to become a substantial importer.

The following is adapted from Mr. Bauer's forecast of probable changes in U.S. foreign petroleum trade between 1947 and 1951 :—

UNITED STATES FOREIGN PETROLEUM TRADE IN 1947 WITH ESTIMATES FOR 1951

	1947	1951	Change mil. brls.	Change per cent.
	In million barrels			
Crude exports	45.6	36.5	— 9.1	— *20*
Crude imports	97.6	197.4	+ 99.8	+ *102*
Crude net imports	52.0	160.9	+ 108.9	+ *209*
Product exports	116.8	45.6	— 71.2	— *61*
Product imports	59.1	85.8	+ 26.7	+ *45*
Product net exports	57.7	— 40.2	— 97.9	— *170*
Total exports	162.4	82.1	— 80.3	— *49*
Total imports	156.7	283.2	+ 126.5	+ *81*
Total net exports	5.7	—201.1	—206.8	—*3,628*

Geographical considerations point to the Caribbean as the source of this prospective American deficit, and Caribbean projected production is adequate to satisfy it. It is, however, a vital United States interest that Caribbean oil should be diverted from its present flow to Western Europe. It can only be replaced in Western Europe by Middle East oil, and the European Recovery Plan is based on the assumption that this replacement will take place.

Middle East oil may also help in some degree to satisfy American import requirements. Small shipments from Saudi Arabia and Kuwait have in fact commenced, and the programme of imports from the Middle East is reported to envisage a total of some five million barrels in 1948. Whether this is the beginning of a regular and permanent flow of Middle East oil to the United States it is difficult to predict, but if so, it appears equally probable that such imports will, in the foreseeable future, be balanced by exports of Western Hemisphere oil to the Eastern Hemisphere. Such a development, therefore, does not affect the broad picture of the impending development of world petroleum trade which is : that the Caribbean will satisfy the American deficit and continue to supply the greater part of other Western Hemisphere requirements ; that the U.S.S.R. will remain self-supporting ; and the Middle East become the principal supplier to the remainder of the world.

As we have seen, the immediate programmes for European recovery and world supply postulate a 100 per cent. increase in Middle East production by 1951. From the point of view of crude production, the Middle East oil industry is technically capable of this expansion. American and co-operative Anglo-American plans have also been made for the transportation and marketing of the increased production and the realisation of the 1951 target is dependent on their fulfilment.

These plans include : Jersey and Socony participation in ARAMCO ; the Anglo-Iranian/Jersey-Socony purchase agreement ; the Shell/Kuwait purchase agreement ; and the construction of the following pipelines :—

(1) A 16 in. line from Kirkuk to Haifa with a capacity of 90,000 barrels per day.

(2) A 16 in. line from Kirkuk to Tripoli with a capacity of 90,000 barrels per day.

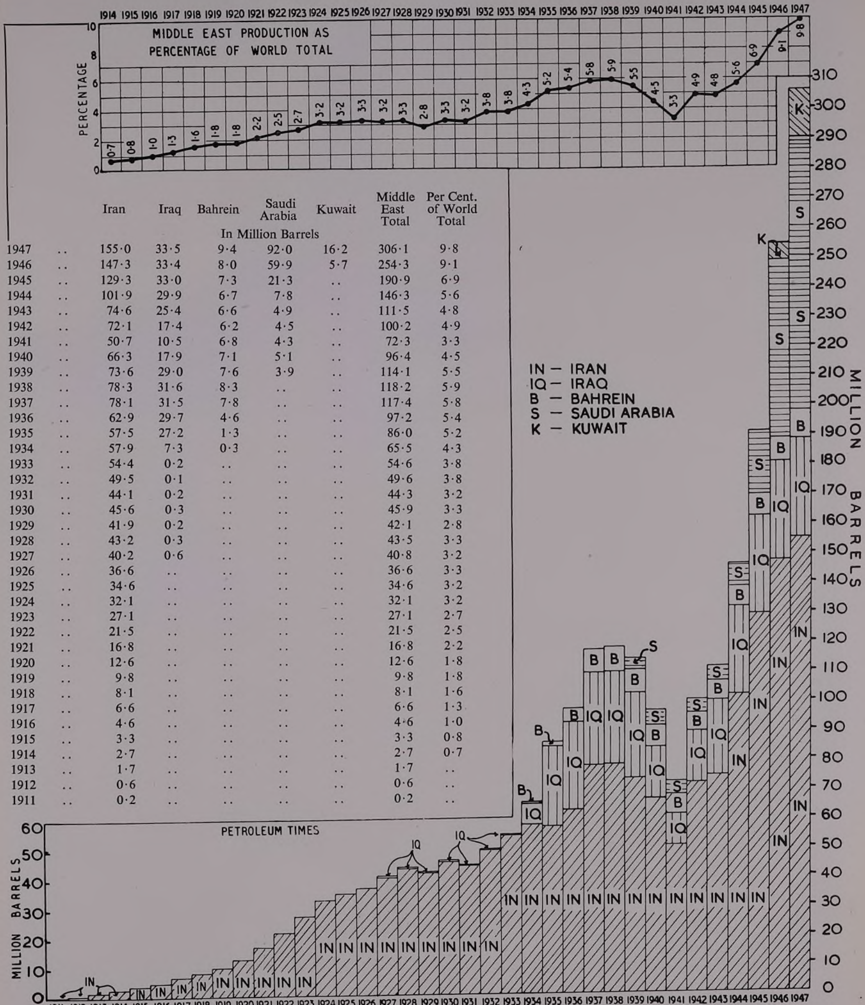
(3) A 30/31 in. line from Saudi Arabia to the Mediterranean with a capacity of 300,000 barrels per day (TAPLINE).

(4) A 34/36 in. line from Iran and Kuwait to the Mediterranean with a capacity of 500,000 barrels per day. (The Middle East Pipeline.)

Further plans since announced but not originally scheduled to mature by 1951 are for the construction of a 30 in. line from Kirkuk to a Syrian port.

Plans for Jersey/Socony participation in ARAMCO and the Jersey/Socony purchase agreement with the Anglo-Iranian Oil Co. were specifically designed to satisfy Jersey and Socony Eastern Hemisphere markets with reduced drain on Western Hemisphere resources. Both agreements, which were announced in December, 1946, are linked with the TAPLINE and Middle East pipeline projects respectively. The Shell/Kuwait purchase agreement, announced in June, 1947, provides for the purchase by the " Shell " of " increasing quantities of crude oil to be produced from the Kuwait fields over the period of the agreement " which is stated to be for a long term. These purchases will enable " Shell " to satisfy its Far Eastern markets, formerly supplied from the British and Netherlands East Indies, and their European markets with reduced drain on their Caribbean production.

Laying of the 16 in. line from Kirkuk to Haifa is already completed with the exception of 40 miles at the western end, where the disturbed conditions in Palestine have caused the suspension of operations. Construction of TAPLINE was commenced in 1947, but this project is also delayed by the political reactions to the proposed partition of Palestine. These reactions have a twofold effect : firstly, the members of the Arab League have stated that they will not confirm wayleaves if the UNO decision to partition Palestine is implemented ; and secondly, the American Government is reluctant to make steel for the pipeline available while this threat exists. Wayleaves and steel for the Middle East Pipeline are similarly in jeopardy. But if the pipelines are not completed to schedule the planned world supply for 1951 cannot be realised and the Marshall Plan for the economic recovery of Europe will be endangered. A solution to the Palestine problem must, therefore, be found which will not only satisfy Jewish and Arab aspirations, but which will also permit the speedy completion of the pipeline projects from the Middle East to the Mediterranean. For Middle East oil is a world necessity : it is also specifically a European necessity, an American necessity, an Arab necessity and a Jewish necessity.



	Iran	Iraq	Bahrein	Saudi Arabia	Kuwait	Middle East Total	Per Cent. of World Total
	In Million Barrels						
1947 ..	155·0	33·5	9·4	92·0	16·2	306·1	9·8
1946 ..	147·3	33·4	8·0	59·9	5·7	254·3	9·1
1945 ..	129·3	33·0	7·3	21·3	..	190·9	6·9
1944 ..	101·9	29·9	6·7	7·8	..	146·3	5·6
1943 ..	74·6	25·4	6·6	4·9	..	111·5	4·8
1942 ..	72·1	17·4	6·2	4·5	..	100·2	4·9
1941 ..	50·7	10·5	6·8	4·3	..	72·3	3·3
1940 ..	66·3	17·9	7·1	5·1	..	96·4	4·5
1939 ..	73·6	29·0	7·6	3·9	..	114·1	5·5
1938 ..	78·3	31·6	8·3	..	..	118·2	5·9
1937 ..	78·1	31·5	7·8	..	..	117·4	5·8
1936 ..	62·9	29·7	4·6	..	..	97·2	5·4
1935 ..	57·5	27·2	1·3	..	..	86·0	5·2
1934 ..	57·9	7·3	0·3	..	..	65·5	4·3
1933 ..	54·4	0·2	..	..	..	54·6	3·8
1932 ..	49·5	0·1	..	..	..	49·6	3·8
1931 ..	44·1	0·2	..	..	..	44·3	3·2
1930 ..	45·6	0·3	..	..	..	45·9	3·3
1929 ..	41·9	0·2	..	..	..	42·1	2·8
1928 ..	43·2	0·3	..	..	..	43·5	3·3
1927 ..	40·2	0·6	..	..	..	40·8	3·2
1926 ..	36·6	..	..	..	..	36·6	3·3
1925 ..	34·6	..	..	..	..	34·6	3·2
1924 ..	32·1	..	..	..	..	32·1	3·2
1923 ..	27·1	..	..	..	..	27·1	2·7
1922 ..	21·5	..	..	..	..	21·5	2·5
1921 ..	16·8	..	..	..	..	16·8	2·2
1920 ..	12·6	..	..	..	..	12·6	1·8
1919 ..	9·8	..	..	..	..	9·8	1·8
1918 ..	8·1	..	..	..	..	8·1	1·6
1917 ..	6·6	..	..	..	..	6·6	1·3
1916 ..	4·6	..	..	..	..	4·6	1·0
1915 ..	3·3	..	..	..	..	3·3	0·8
1914 ..	2·7	..	..	..	..	2·7	0·7
1913 ..	1·7	..	..	..	..	1·7	..
1912 ..	0·6	..	..	..	..	0·6	..
1911 ..	0·2	..	..	..	..	0·2	..

Middle East Oil Production


MIDDLE EAST
IRAN FIELDS
U. S. S. R.
IRAN
IRAQ
ABADAN
SAUDI
ARABIA
Dizful
LALI
Karun
River
MASJID-I-SULAIMAN
Shushtar
Ab-I-Din
River
River
Karkheh
WHITE
OIL SPRINGS
Gird Bishah
HAFT KEL
Haft Kel
Ahwaz
Khodaja
Ram Hormuz
River
River
Khalafabad
Jarrahi
Marun
Gargar
Dorquain
Karun
AGHA JARI
River
PAZANUN
Pazanun
Behbehan
Khorramshaur
Bandar Shanpur
Abadan
GACH SAR
Rud-I-Zuhreh
River
Gach Saran
Hindian
IRAQ
Bandar Dilam
Ras Barghan
LEGEND:
Oil Fields
Refineries
Pipelines
Railroads
Gas Fields
Towns
Roads
P E R S I A N G U L F

IRAN

ON MAY 28, 1901, Mr. W. K. D'Arcy obtained from the Persian Government a concession valid for 60 years "to search for, obtain, exploit, develop, render suitable for trade, carry away and sell natural gas, petroleum, asphalt and ozokerite throughout the whole extent of the Persian Empire" (with the exception of the five northern provinces).

In December 1902 drilling operations were commenced at Chiah Surkh near the Iran/Iraq frontier, 120 miles north-east of Baghdad and some 270 miles north-west of the present Masjid-i-Sulaiman oilfield. On May 21, 1903, Mr. D'Arcy formed the First Exploitation Company which continued drilling at Chiah Surkh until oil was struck in November 1904. The yield, however, was small and insufficient to warrant the expense of laying a pipeline to seaboard.

In 1905-1906 an unsuccessful well was drilled on the surface anticline at Haft Kel which, as is now known, lies far to the south-west of the limestone structure.

Undaunted by this failure Mr. D'Arcy and his associates transferred their primitive cable tool drilling equipment to Maidan-i-Naftun near a group of oil and gas seepages in what is now known as the Masjid-i-Sulaiman field. Here oil was struck at a depth of 1,180 ft. on May 26, 1908. Further successful wells were drilled here and in 1909 the Anglo-Persian Oil Co. (now the Anglo-Iranian Oil Co.) was formed. A site for a refinery was selected at Abadan and construction of a pipeline with an annual capacity of 400,000 tons commenced. This was completed in 1911 and production from the Masjid-i-Sulaiman field started in that year.

In 1914 production reached an annual total of 2,707,000 barrels (354,500 tons) and in May of that year the British Admiralty under Mr. Winston Churchill placed a long-term contract with the company for fuel oil. Simultaneously the British Government invested £2 million in the company, thus acquiring the 50 per cent. interest which it has since held.

The first world war saw rapid expansion of the company's development and by 1917 the annual production from MIS rose to 6,648,000 barrels (870,800 tons) and in that year the pipeline capacity was increased to 3 million tons a year. Two years later MIS passed another milestone when its annual production passed the million ton mark.

In 1923 the Naft-i-Shah field near the Iran/Iraq frontier was discovered and production from this field commenced in 1935. It has been small in comparison with the southern fields, the daily average production in December 1947 being 3,000 barrels a day and the cumulative total at the end of 1947, 9,300,000 barrels (1,180,017 tons).

By 1928 annual production from MIS exceeded 5 million tons and in this year the Haft Kel field some 50 miles to the south-east was discovered. A 12 in. pipeline was laid to join the MIS-Abadan line at Ahwaz and production from Haft Kel commenced in 1929. This field was developed rapidly and by 1934 contributed over 2 million tons to the company's total production of 7,537,372 tons in that year. In 1928 also the Gach Saran field was discovered but production from this area did not commence until 1940 when a pipeline was laid to Abadan.

The discovery well at Naft Safid (then known as White Oil Springs) was drilled in 1934 but the pipeline connection to Abadan was not laid until 1945 when production from this area commenced.

The year 1937 was another milestone in the company's progress for in this year, not only did annual production reach 10 million tons for the first time, but the important fields of Agha Jari and Pazanun were discovered, but due to the second world war these fields were not developed until some years later.

In 1940 the closing of the Mediterranean and the loss of European markets resulted in a decline in offtake from the Iranian oilfields to 8,626,639 tons and in 1941, the adoption of the short haul system, to make the optimum use of tanker tonnage, caused a suspension of shipments to the United Kingdom with the result that in that year production fell to 6,605,320 tons.

Notwithstanding this decline of demand from Iran, capacity which before the war was about 13,800,000 tons per annum was increased to 15,500,000 tons by the development of the Gach Saran field from which a 166 mile 12 in. pipeline was laid to Abadan in 1940.

The loss of production from the Far East due to the Japanese occupation of the Netherlands East Indies and Burma, resulted in an increased demand for oil from Iran, and production again rose to 9,399,231 tons in 1942. The reopening of the Mediterranean in 1943 and the commissioning in 1944 of the new aviation fuel plants, construction of which was commenced at Abadan in 1942, caused production to soar above the pre-war level, reaching a total of 13,274,243 tons in 1944.

Meanwhile, to relieve the strain on MIS and Haft Kel, which were near the limit of their maximum potential, and as a necessary step to ensure the maintenance of adequate supplies of oil for the conduct of the war, it was decided with the agreement of the British and American Governments to develop the Agha Jari, Naft Safid and Lali fields. Work at Agha Jari began in the autumn of 1943 with five strings of tools with the object of drilling 12 wells for production at an annual rate of 6 million tons by 1945. This project involved also the construction of a 12 in. pipeline 97 miles long to Abadan; the erection of a stabilization unit; the construction of over 100 miles of roads; the installation of power and water services and the provision of camps for 5,000 operating personnel. To accomplish this it was necessary to ship material into the area at the rate of 5,000 tons a month, and in view of the war-time shortage of materials to salvage as much line pipe as possible from other areas. Notwithstanding the equipment shortages and the difficulties of the mountainous terrain, the project was completed to schedule, and production from Agha Jari commenced in 1945.

In 1945 also a 32 mile combination 10 in. and 12 in. pipeline was completed linking Naft Safid with the MIS-Abadan pipeline system and production from this field commenced in that year.

The dates of discovery and commencement of production; the productive area; the depth to the top of the producing zone; the thickness of the producing zone; the numbers of producing and observation wells; the daily average and cumulative production; specific gravity of the crude; the gas/oil ratio; and the saturation pressure for each of the Iranian fields are as follows:—

Field	Masjid-i-Sulaiman	Naft-i-Shah	Haft Kel	Gach Saran	Naft Safid	Agha Jari	Pazanun
Year of discovery	1908	1923	1928	1928	1934	1937	1937
Production commenced	1911	1935	1928	1940	1945	1945	1943
Productive area, in acres	34,500	3,840	28,800	38,400	6,400	23,000	6,400
Depth to top of producing zone, in feet	600	2,400	2,000	2,500	3,000	4,500	5,500
Thickness of producing zone, in feet	1,000	250	900	1,500	900	600+	700+
No. of producing wells in December 1947	29	2	23	3	2	12	Nil
No. of observation wells in December 1947	20	Nil	15	2	2	3	Nil
Daily average production in December 1947, in thousand barrels	73	3	197	38	17	144	Shut in
Cumulative production to end of 1947, in million barrels	793.3	9.6	749.5	75.8	12.8	94.3	6.5
Specific gravity of crude	0.836	0.813	0.833	0.864	0.848	0.856	..
Gas/oil ratio: Single flash-vols./unit vol.	40/1	180/1	80/1	110/1	165/1	165/1	3,500/1
Saturation pressure: p.s.i.	500 at 95° F.	2,100 at 109° F.	1,400 at 109° F.	2,150 at 110° F.	3,200 at 109° F.	3,450 at 164° F.	..

AIOC photo.] [By Hunting Aerosurveys, Ltd.

Asmari Mountain : An exposed full-scale model of the MIS structure

Geology

THE PRODUCING FIELDS OF IRAN are situated in a belt of highly folded Tertiary strata forming the foothills of the Zagros Mountains in which Mesozoic and Palaeozoic sediments are exposed.

From Permian to Cretaceous times the area now occupied by the Zagros Mountains, the Persian Gulf, the valleys of the Tigris and Euphrates, and the eastern Arabian littoral, formed a deep and continually sinking geosyncline in which a great thickness of dominantly calcareous sediments was deposited. This geosyncline lay to the north-west of the ancient granitic land mass forming the so-called Arabian shield, against which its sediments were compressed by the Tertiary folding movements which produced the great mountain arcs stretching from the Alps to the Himalayas.

Lees and Richardson* have adduced evidence to show that the first phase of the folding movements took place along the north-eastern margin of this geosyncline between Turonian and Maestrichtian times during which bituminous marls with intercalated limestones were deposited in the centre of the geosyncline and sands, locally with conglomerates, along its north-eastern margins.

From Eocene times subsidence continued but was periodically overtaken by deposition : shallow water conditions spread into the centre of the geosyncline where limestones alternate with globigerina marls. In the Lower Eocene, anhydrites, which alternate with limestones throughout the Jurassic and Cretaceous sediments of the Hasa Province of Saudi Arabia, made their appearance in Iran. The succession of limestones and marls with subordinate anhydrite is repeated in the Oligocene and Lower

* G. M. Lees and F. D. S. Richardson : "*The Geology of the Oil Belt of S.W. Iran and Iraq*," Geological Magazine, Vol. LXXVII, No. 3 (1940), pp. 228-251.

Miocene, and it is to these periods of oscillatory sedimentation, in which reef and other shallow-water limestones alternate and interdigitate with globigerina marls, that the reservoir rocks of Iraq and Iran belong. In south-west Iran these limestones are known locally as the Asmari limestone after Asmari Mountain, near the Masjid-i-Sulaiman oilfield, where they are exposed by denudation.

In the late Lower Miocene widespread development of salt reflects the periodic isolation of portions of the area from the open sea. The appearance in Oligocene times of a shallow-water platform across the middle of the Persian Gulf has been postulated and it has been suggested that its periodic emergence throughout the Miocene may account for the recurrent precipitation of salts within the main part of the basin. To the alternating series of grey marls, anhydrite and salt with occasional thin limestones, red marls, and bituminous shales deposited during this period, the name Lower Fars Series has been given, but when applied over a wide area, as for example in central Iraq, this term, and still more so the terms Middle and Upper Fars, and Bakhtiari Sandstones applied to the Upper Tertiary sediments, are descriptive of facies groups rather than of stratigraphical subdivisions.

In Middle and eaıly Upper Miocene times a rapid south-eastward withdrawal of the sea took place, with the deposition of red marls and sands in the north while grey marls and marine limestones were being deposited in the south, where the absence of chemical precipitation reflects the restoration of connection with the open sea.

In late Miocene and Pliocene times the 25,000 to 30,000 ft. of Palaeozoic to Tertiary sediments laid down in the central portions of the geosyncline were folded into a series of NW-SE anticlines and synclines by the compressive forces of the Alpine folding movements acting against the stable Arabian shield. The Zagros Mountains were elevated above sea level and in the foredeep to the south-west a large number of anticlines including the producing fields of SW Iran and Iraq were formed. In the still submerged portions of the basin detrital sediments were deposited and the Upper Miocene and Pliocene sediments are dominantly red and sandy with conglomerates occurring in the higher members.

The south-eastward withdrawal of the sea, initiated in Middle Miocene times, was accelerated, and red fluviatile sediments spread far into the basin with typically marine sedimentation persisting only in the extreme south-east. Thus the Middle Miocene (Middle Fars) around the Gach Saran oilfield consists of marine grey marls and reef limestones while further north-west it is represented by red, sandy sediments indistinguishable from the red marls, silts and sandstones of the Upper Fars. These are followed by the Pliocene (Bakhtiari) sediments consisting mainly of fresh-water marls, silts and sandstones with occasional anhydrites, and coarse conglomerates in the higher members, which in many places rest unconformably on the Lower Bakhtiari sediments.

The producing fields of SW Iran all occur in large elongated anticlines where the Asmari limestone is covered by the evaporite series of the Lower Fars, the lowest member of which is a massive anhydrite group some 70 to 140 ft. thick known as the cap rock, though the soft marls, salt and anhydrites of the Lower Fars in combination form the impervious cover.

Exploratory and exploitation drilling and geophysical investigation have demonstrated not only that the buried limestone folds, like the exposed anticlines, are of great size and amplitude but also that they are of a simple asymmetric type with steep south-west flanks, broad crests, and gently dipping north-east flanks. They are in fact perfect " text book " examples of anticlinal limestone reservoirs. In strong contrast, however, to the bold simplicity of the Asmari limestone folding is what Lees and Richardson* have termed the " vexatious turbulence of the Lower Fars." These authors have described how the disharmonic movements of the Lower Fars, " which has behaved as a plastic medium between the limestone below and the relatively rigid masses of Middle and Upper Fars and Bakhtiari sediment above," are of such a degree that not only do the outcropping beds fail to duplicate the structural features of the limestones, but sometimes exhibit structures which are entirely dissimilar to them.

" In a few places," they state, " where the Lower Fars is thin and deficient in salt, the surface structure does conform more or less closely with that of the limestone. Most commonly, however, it is only on the north-east limb that the structure of the limestone and of the surface beds is essentially similar. In these folds the Lower Fars and its cover have been driven south-westwards across the limestone anticline, and whereas on the south-west limb the limestone descends more or less steeply, the surface beds continue to rise gradually for a considerable distance, and then either turn down abruptly into the fore-syncline or, more frequently, are thrust forward across its margin."

These features which have immensely complicated the search for oil in south-western Iran are illustrated by consideration of the individual producing fields, to which we must now proceed, and by the accompanying profiles which have been specially drawn for PETROLEUM TIMES by the Anglo-Iranian Oil Co. As in the whole of this section, the author has drawn freely on the published works of Dr. G. M. Lees and Mr. F. D. S. Richardson and has also enjoyed the great benefit of discussion with them.

The Masjid-i-Sulaiman and Lali Oilfields

The limestone reservoir at Masjid-i-Sulaiman (MIS) is a broad flat-topped asymmetric anticlinal structure some 18 miles long and 4 miles wide. Dips on the south-west flank are from 40 to 50° and on the north-east flank from 20 to 30°. Twelve miles to the south-east and separated from the MIS structure by a gentle saddle the Asmari limestone outcrops in Asmari Mountain, a typical whale-backed, asymmetrical anticline some 18 miles long and 3 miles wide.

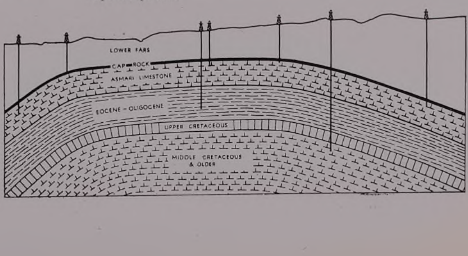
The MIS limestone structure is covered by a broad sheet of Lower Fars sediments folded into a complex pattern of minor folds. The eroded Lower Fars cover is only 600 ft. thick over the culmination of the dome but it increases to 5,000 ft. and more on both flanks, the thickening being accompanied by a great increase in the proportion of salt.

Near the ancient temple of Masjid-i-Sulaiman (after which the field was renamed in 1926, having previously been known as Maidan-i-Naftun) there are copious oil and gas seepages in the Lower Fars and it was near this seepage group that the discovery well was drilled in 1908.

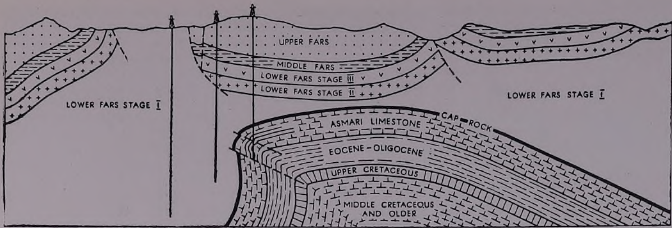
Similar gas seepages are associated with all the known fields but in some instances they do not lie directly above the limestone

*Op. cit. p. 251.

The orientation of this and the succeeding transverse sections of the Iranian oilfields is from (left) southwest to (right) northeast.



Section through the MIS structure



Section through the Lali structure

reservoirs but, where major overthrusting has occurred, near the outcrop of the thrust plane, sometimes several miles to the south-west of the limestone structure. Present and former gas seepages are accompanied by characteristic changes in the surrounding sediments resulting in the replacement of gypsum by aragonite and of limestone or marls by a friable mixture of gypsum and sulphur accompanied by free sulphuric and sulphurous acids, known locally as Gach-i-turush (sour gypsum).

Some 5 miles north-east of the crest maximum of the MIS limestone reservoir Lower Fars are overlain by steep north-easterly dipping Middle Fars, forming the south-western limb of a deep syncline, the trough of which is occupied by Bakhtiari silts, sandstones and conglomerates. On the south-west flank of the limestone structure Lower Fars are thrust over steep north-easterly dipping Upper Bakhtiari conglomerates forming the south-west limb of a deep narrow syncline, the trough and north-westerly limb of which are buried beneath the Tembi thrust.

Two miles north-west of the culmination of the limestone dome the Asmari structure plunges gently beneath a broad synclinal outlier of Upper Fars, where its course is marked by a gentle anticlinal fold in the surface beds. Dips in the Upper Fars are from 12 to 15° on both flanks, bringing in Lower Bakhtiari sediments in a broad syncline to the north-east, and unconformable post-Bakhtiari conglomerates in a narrower syncline to the south-west.

The Asmari limestone at MIS is approximately 1,000 ft. thick. It is a marine limestone of Upper Oligocene to Lower Miocene age and, while of low average porosity, it is highly fractured giving free fluid communication over wide areas of the structure. The top 400 ft. is a massive thick-bedded limestone, but grey marls appear as intercalations lower down and become dominant in the lowest 100 ft. ; several anhydrite bands occur 600-700 ft. below the top, and there is a persistent anhydrite bed at the base. Below the Asmari limestone an exploration well proved 1,300 ft. of Eocene marls and marly limestones followed by 600 ft. of Upper Cretaceous marls resting on Middle Cretaceous limestones. A small production has been obtained from an Eocene limestone but with this exception no oil has yet been produced in Iran from beds below the Asmari limestone.

In the region of Zeloi, north-west of the Upper Fars syncline which overlies the north-western portion of the MIS dome, is another broad Lower Fars anticlinorium similar to the one covering the south-eastern half of that structure. On the north-east the Zeloi Lower Fars anticlinorium is flanked by the Jehangiri syncline occupied by Upper Fars and Lower Bakhtiari beds, and on the south-west by a still deeper syncline in which beds up to and including Upper Bakhtiari conglomerates occur. By analogy with MIS it was thought that there should be a limestone anticline at reasonable depth below the Zeloi anticlinorium but three wells drilled there in the late '20's failed to reach the limestone. Geophysical work in the early '30's suggested the presence of an anticlinal axis in the limestone near the old wells, and a fourth well drilled in 1936-37 reached the limestone at a depth of some 10,700 ft. where, however, it was waterlogged.

After investigation of the Zeloi area the Lali area lying to the north-east beyond the Jehangiri syncline was examined. Here there is another large Lower Fars anticlinorium, overthrust over Bakhtiari sediments at its north-eastern margin. Geophysical investigation failed to detect any limestone anticline beneath the Lower Fars but to the south-west beneath the Jehangiri syncline the presence of a large limestone dome was revealed.

A well drilled on the geophysical axis in 1938 penetrated limestone at a depth of less than 4,000 ft. where it was gas-bearing. In this well the salty part of the Lower Fars was less than 300 ft. thick compared with 11,000 ft. at Zeloi, 4 miles away to the south-west.

Subsequent exploration of the Lali structure has confirmed the presence of a large limestone anticline of which the length and breadth are not yet fully known. It is separated from the MIS dome by a gentle saddle from which the Lali structure rises gently for several miles before plunging to the north-west. It is a sharply asymmetrical structure, the south-west flank being locally overturned, with a great piling up of a salty Lower Fars beneath the south-western limb of the Jehangiri syncline which is broken by an extrusion of salt at Ambal a little further north-west. The north-east flank dips at 20° beneath highly disturbed Lower Fars salty deposits occupying the Lali Plain.

As at MIS the lowest member of the Lower Fars is the anhydrite cap rock, here some 70 ft. thick, which has partaken in the simple Asmari folding. The discovery well situated south-east of the crest maximum penetrated 1,200 ft. of Asmari limestone. On test another well yielded a million gallons (3,770 tons) of oil per day. A pipeline link with the refinery was constructed early in 1948 and production from the Lali field commenced in May.

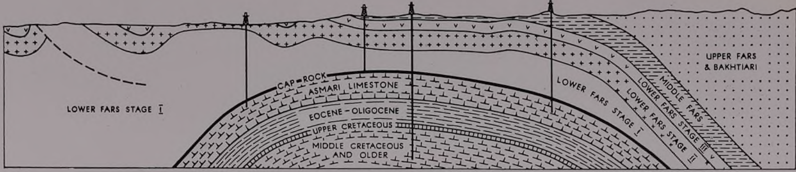
The Haft Kel and Naft Safid Oilfields

The Haft Kel field lies 35 miles SSE of MIS on an anticlinal axis en echelon with the MIS axis and 13 miles to the south-west of it. The limestone reservoir is 17 miles long and 2¾ miles wide forming an elongated dome on an anticlinal axis extending in a NW-SE direction for some 80 miles. It is markedly asymmetric with a moderately steep south-west limb, a broad flat crest some 1½ miles in width and a gentle north-east flank. The crestal portions of the limestone structure are overlain by some 2,000 ft. of disturbed Lower Fars which, 5 to 7 miles south-west of the axis of the fold, is probably thrust over the upturned north-east limb of a deep Bakhtiari syncline. On the north-east flank is a broad syncline between which and the Asmari Mountain there is a broad belt of much disturbed Lower Fars.

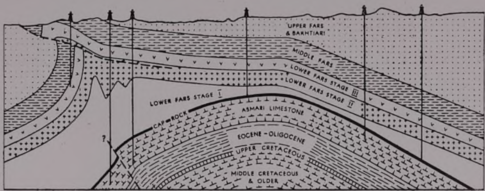
At the north-west end of the structure Middle and Upper Fars occupy a saddle between the Haft Kel field and the Naft Safid structure (formerly known as White Oil Springs) some 10 miles to the north-west. Here the limestone structure, which is 2½ miles wide and of undetermined length, is oil and gas-bearing ; the crest maximum is some 1,500 ft. lower than at Haft Kel.

There is a great area of active gas seepages in the crestal area of Haft Kel, and at Naft Safid there are both gas seepages and springs of a light straw coloured oil of 0.779 S.G. Originally regarded as a product of filtration, this light oil is now believed to be a condensate from the escaping gas.

Both at Haft Kel and Naft Safid the lowest member of the Lower Fars is an anhydrite group some 70 ft. thick which forms



Section through the Haft Kel structure



Section through the Naft Safid structure

the cap rock to the Asmari limestone. During the development of the Haft Kel field in the late '20's a remarkable mineralogical study of the anhydrite bands of the Lower Fars was carried out by M. W. Strong who, by means of inclusions and crystal habit in the anhydrites, was able to correlate a number of them throughout the field. As a result of this and later work it is possible to recognise certain beds which give warning of the proximity of the cap rock in exploitation drilling.

In both fields the Asmari limestone is 900 ft. thick. It is underlain by 1,000 ft. of Eocene strata, followed by 150 ft. of Upper Cretaceous and then by a great thickness of Middle Cretaceous limestone which yield water only on test.

The Agha Jari and Pazanun Fields

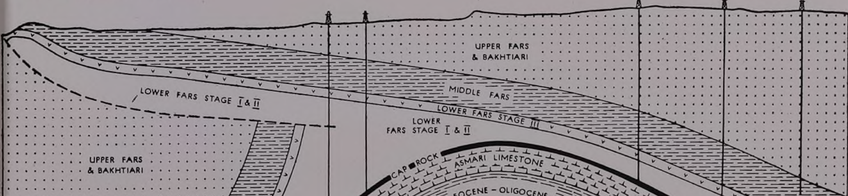
The Agha Jari field is situated some 60 miles SSE of Haft Kel on an anticlinal axis extending for over 50 miles and lying 30 miles to the south-west of the Haft Kel—Naft Safid axis. The closed structure in the limestone at Agha Jari is at least 15 miles long and 3 miles wide, pitching south-east under a deep saddle which separates it from the Pazanun structure some 15 miles further south-east.

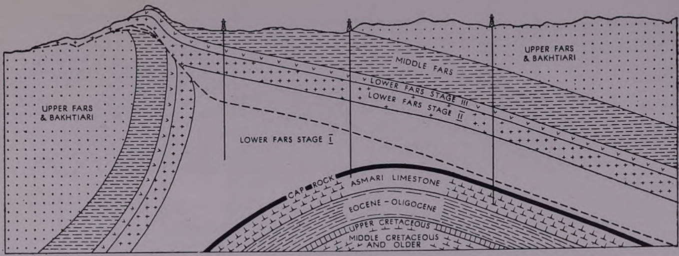
The limestone structure at Agha Jari is a broad slightly asymmetric dome, overlain at the culmination of the dome by 4,500 ft. of Lower, Middle and Upper Fars. Here the combination of scarp and dip slope is beautifully seen in the Upper Fars which dip consistently north-eastward over the entire limestone structure. Flying over the field from the north-east one asks where *is* the south-west flank ? but remains without a clue to the answer until approaching the field from the airport some 4 miles further to the south-west. Here, where rugged hills rise abruptly for 500 ft. from the alluvial plain, Lower Fars shales with gypsum and anhydrite are sharply overturned where they are thrust over the south-westerly dipping Bakhtiaris. Ignoring the thrust, the hade of the axial plane of this surface structure would place the limestone crest (assuming it to lie at 4,500 ft.) approximately 1½ miles north-east of the crest of the surface structure. In fact it lies 3½ miles to the north-east, indicating that the Fars series has been thrust some 2 miles over the limestone structure. This is perhaps the simplest, but by no means the most extreme example of the disharmony between the limestone structures and those in the surface beds, which characterises the oilfield belt of SW Iran and which has immeasurably complicated the search for oil in that region.

Near the emergence of the thrust at the foot of the Agha Jari hills, burning gas seepages accompanied by altered gypsum, anhydrite and limestone (Gach-i-turush) are numerous, gas having migrated laterally along the thrust plane for a distance of 3 miles from the nearest edge of the gas accumulation in the limestone dome.

The Pazanun structure, 15 miles south-east of Agha Jari is a fold of considerable dimensions and here again the results of overthrusting in the Lower Fars are pronounced. On the north-east

Section through the Agha Jari structure





Section through the Pazanun structure

flank thrusting has cut out many hundreds of feet of salty beds which are piled up in a contorted mass on the south-west flank. At the emergence of the thrust, beds of Lower Fars are thrust over vertically dipping Middle Fars and younger beds. The first well, drilled half-a-mile north-east of the surface crest, penetrated a great thickness a highly disturbed Lower Fars and was discontinued in salt at 5,318 ft.; a second well drilled a mile further north-east reached the Asmari limestone in the crestal area at 5,786 ft. Only gas has been proved in this field to date.

In both the Agha Jari and Pazanun structures the anhydrite cap rock is thicker than in the more northerly fields, being 140 ft. at Agha Jari and somewhat less at Pazanun. In neither field has the Asmari limestone been bottomed, 600 ft. having been penetrated at Agha Jari and 700 ft. at Pazanun.

The Gach Saran Field

The Gach Saran field, the most southerly proved field in Iran, lies 50 miles ESE of Pazanun. It is a broad asymmetrical dome some 20 miles long and 4¼ miles wide.

In this area the disharmonic movement of the Lower Fars is intense, though less so than in the MIS-Lali region and the crestal portion of the limestone structure lies under a Middle Fars syncline flanked on the south-west by an accumulation of overfolded and faulted Lower Fars. The first two wells were placed too far to the south-west, but the third well reached cap rock at 3,213 ft. and struck oil at 3,250 ft.; it was subsequently deepened into the limestone, entered at 3,286 ft. Here the Asmari limestone is thicker than in the more northerly fields, being some 1,500 ft. thick in the Gach Saran dome.

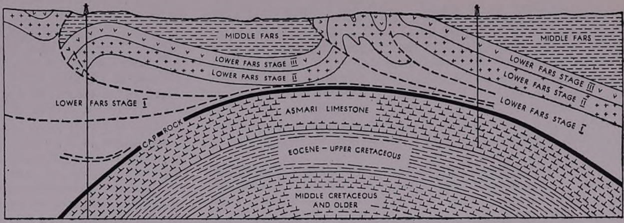
The Naft-i-Shah Field

The Naft-i-Shah oilfield, the most northerly of the fields of SW Iran, lies on the Iraq-Iranian frontier, 80 miles north-east of Baghdad and some 270 miles north-west of Masjid-i-Sulaiman. Here the structural conditions are less complicated than in the more southerly fields. An inlier of Middle and Lower Fars some 3 miles long and three-quarters of a mile wide overlies the limestone structure but the surface axis is displaced to the south-west of the limestone structure by a thrust fault which thrusts the north-easterly dipping Middle and Lower Fars over the steeply dipping

Petroleum Times] [Photo

The Surface structure at Agha Jari

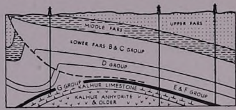
Section through the Gach Saran structure



Upper Fars of the south-west flank. In contrast also to the steep asymmetrical surface anticline the limestone structure is a gentle almost symmetrical fold, again illustrating the almost invariably incompetent behaviour of the Lower Fars salty series.

The closed structure in the limestone is 8 miles long and 1,1/3 miles wide at the culmination of an anticlinal axis which pitches gently to the north-west and south-east and is traceable north-westwards in Iraq for over 50 miles.

Here the limestone reservoir rock is much less well developed than in the southern fields, being only 250 ft. thick. It represents only the higher part of the Asmari limestone and has been given



Section through the Naft-i-Shah structure

the local name of Kalhur limestone. The crestal portions are overlain by 1,800 ft. of Lower Fars and 400 ft. of Middle Fars with strong oil and gas seepages at the crest of the surface structure.

Drilling

There are at present 15 drilling rigs in operation in Iran, and the drilling programme for 1948 calls for 75,000 ft. of drilling as compared with 50,000 ft. in 1947.

The plastic deformation of the Lower Fars, the geological effects of which are outlined above, is probably responsible for the abnormal pressure gradients in the strata overlying the cap rock where pressures in some of the fields are equivalent to 1.1 p.s.i. per foot of depth. These pressures, frequently accompanied by water and gas shows, result in heaving formations which have necessitated the development of pressure drilling technique. The presence of great thicknesses of salt and the chemical content of the waters make the maintenance of stable bentonite suspensions difficult and result in heavy loss of weighting materials and treatment chemicals. The use of pressure drilling with a light mud has reduced these losses and permits the maintenance of a required pressure differential between any two points in the hole. In one well in Agha Jari 500 ft. of reservoir rock were penetrated without mud loss in a formation so fissured that the well yielded 30,000 barrels of oil per day. In contrast to this, in a well where control was previously attempted by the use of heavy mud, over 70,000 cu. ft. of mud and sealing compounds were used at one point without success.

Derricks are mounted on a 6 ft. substructure which, with a 10 ft. cellar and 6 ft. subcellar permits the installation of a Cameron blowout preventer and Seamark blowout preventer. The mud manifold and wellhead connections are so arranged that circulation can be open, through beans to separators, or across the wellhead, giving a high degree of flexibility of pressure control.

A conductor string of $15\frac{1}{4}$ in. casing is set at depths varying from 300 to 500 ft., and an $11\frac{3}{4}$ or $8\frac{3}{4}$ in. string is usually set above the high pressure zone of the Lower Fars and cemented to the surface. Pressure drilling equipment is then installed and light mud fluid used with back pressures varying from 800 to 1,600 p.s.i. This is adjusted to maintain a balance with the formation pressures which in many cases are not proportional to depth. To obviate the use of snubbing gear the tools are pulled under pressure only to the casing shoe where back pressure is reduced and light mud inside the casing displaced by a heavy mud column of sufficient weight and height to compensate for the reduction in back pressure, and the tools are pulled with open circulation over the wellhead. Conversely, when running in, the bit is lowered to the casing shoe with open circulation of heavy mud over the wellhead, back pressure is then gradually applied and heavy mud circulated out until the desired balance is maintained.

An oil string, usually of $6\frac{1}{4}$ in. casing is set in the cap rock and like the previous strings cemented to the surface. No tubing is run, the oil being produced through the casing.

Reservoir Studies and Characteristics

The producing fields of SW Iran are notable not only for their great present and potential production from a small number of wells but also because they have been the scene of epoch making developments in the technique of limestone reservoir control.

With a cumulative net production of just over 103 million tons (793.3 million barrels) in 36 years MIS is the fourth largest field in the world, but the greatest number of producing wells at any one time has been 31. At present it is producing $3\frac{3}{4}$ million tons (29 million barrels) gross per annum from 29 wells. Haft Kel has produced nearly 100 million tons (749.5 million barrels) in 19 years from 18 wells and is now producing 9.8 million tons per year (197 thousand barrels a day) from 23 wells, making it second only in terms of current production to East Texas, which is producing 17 million tons from 24,000 wells.

The cumulative production from the whole of Iran at the end of 1947 was 227 million tons (1,741.8 million barrels) and the daily average production in December, 1947, was 62,000 tons (472,000 barrels) from 71 wells.

Yields of this order of magnitude from so small a number of wells are unequalled anywhere else in the world with the exception of the newer fields of the Middle East where the system of reservoir control is based on the experience of the Anglo-Iranian Oil Co. in Iran. They are due not only to the high degree of communication in the limestone reservoirs, and the great extent, thickness and richness of the oil accumulations, but also to the production technique evolved as a result of the reservoir studies carried out by the company from the commencement of production, and more particularly in the last 30 years.

Under the inspiration of Mr. J. A. Jameson, C.B.E., then fields manager, some of the earliest field studies of the control of gas/oil ratios were carried out at MIS immediately after the first world war, an account of which was given by Mr. D. Comins, M.C. and Mr. L. A. Pym to the First World Petroleum Congress held in London in 1933.* A more recent account of the reservoir studies carried out by the company was given by Mr. H. S. Gibson, C.B.E., present fields manager and Institute of Petroleum Redwood Medallist for 1947, in his lecture to the Institute in March, 1948†

In 1921 the epoch making discovery was made that the closed-in pressure of a well drilled at Naftak in the MIS field was affected by the opening and closing of wells at Naftun some three miles away. This early demonstration of the extreme freedom of connection through the reservoir was the beginning of the production system since evolved in the fields of Iran and Iraq, whereby large volumes of production are maintained with an unparalleled economy of drilling effort and of surface installations.

This high degree of connection was even more forcibly demonstrated at Haft Kel where, in the early years of development, wells were concentrated on the southern portion of the structure, but pressure decline throughout the reservoir was uniform.

Notwithstanding this high degree of connection within the reservoir it was realised as early as 1924 that the oil-water level at MIS was not rising at a rate sufficient to replace the whole of the oil produced, resulting in a pressure decline in the reservoir and the partial replacement of produced oil by the formation of a secondary gas dome in the crestal portions of the structure. As a result of subsequent study and experience it is now believed that the slowly rising edge water is due to a combination of a very restricted connection with an external water table and the expansion of fluids in the limestone reservoir below oil-water level as a result of pressure decline.

As a result of Mr. Comins' early studies of gas/oil ratios the importance of gas conservation was fully appreciated. By 1927 all wells which had gone to gas or were showing signs of doing so had been mudded off or equipped with high pressure fittings and shut in, no oil being drawn from any well which produced gas in excess of the volume held in solution at the bottom of the casing. As a result the decline of the gas dome pressure was less than 2 p.s.i. per annum.

In August 1927 an event occurred which has had far reaching consequences on the subsequent development of limestone reservoir control. A well on the south-west flank began to produce salt water, although the bottom of the well was 200 ft. above the estimated oil-water level. Investigation showed that the rise of water was very local and it was also demonstrated that in the vicinity of this well, pressure was nearly 40 p.s.i lower than in the surrounding producing area on the south-west flank and 65 p.s.i. lower than on the north-east flank. It was realised that this pressure difference was the cause of water entering the well and production from the surrounding area was at once closed down. As a result of this experience it was decided that in future the reservoir would have to be treated as a unit and a uniform pressure maintained in all sectors. To implement this decision it was necessary to have continuous records of pressures all over the field and hence the necessity for special observation wells which since that time have been an essential feature of limestone reservoir control.

The process of balancing pressures and fluid levels throughout the MIS reservoir took four years to complete, during which time it was established that the Asiab area at the north-west pitching end of the structure was practically non-productive. It was demonstrated during the drilling of wells that production was obtained only when a fissure was penetrated, suggesting that the oil produced came from fissures, but the possibility of production coming from porous limestone was never entirely ruled out.

In 1930 a detailed and extensive study of the reservoir rock was commenced. Continuous cores had been taken in two wells through 300 ft. of limestone and these and several hundred samples from other wells distributed throughout the structure were examined.

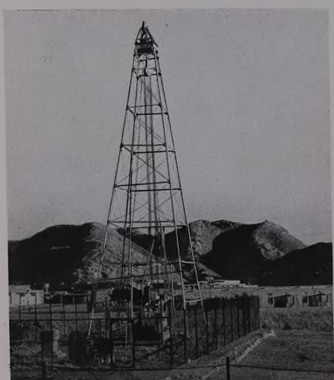
* D. Comins, "Gas Saturation Pressure of Crude Under Reservoir Conditions as a Factor in the Efficient Operation of Oilfields": *Proceedings of the first World Petroleum Congress* (1933); Vol. I, pp. 458-466.

L. A. Pym, "The Measurement of Gas/Oil Ratios and Saturation Pressures and Their Interpretation": *loc. cit.*; pp. 452-457.

† H. S. Gibson, Institute of Petroleum Redwood Lecture, March, 1948.

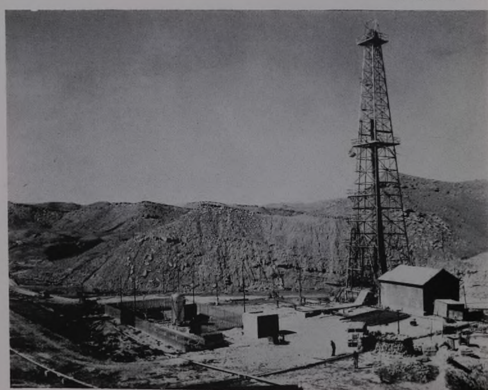
The discovery well at MIS

AIOC Photos]



A modern well at Naft Safid

[by Raymond Wilson



As a result of this investigation it was concluded that while the limestone was to some extent porous and permeable, production was mainly dependent on open fractures, rather than on the permeability of porous or cavernous limestone. A year later doubt was thrown on this conclusion by the behaviour of a well in a previously undeveloped sector of the north-east flank. On test the well appeared capable of producing 1,000 tons per day, but it was put on production at about one-third of this quantity. Within eleven days the gas/oil level in its vicinity had fallen an average of 85 ft. as compared with the maximum anticipated fall of 2 ft. After being closed in for a month the gas/oil level was completely restored and when the well was slowly brought into production it was found that with an offtake of 150 tons per day pressure in that sector remained in equilibrium with the remainder of the reservoir. At this rate of production the fall of the gas-oil level was approximately one-fifth of a foot per day as compared with 8 ft. per day during the initial period of production at a rate of 330 tons per day. In Mr. Gibson's words : " This difference could only mean that although the well was supplied with oil from a fissure, the fissure was replenished from porous limestone, the rate of flow from which was limited. Assuming that the additional 180 tons per day came entirely from 7.8 ft. of fissure space, then one-fifth of a foot would supply 4.6 tons, and therefore of the 150 tons per day steady production it appeared that 145.2 tons, or 97 per cent., came from the pores of the limestone. This is a minimum value, for if during the heavy initial withdrawal of oil any migrated into the area from adjacent sectors, or if any was produced from porous limestone (which was quite likely), then the amount obtained from the fissures must have been correspondingly less than 180 tons per day."

This discovery stimulated an intensified study of limestone porosity and permeability, leading to the following classification of Asmari limestone types.

Asmari Limestone Classification.

Types.	Visual characteristics	Average porosity (approx.)	Average permeability (millid'arcys)	Microscopic characteristics	Degree of recrystallisation.
Type 1	Dark grey to light grey and fawn limestones, compact and shiny.	2%	0.00005	Very fine grained, rather marly, fossils well preserved.	Practically nil.
Type 2	Light grey, fawn and light brown limestones, compact.	5%	0.0007	Fine grained, more crystalline and less marly than Type 1. Fossils well preserved.	Negligible.
Type 3	Brown and sometimes light brown limestones, rather granular with some visible voids.	10%	0.05	Rather coarse-grained crystalline limestones. Fossils often destroyed or poorly preserved.	Considerable.
Type 4	Brown and dark brown limestones ; granular, with many visible voids.	15%	0.5	Coarsely grained crystalline limestones, only rare traces of fossil remains.	Almost complete.

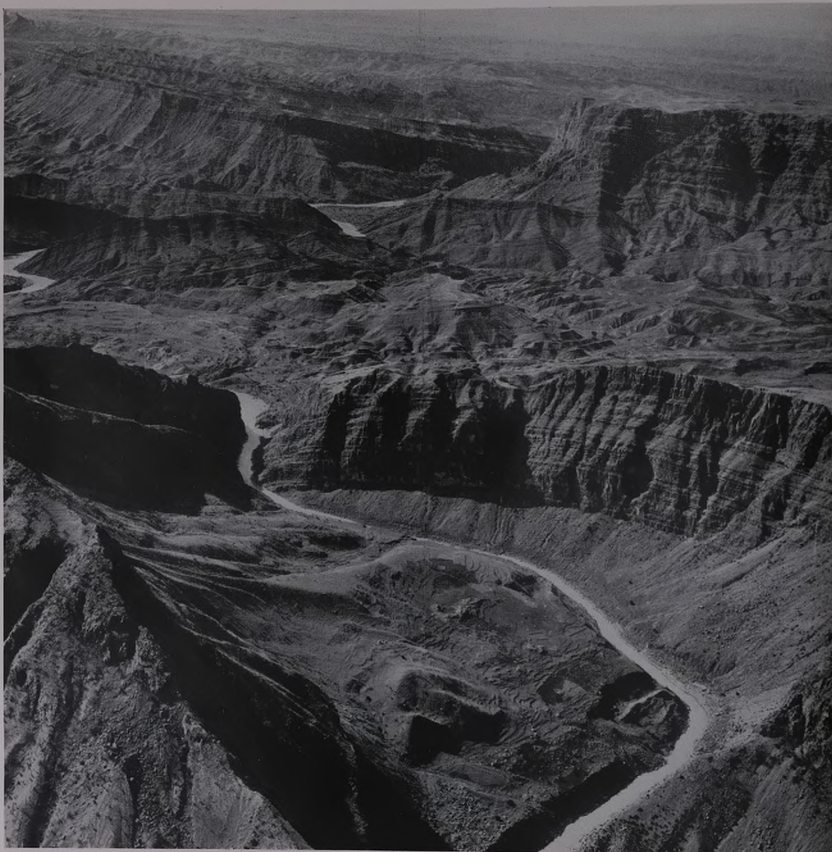
If 100 per cent. core recovery were obtained from every well drilled in the MIS reservoir the material available for examination would amount to less than 1/200,000,000 part of the total volume of the reservoir rock but, in their studies of porosity, permeability and fracturing, the AIOC technologists made full use of the existence in Asmari Mountain, 12 miles to the south-east of an exposed full scale model similar in shape and size to the MIS reservoir. Here two facts became obvious : the infrequency of fissuring over a great part of the mountain ; and the very small width of the fissures which existed. These field studies were followed by the investigation of the flow of fluids along artificial fissures in a cylindrical concrete block in which the width of fissure could be varied by means of differential screw-jacks. Tests were carried out with fissure widths of from one-fiftieth of an inch, as a result of which it was concluded that the width of fissures feeding wells in the MIS reservoir fall within this range. It was therefore concluded that the volume of fissures available for the storage of oil in the reservoir may be quite small.

Confirmation of this conclusion was available in 1934 when all the wells in the most productive sector of the MIS reservoir were simultaneously closed in and readings of the free oil and oil-water levels taken at frequent intervals. Within an hour of shutting down, the gas/oil level, which during production had been falling at the rate of 2½ in. per day, rose 10 in. and continued to rise at the rate of 4 in. per day for the next five days. The initial rapid rise was interpreted as the differential head required to establish a flow gradient from the observation well to the producing wells, but thereafter the fissures were steadily filling up at the rate of 4 in. per day. When production was recommenced over the whole area the flow gradient was re-established by an immediate fall of 12 in. in the gas/oil level, which fell another 8 in. in the next 24 hours. Assuming that during this period the fissures continued to be replenished at a rate of 4 in. per day, as during the shut down period, the production was being supplied by a 12 in. oil column in the fissures. It was concluded therefore that under normal steady production, when the fall of the gas/oil level was 2½ in. per day, approximately 20 per cent. of the oil came from fissures and 80 per cent. from porous limestone.

Having arrived at this conclusion and having obtained an idea of the porosity distribution throughout the reservoir on the basis of the four recognised types of limestone enumerated in the above table, the next step was to determine experimentally if oil, and what proportion, could be obtained from porous limestone. A piece of limestone of about 10 per cent. porosity was filled with crude oil saturated with gas at the initial saturation pressure of 600 p.s.i. of the MIS reservoir. On reduction of pressure at the rate of 100 p.s.i. per hour oil was released from the limestone, the ultimate recovery at atmospheric pressure being 25 per cent. of the original oil content, but four-fifths of this was recovered in the first two hours during which the pressure reduction was 200 p.s.i. In a second experiment with limestone of slightly higher porosity, 20 per cent. recovery was obtained and three-quarters of this was released by the time the original pressure had been halved. These results are almost identical with those obtained with oil sands of much greater permeability, where the mechanism of dissolved gas drive gives a maximum recovery of from 15 to 25 per cent. of the oil content of the sand. In sand fields the porosity has very little effect on the percentage recovery and the experiment suggests that the much lower permeability of the limestone also has a negligible effect.

The demonstration that a large part of the production comes ultimately from porous limestones which feed the fissures, and hence the importance in limestone production of the mechanism of dissolved gas drive, had far-reaching effects. From it springs the realisation that control of pressure decline and therefore of rate of production has a profound effect on ultimate recovery. In the case of Haft Kel it was demonstrated in 1935 that a production of 2.22 million tons a year was more efficient than a rate of 4.1 million and at MIS experience suggests that the optimum rate of production is equivalent to 5 per cent. per annum of the remaining recoverable crude in the reservoir.

As Mr. Gibson points out there is, however, another aspect to this problem : in describing the gas conservation measures in MIS in 1927 it was stated that the pressure in the gas dome was falling at a rate of less than 2 p.s.i. per annum. But this dome pressure is maintained by gas escaping together with oil from the porous limestone, the oil replenishing the oil content of the fissures and the free gas migrating to the gas dome. For this oil and gas to be liberated from the porous limestone the pressure in the fissure system must be lower than the saturation pressure of the oil in the limestone, but the collection of gas in the dome and the maintenance of pressure there also maintain a similar pressure throughout the pressure system. The maintenance of dome pressure therefore inhibits the release of oil and gas from the



AIOC Photo] [by Raymond Wilson

Typical topography in the Lali area

porous limestone to the fissures. The gas/oil ratio of the oil escaping from the porous limestone is approximately 45 to 1 but that of the oil produced at the surface is about 35 to 1. In other words 10 volumes per unit volume of oil produced are collecting in the gas dome. Instead of allowing it to collect there and hinder the production of oil this gas should be produced with the oil to which it belongs. Although this is not physically possible the same result may be achieved by producing from the gas dome sufficient gas to bring the overall producing gas/oil ratio up to 45 to 1. These considerations lead inexorably to the conclusion that the injection of gas into the gas cap, for pressure maintenance or restoration, in fields of the MIS type would be to the detriment of ultimate recovery since it would reduce the pressure differential between the fissures and the porous limestone and so inhibit the replenishment of the fissures by oil from the porous limestone.

The Production System

THE GREAT SIZE AND amplitude of the anticlinal structures and the high degree of connection throughout the reservoirs endow the oilfields of SW Iran with natural advantages which are equalled only in the other limestone fields of the Middle East. These characteristics, together with the undivided control of the entire reservoirs, and the knowledge of the mechanism of oil production gained from unremitting reservoir studies of unparalled scope and detail during the past 30 years, have resulted in the evolution of a production technique which will ensure the maximum ultimate recovery of oil with an unprecedented economy of drilling effort.

In this technique two principles are fundamental : the maintenance of a uniform rise of the oil-water level throughout the entire reservoir ; and the maintenance of bottom hole flowing pressure safely above the bubble point of the crude, so that no free gas is drawn into producing wells. These objectives involve a strict control of pressure and the use of observation wells for the continual check of gas dome pressures, and gas/oil and oil/water levels throughout the reservoir.

The system is typified in the Naft Safid field which is a microcosm of a Middle East oilfield. Here there are two producing wells 1 mile apart, a gas/oil level observation well at the apex of the dome and a oil/water level observation well on the southwest flank. In other fields there are one or more gas/oil level observation wells, oil pressure indicator wells interspersed with producing wells, and oil/water observation wells on the flanks and pitching ends of the structures. Pressures and levels are measured at regular intervals, usually fortnightly, and bottom-hole samples of crude are taken for laboratory study.

Gas dome pressures are measured with a dead-weight tester to an accuracy of half a pound up to pressure of 1,000 p.s.i. and of 1 lb. up to 5,000 p.s.i. Oil pressures are measured originally and at intervals with an apparatus which has been developed from the Kelvin Deep Sea Pressure Gauge. It consists of a graduated Torricelli tube, silvered on the inside and filled with pure dry air above a mercury reservoir. When run into the well mercury rises to balance the reservoir pressure, dissolving the silver from the inside of the tube. Maximum thermometers are run along with the Torricelli tube so that the reservoir temperature is taken concurrently. The tube and thermometers are withdrawn, mercury forced into the tube to the level to which the silver is dissolved, with the tube maintained at the reservoir temperature, and the mercury column balanced against a dead-weight tester. After the original determination of reservoir pressure, and between periodic checks by the Torricelli tube method, reservoir pressures are determined by measuring the wellhead pressure with a dead-weight tester in wells in which the oil level rises to the surface, or by taking the level to which the oil rises in the casing in other wells. Both types of measurement are taken with a conditioned column of oil, in which the crude is saturated at the existing temperature at all points in the column. The reservoir pressure is then calculated from the head of the column of oil, plus the wellhead pressure if any. Oil/water levels are determined by running in a float which sinks in oil but floats in water, which is run on a Halliburton line through a gland on the wellhead. These are taken to an accuracy of 6 in., three consecutive readings within this range being required. Indirect determination of oil/water levels are also made from pressure data, but since pressures above 5,000 p.s.i. are determined to an accuracy of 1 lb., these are accurate only to within 5 ft.

The high degree of connection in the reservoir rock permits a much wider spacing of wells than in sand fields, the average spacing in the developed fields of SW Iran being one well to every two square miles of productive area. Except at MIS, where there are pronounced variations in the distribution of fissures, wells are evenly spaced along both flanks of the structure, and production from the two flanks is regulated to maintain an even rise of the oil/water level throughout the reservoir.

The production system is entirely closed, crude flowing from the wellhead direct to stabilisation units situated at the highest topographical level to which the wellhead pressure will deliver the crude, so that the maximum head is available for the gravity flow of the crude to Abadan.

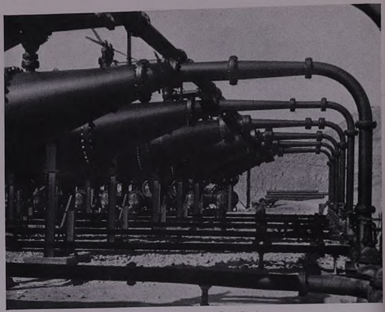
Multistage stabilisation, employing horizontal separators, was installed at Haft Kel in 1930, and units embodying new features were installed at Gach-Saran in 1940 and Agha Jari in 1944. The Gach Saran unit consists of six horizontal separators each 6 ft. in diameter and 100 ft. long, designed to handle 6,000,000 tons of crude per annum. This system is equipped with completely automatic control by means of which a single operator controls both the production of wells and the operation of the stabilisation unit by the manipulation of a centrally situated control panel. Through an electrically operated system the turn of a hand-wheel is relayed to a regulator which controls the flow of stabilised crude in the main pipeline. Restriction of flow raises the level of the crude in the last stage separator where in turn a level controller operates a regulator on the inlet through a pneumatic relay. This in turn raises the level in the next separator and the operation is automatically repeated from separator to separator until the whole unit settles down at the curtailed rate of throughput. The restricted flow to the stabilisation unit similarly raises the crude oil level in the wellhead separator where a level controller operates the wellhead regulator through a pneumatic relay. The operation initiated in the control room and transmitted for some 3½ miles from the pipeline regulator, through the stabilisation unit to the wellhead, is completed in approximately 20 minutes, when the wells settle down to the new production rate predetermined by the operator.

The installation of the stabilisation unit at Agha Jari in 1944 was a war operation, carried out by the company to make available additional supplies of crude for Abadan in the shortest possible time. New pressure vessels designed for the job could not be obtained in under two years and the commissioning of the unit in the spring of 1945 was a masterpiece of improvisation. Pressure vessels, instruments and pumps and every foot of linepipe which could be spared were collected from other areas and pressed into service, and heat exchangers, necessitated by the high temperature of the crude (140° F.), were fabricated from welded nests of 2 in. tubing inside oilwell casing.

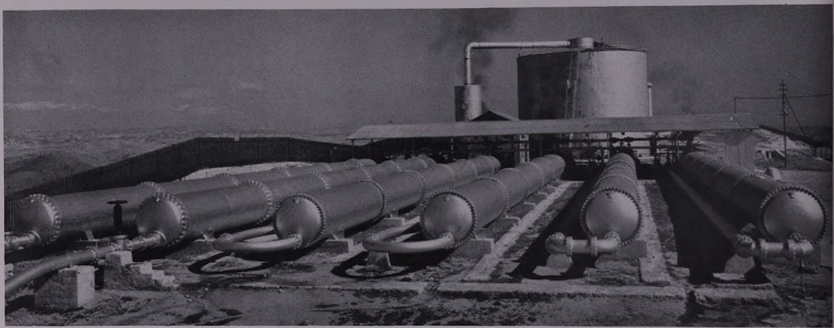
The temporary unit designed for 1½ million gallons per day (2 million tons per annum) consisted of seven horizontal separation operating at pressures of 900, 380, 150, 80, 30, and 18 p.s.i., and atmospheric pressure respectively. The permanent unit consists of three horizontal vessels of the laminated-skin type tested to 1,500 p.s.i. and operated at 1,100 to 1,200 p.s.i. and seven vessels operating at 480, 180, 70, 35, 18, and 8 p.s.i. There is also a vacuum unit for processing export crude. The stabilisation unit is designed for a throughput of 4½ million gallons per day (6 million tons per annum) and in December 1947 was handling 3.7 million gallons per day from 9 wells. The gravity of the crude is 0.856, the gas/oil ratio 151/1, the temperature 140° F. and the flowing pressure 1,500/1,600 p.s.i.

In order to retain the light fractions in the hot Agha Jari crude it is necessary to cool it at the stabilisation unit from 140° F. to 83° F. This is accomplished in batteries of sixty 36 in. heat exchangers and eight 18 in. heat exchangers. The 36 in. units each contain 560 seamless 1 in. tubes through which the incoming crude circulates and where it is cooled by cold stabilised oil circulated through the shell. This is pumped from the last stage separator through the shells of the heat exchangers to the vacuum stage of the stabiliser by centrifugal pumps powered by gas-driven turbines. Gas for the turbines is drawn from the first stage separators, reduced to 280 p.s.i. and preheated to 250° F. In the 18 in. units the cooling medium is gas, which circulates through the shell at 1,500 p.s.i. and enters at a temperature of 49° F. The total surface area of the 36 in. units is 78,120 sq. ft. and of the 18 in. units 3,840 sq. ft.

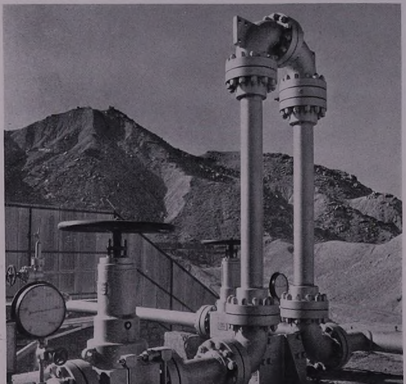
Heat Exchangers at the Agha Jari production unit



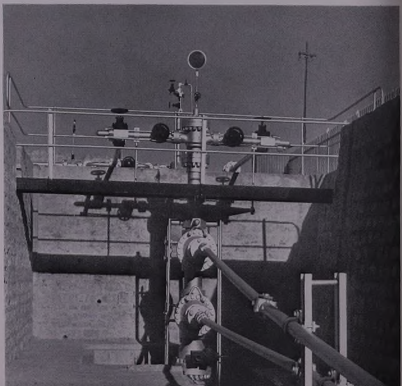
Separators at Agha Jari



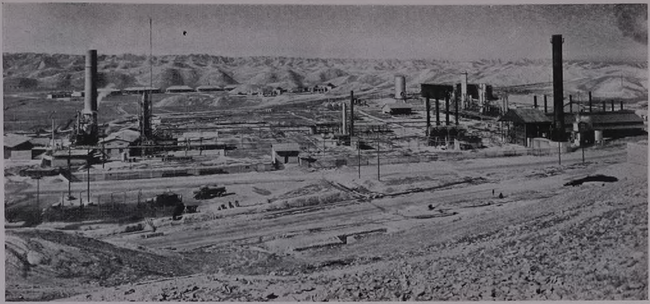
Multi-stage separator at Hafț Kel



Automatic flow valve at Agha Jari



High pressure wellhead fittings at Gach Saran



AIOC Photo] [by Raymond Wilson

The Sulphur plant (left) and absorption plant (right) at MIS

Sulphur Recovery

AT MIS GAS/SEPARATION is carried out in individual wellhead separators instead of at a central production unit as in the newer fields. The wellhead separators are operated at a pressure of around 40 p.s.i. and a further separation is effected in four batteries of flow tanks which are operated at atmospheric pressure. Gas from the individual wellhead separators and from the flow tanks is stripped in a gasoline aborption plant of conventional design and then goes to the sulphur recovery plants where the H_2S is removed by absorption in a solution of potassium tri-phosphate and is afterwards released by heating, and oxidised to elemental sulphur in a restricted stream of air. The two sulphur plants at MIS, capable of producing 40 tons of sulphur per day, are the source of the greater part of the sulphur required at Abadan for the manufacture of sulphuric acid.

Oil from the flow tanks is pumped either to the Tembi pipeline terminal for despatch to Abadan or to a topping plant consisting of three tube stills with an aggregate capacity of 2½ million gallons per day. This is operated in such a way as to balance the offtake requirements of light and heavy products from the refinery at Abadan. When fuel oil residues at Abadan become surplus to immediate requirements, the topping plant at MIS is operated to produce a 55 per cent. distillate which is blended with untreated crude for despatch to the refinery, and the residue is returned to the reservoir through injection wells located to ensure even distribution throughout the formation. Great care is taken to prevent the injection of sufficient quantities of viscous products to raise the viscosity of the reservoir crude to a point where it would inhibit production. In fact, tests have shown that the heavy injected products settle in the reservoir to just above the oil/water level.

At other times, when fuel oil offtake at Abadan has been disproportionately high in relationship to the demand for motor spirit, residue from the topping plant has been blended with untopped crude for despatch to Abadan and distillate has been injected into the reservoir.

During the war, when the normal balance of demand from Abadan was severely disturbed by military requirements, heavy or light products from the refinery were also returned by pipeline for injection into the MIS reservoir. Thus the accumulation of surplus products, which would ultimately have involved curtailment of output of much needed products from Abadan, was avoided.

Products from the topping plant, together with untreated crude from the flow tanks, are pumped to the pipeline terminal at Tembi where there are two balance tanks each of 2.5 million gallons capacity. The Tembi pump station manifold is so arranged that, when required, distillate or fuel oil cuts from the MIS topping plant can bypass the balance tanks and be pumped direct to Abadan in uncontaminated state through one of the pipelines which is temporarily isolated from the main system.

The Pipeline System

The total capacity of the pipeline system connecting the fields of SW Iran to Abadan is 22 million tons per annum or an average 16 million gallons per day. The total length of line is 1,533 miles made up as follows :—

The Pipeline System in SW Iran.

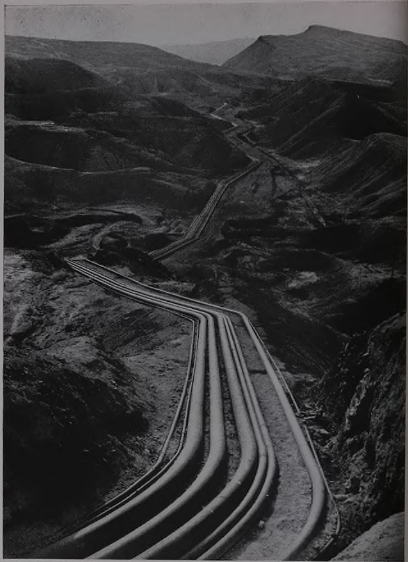
Field	Completion date	Length in miles	Diameter in inches	Route
Masjid-i-Su'aiman	1911	133	10	Masjid-i-Sulaiman—Abadan
	1916	133	10	Masjid-i-Sulaiman—Abadan
	1917	133	12	Masjid-i-Sulaiman—Abadan
Haft Kel	1929 to 1938	136	12	Haft Kel-Abadan
		136	12	Haft Kel—Abadan
		124	12	Haft Kel—Marid
		61	12	Haft Kel—Kut Abdulla, where it joins the main system to Abadan
Gach Saran ..	1940	166	12	Gach Saran—Abadan and Bandar Mashur
Agha Jari ..	1945 to 1948	97	12	Agha Jari—Abadan
		97	12	Agha Jari—Abadan
		97	12	Agha Jari—Abadan
		42	12	Agha Jari—Bundar Mashur
Naft Safid ..	1945	32	10 and 12	Naft Safid—Wais, where it joins the main system to Abadan
Naft-i-Shah ..	1935	146	3	Naft-i-Shah—Kermanshah

Lines laid before 1932 were screwed and coupled, but since that time welded lines of 12 in. diameter have been employed. The normal wall thickness is 0.330 in. with heavy sections of 0.375 in certain parts of the foothills. To minimise soil corrosion and facilitate maintenance all lines are laid on the surface and are snaked to allow for expansion and contraction. To allow for the diurnal range of temperature of 100° F., and a range of 120° F. throughout the year, the degree of offset in the line is 6 ft. per 100 ft. of pipe, giving an average angularity of 3° 29″ from the true alignment. The line is laid on bearers which not only permit full movement during expansion and contraction but also prevent soil corrosion.

Except at MIS the production units are located at elevations which enable them to deliver crude to Abadan by gravity flow, but booster pumps are installed at the production units to increase the capacity of the pipelines. At Agha Jari there are five multi-stage centrifugal pumps each capable of delivering 1.5 million gallons per day (2 million tons per annum), three at a pressure of 800 p.s.i. and two at a pressure of 600 p.s.i. They are driven by gas-expansion turbines operated by gas obtained from the stabilisation unit as in the case of the circulating pumps in the unit itself. The gas has to be pre-heated before use in the turbines to prevent condensation.

At Gach Saran there is at present a booster pump at the production unit which gives a capacity of 1.9 million tons per annum. The throughput in the Agha Jari and Gach Saran lines will eventually be increased by installation of a boost station at the meeting point of the two lines. Further development of the lines and pumps at the production units is also in hand.

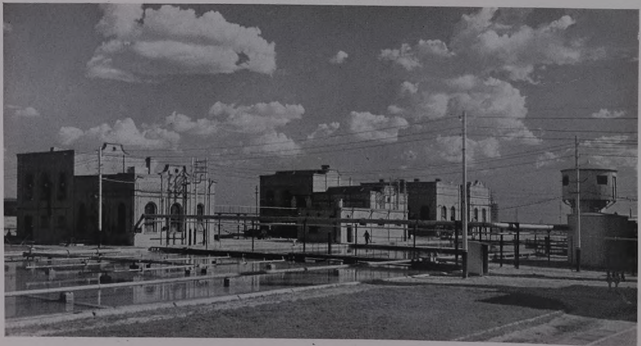
A high degree of flexibility is a feature of the entire pipeline system, the lines and manifolds being so arranged that pressure crude, stabilised crude or topping plant products can be pumped separately to the refinery from any field. As all crude or products entering the pipelines are water free, any water produced being flashed off in the first stage of separation, crude is normally fed direct from the pipelines to the distillation benches at the refinery, where the crude storage is used to balance field production and refinery throughput.



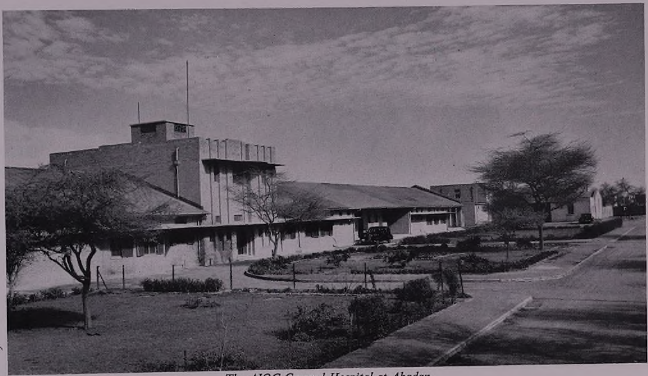
AIOC Photos] [by Raymond Wilson

The pipelines from Agha Jari

The Kut Abdulla pump station



The approach to the Gach Saran Oilfield



The AIOC General Hospital at Abadan

General view of the Haft Kel country

AIOC Photos
by Raymond Wilson

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A general view of the refinery from Braim

ABADAN Refinery

THE ABADAN REFINERY is the largest refinery in the world, not only in input capacity which is 16.7 million gallons (495,000 barrels) per day, but in its cumulative throughput, which at the end of 1947 was 1,543 million barrels. It manufactures a complete range of products from aviation spirit to fuel oil and bitumen, with the exception of lubricating oils, but a plant for the production of 20,000 tons of lubricating oil per annum is under construction. Mere enumeration of the capacity of the various units comprising the plant, or of the volume of products produced, does not, however, give an adequate impression of the vast size and scope of the refinery and its ancillary services which, excluding tank farms and housing, cover an area of approximately 400 acres.

Crude oil is delivered to Abadan from the five fields at Masjid-i-Sulaiman (MIS), Naft Safid (White Oil Springs), Haft Kel, Agha Jari and Gach Saran, through eight 12-in. and two 10-in. pipelines at a terminal pressure of from 40 to 45 p.s.i. The crude, which may also contain products from the three topping plants at MIS, is water free and has a Reid vapour pressure of 10 lb.

Crude storage capacity at the refinery is 28 million gallons, and is usually kept half full to balance field production and refinery throughput, but in normal circumstances crude is fed direct from the pipelines to distillation units through a manifold which is so arranged that all incoming streams of crude can be mixed. The reader is now referred to the accompanying flow sheet where the courses of various fractions derived from crude oil are followed until these fractions become marketable products.

Crude Oil Distillation

There are four large distillation units with an aggregate input capacity of 12 million gallons per day and five smaller units with an aggregate capacity of 4.7 million gallons per day, giving a total input capacity of 16.7 million gallons per day.

A simplified typical flow diagram for a crude distillation unit is shown in the accompanying figure. After heating to about 335°F. by heat exchange against hot products, fresh crude oil passes into the first column (or primary tower) which is operated at a pressure of 50-60 p.s.i. Here, material boiling up to about 90°C. (including H_2S and permanent gases) is removed. The gaseous fractions which contain appreciable quantities of valuable butane are passed through a gasoline recovery plant, and permanent gases are subsequently used as works fuel. The liquid overhead from the primary tower (which is known as primary flash distillate) is passed via an alkali wash to pressurised storage and then goes to a gasoline fractionation area as feedstock for the manufacture of certain components of aviation fuel.

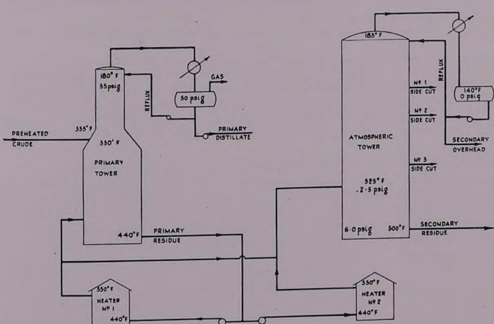
The residue from the primary flash column passes to two pipestills which are operated in parallel. In these pipestills the oil is heated to about 550°F. From one of these stills a proportion of the output is recycled to the primary column base, in order to supply sufficient heat at this point for proper operation of this tower. The remainder of the output from the first furnace and the whole of the output from the second furnace passes to the vaporisation zone of the secondary or atmospheric distillation column. A secondary column normally contains 20-25 fractionating plates and four to six stripping plates, the latter being located in the section of the column beneath the vaporisation zone. A correct temperature gradient is established in this tower by close regulation of the reflux applied at the tower top. The overhead product is a closely fractionated material boiling between 70°C. and 105°C. (ASTM Method) and is known as iso-heptane base. This material is subsequently refractionated to produce aviation spirit components. The tower is provided with three sidestream offtake points from which the three main streams are normally drawn :—

(1) Straight run benzine cut—boiling range 115-170°C.

(2) Kerosine—boiling range 160-240°C.

(3) Gas oil—boiling range 230-360°C.

By modification of operating conditions, the unit can be made to produce a rather wider benzine cut as the column overhead, and white spirit of boiling range 140-180°C. as the No. 1 sidestream product. Another variation in operating conditions enables the units to produce a " once run distillate " suitable for feedstock for thermal reforming, from the upper side streams. The residue from this column, comprising some 46 per cent. by volume of the crude charge, passes through heat exchangers in order to give up its heat content to incoming crude oil, and is then stored for either subsequent processing or blending into fuel oils.



Simplified flow diagram—crude oil distillation unit

Vacuum Distillation

Part of the residue from the atmospheric pressure column is pumped to vacuum distillation units, of which there are five with a total input capacity of 2.55 million gallons per day. In these units, the residue is heated to about 700°F. in pipestills and fractionated in columns operated at a vacuum of 100 mm. of mercury to yield the following products :—

(*a*) Heavy gas oil, which is blended with the lighter gas oil fraction from the atmospheric column.

(*b*) A jute batching oil which is sold as such.

(*c*) A long wax distillate cut which is used as charging stock for thermal cracking operations. A catalytic cracker of 1,000,000 gallons per day input capacity is projected and will replace the existing thermal cracking units. It will be operated to yield 30 per cent. of motor spirit component, 15 per cent. gas and butanes, and 55 per cent. gas and fuel oil residues.

(*d*) Bitumen which is subsequently rectified into a variety of sales grades of asphalt.

Part of the wax distillate fraction will, in the future, be separated into three different streams which will become charging stocks for lubricating oil manufacture.

Superfractionation

The primary flash distillate from the pressure columns of the distillation unit, and gasoline from the gasoline recovery plant are refractionated in a series of columns containing from 30 to 50 plates each, and operating at pressures ranging from 250 p.s.i. down to 50 p.s.i. There are six of these units and they are normally used to carry out three operations :—

(i) the removal of propane and lighter hydrocarbons for use as works fuel.

(ii) refractionation of the residue from the first operation to collect butanes.

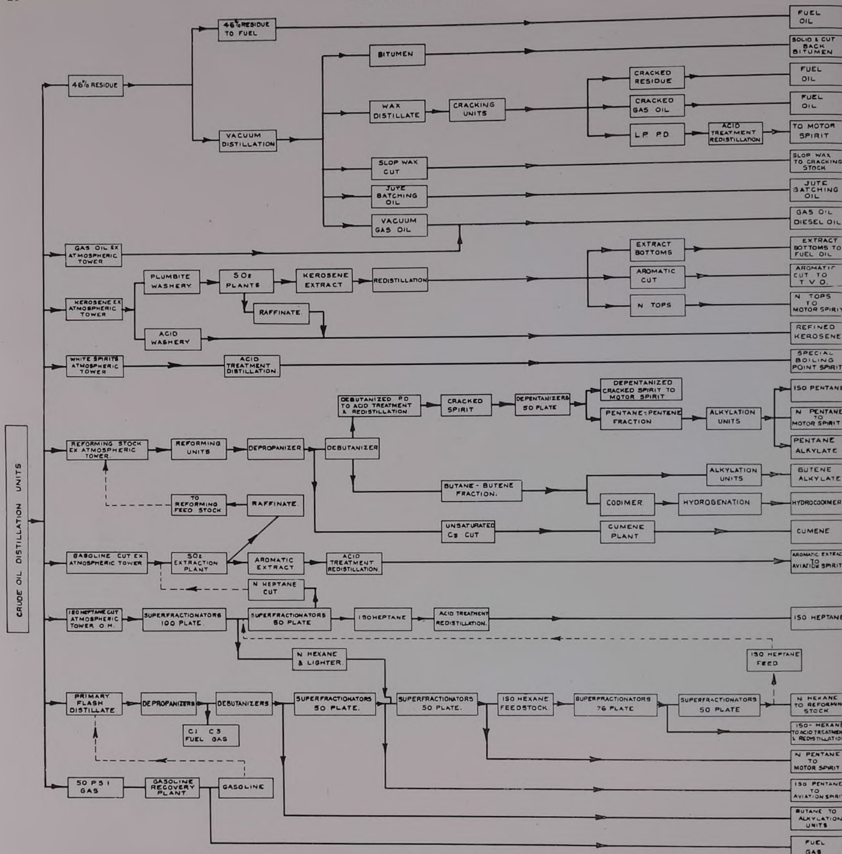
(iii) refractionation of the residue from the second operation to collect iso-pentane.

The butanes are used in the manufacture of alkylate for aviation spirit, whilst iso-pentane, after refining with sulphuric acid, also becomes an aviation spirit component.

The residue from these operations is forwarded to a special products area, where there is a total of 14 superfractionation columns. Some of these columns contain 50 fractionating plates, others 38. The two types can both be used in pairs, so that for certain high precision distillations, units of either 76 or 100 fractionating plates are available. The sequence of operations through the units in this area may best be understood by reference to the flow sheet. The products obtained are (1) normal pentane, which passes after refining to motor spirit, and (2) iso-hexane and iso-heptane, both of which fractions are suitable for inclusion in high grade aviation fuel. Discards from this series of operations consist mainly of the normal paraffins in the C.6 to C.8 range ; these discards are passed to thermal reformer feedstock. The iso-hexane and iso-heptane fractions are refined by treatment with sulphuric acid followed by redistillation and are then ready for blending in aviation fuel.

Alkylation and Isomerisation

Aviation alkylate is produced by the chemical combination of iso-butane with butenes and pentenes, the latter being recovered from thermal reforming operations. The necessary iso-butane is obtained from the close fractionation of



Refinery flow diagram at Abadan

mixed butanes followed by the iso-merisation of the residual normal butane to the iso-compound. There are three alkylation units with a total output of 350,000 gallons of aviation grade alkylate per day. No. 3 unit with an output of 140,000 gallons per day is the largest unit of its type in the world. In these units, iso-butane is contacted in horizontal reactors with butenes or pentenes in the presence of 98 per cent. sulphuric acid. This process yields a stable alkylate with a motor method octane rating of 90-94 and a good rich mixture performance. Three iso-merisation units are operated in conjunction with the three alkylation units and the whole process can really be considered as one operation.

Catalytic Polymerisation and Hydrogenation

Before the invention of the alkylation process it was customary to prepare butene polymers which could subsequently be hydrogenated to give mixed iso-octanes. These processes would have been regarded as obsolete with the advent of alkylation, but were kept in operation during the war, to the limit of available feedstocks, in order to augment the production of aviation fuels. In the catalytic polymerisation process, a molecule of normal butene reacts with a molecule of iso-butene to form a "codimer," and a full scale plant for this purpose is installed in Abadan. In another plant iso-butene may be polymerised to produce di-iso-butene in the presence of 55 per cent. sulphuric acid.

AIOC Photo.] By Hunting Aerosurveys Ltd.

The western portion of the refinery

The unsaturated compounds from both these plants are hydrogenated at 1,300-1,400 p.s.i. in a conventional type of hydrogenation unit, to produce a saturated material consisting of mixed iso-octanes. The hydrogen required for this reaction is manufactured at the hydrogenation unit from methane, from the thermal reformers.

Solvent Extraction

Aromatic hydrocarbons for inclusion in aviation fuels are prepared from the benzine cut, which is taken from the atmospheric columns of the main distillation units, by solvent extraction. The method used is similar to the conventional Edeleanu sulphur dioxide extraction process. A product containing 75 per cent. of aromatic hydrocarbons may be prepared. If necessary a product of higher purity, up to 95 per cent. aromatics, can be produced by a second extraction for which facilities are provided in the fourth and most modern of the solvent extraction plants at Abadan.

Kerosine is also given a solvent extraction treatment with liquid sulphur dioxide. In this case the treatment is applied to improve the burning qualities of kerosine, but the extracted aromatic hydrocarbons form a valuable by-product, which is used in the preparation of tractor vapourising oil.

Aviation Fuel Blending

The several aviation fuel components previously described are collected separately in refined oil storage and are subsequently blended and leaded to produce the normal 100-130 grade aviation fuel, which was used by the Allied Air Forces during the war and is now used by most commercial air lines. During the war, more than 20,000,000 barrels of this product were supplied to United Nations forces.

Thermal Reforming

Once-run distillate (light fractions in the spirit and kerosine boiling range) from the atmospheric columns of the main

Two of the 3,000,000 gallons per day distillation units

Super-fractionators for the preparation of aviation fuel

One of the cracking units

AIOC Photos by Raymond Wilson

distillation units, and discards from superfractionation operations are used as charging stock to a battery of ten thermal reformers, which have an aggregate input capacity of approximately four million gallons per day. The stock is processed through the unit furnaces at temperatures up to 1025°F. and pressures which may range from 200 to 900 p.s.i. Products from the reforming process are fractionated for the removal of gases and for the recovery of butenes, pentenes and pressure distillate. The butenes and pentenes are subsequently used in the alkylation process, whilst pressure distillate is treated with sulphuric acid and redistilled to yield cracked spirit which is suitable for inclusion in motor spirits. Acid treatment and redistillation is applied to remove unstable or "gum-forming" compounds. A heavier cracked spirit is also recovered from the redistillation stage and is used as a component of tractor vapourising oil, whilst the redistillation residue is employed as a diluent of heavy fuel oils. When reforming a once-run distillate stock of about 40 octane number, the yield of 70 octane motor spirit is from 65-70 per cent.

Bitumen Manufacture

The residue from the vacuum distillation units is transferred to rectification stills where it is air blown to yield products with the desired characteristics. A wide range of solid and "cut-back" bitumens, including emulsifiable grades, is manufactured and exported in drums which are made in the refinery. The present capacity of the bitumen plant is 240,000 tons per annum, and during the war 800,000 tons were supplied to the United Nations for the construction of roads and airfield runways.

Chemical Refining

Extensive chemical refining plant has been installed in Abadan and all products with the exception of gas oil, diesel oil, fuel oil and bitumen are chemically refined. Sulphuric acid treatment is widely used, particularly for aviation spirit components where the removal of sulphur compounds is all important. These acid treatments are usually followed by redistillation when a product of very low sulphur content is required. Kerosine is normally extracted with sulphur dioxide for the removal of aromatic hydrocarbons. This process improves the smoke point of the kerosine, i.e., improves its burning qualities. The plumbite process is employed for the final sweetening of kerosines and certain motor fuel components. A unique feature of the refinery is the employment of the Holley Mott system of continuous counter-current washing in the refining treatments area. The Holley Mott washery is used for acid or hypochlorite treatments and consists of a number of treatment stages. The system is so arranged that the oil under treatment and the chemical used flow counter-currently through the unit, the flow from stage to stage being actuated by the difference in specific gravity between the oil under treatment and the chemical used. Each treatment stage consists of a compartmented vessel, one part of which contains a motor-driven paddle, the other section of which is used as a settler. The counter-current system ensures the best utilisation and therefore the minimum consumption of chemicals.

Still more unique is the extent to which chemicals required in refining are produced by the company itself in the refinery area.

Sulphuretted hydrogen is removed from natural gases by scrubbing with a solution of potassium triphosphate. This solution liberates the H_2S on heating and this is converted into sulphur by burning in a restricted air supply, whereby the hydrogen in the H_2S is oxidised to water, releasing the sulphur in the free state. There are two plants at MIS with a combined capacity of 40 tons of sulphur per day from natural gas, and one plant at Abadan with a capacity of 15 tons per day from refinery gas.

Sulphuric acid is manufactured from imported sulphur and from the sulphur recovered from natural and refinery gases. 225 tons per day of concentrated sulphuric acid can be made from sulphur, whilst a further 130 tons per day may be recovered from spent acid from alkylation processes, and 90 tons per day from acid tar obtained from various treatments. Most of the sulphur used is that obtained from local resources.

Hydrochloric acid is manufactured both as a dry gas for use in the isomerisation plant and as liquid for descaling refinery equipment and for the acid treatment of wells in the fields.

Lime water is widely used in the refinery as a neutralising agent for removing acidity from chemically treated products and for removing H_2S from crude distillates. Some 25 tons per day of lime are produced by calcining sea shells, which are collected from deposits occurring in the Persian Gulf area.

Ancillary Services

The power requirements of the refinery can only be compared with those of a great city. The consumption of power as steam and electricity is in fact equivalent to 100,000 h.p., which is of the same order of magnitude as that of the Central London area. The water requirements for steam raising and cooling are

Pipelines from fields entering the refinery even more astronomic, the rate of pumping being 20 million gallons per hour—one and a half times as much as that pumped by the Metropolitan Water Board.

Steam is generated in four large batteries of boilers strategically located throughout the refinery. The power station battery supplies steam for the turbine driven generators and to the neighbouring parts of the refinery. It consists of 12 boilers rated at 100,000 to 150,000 lbs. per hour and twelve rated at 40,000 lbs. per hour, with a combined working output of 1,200,000 lbs. per hour. The boilers are of the water-tube type equipped for oil or gas firing and fed by softened and de-aerated water. They generate steam at 200 p.s.i. which is superheated to 700°F. The power station is fed direct from the boilers and the remainder of the output of this battery is distributed to the refinery plant through overhead steam mains of 12 and 14 in. diameter.

The cracking area is serviced by a battery of six large and 10 smaller units with a working output of 850,000 lbs. per hour, and the special products area by 15 boilers of 135,000 lbs. per hour capacity. The fourth battery is at the No. 3 water pump house and consists of four boilers each rated at 45,000 lbs. per hour.

The total output of steam is thus some 3,690,000 lbs. per hour, which, if all were used for electricity generation, would yield 370,000 kW. All the boiler batteries are inter-connected by insulated overhead steam mains of 14-in. diameter and operating at 200 p.s.i.

Electric power required in the refinery and in the residential areas is generated at a central power station with a total capacity of 84,000 kW. and a working load of 60,000 kW. The station contains nine turbo-alternators, three of which are rated at 20,000 kW., two at 6,000 kW., two at 4,000 kW. and two at 2,000 kW. All the turbines run at 3,000 r.p.m. and are provided with automatic speed governors. The steam exhausts to a surface condenser immediately below the turbine from which the condensate is returned to the boiler battery. The condensers of the 20,000 kW. machines contain upwards of 10,000 tubes through which the condensing water flows. This water is brought from the river by 48-in. diameter mains and returns to the river through 54-in diameter pipes.

The generators produce alternating current at 50 cycles per second and are all three-phase machines. The large generators operate at 11,000 volts while the smaller machines generate at 3,300 volts. Each machine has its own direct current exciter, which is mounted on an extension of the main shaft. The generators are cooled by air, driven through them by fans which, after use, is cooled by a tubular water cooler. The air system is a closed one and so no dust is drawn into the machines from outside.

The large machines deliver their power to the main totally enclosed 11,000 volt switchgear. The stationary parts of this switchgear are filled with insulating compound, while the actual switch opens and closes beneath the surface of oil contained in a strong steel tank. All the main refinery feeders are taken from this switchboard. The smaller sets are connected to an older, 3,300 volt switchboard which is also of the metal-clad type. In order to transfer power from this board to the main board, there are five interconnecting transformers which are connected between the two switchboards. The power required for internal use in the station is taken from the 3,300 volt switchboard, through two transformers which convert it to 440 volts and supply a small auxiliary switchboard.

The control of the running generators and all the main switches is performed from the station control room in which a series of panels carry the control switches for the various units, the instruments showing the amount of power from each machine, or to any particular feeder, the protective relays, and a number of coloured lights which show at a glance which switches are closed or open.

Distribution of power is effected over a network of underground cables which connects the main switchboard at the power station to 17 major substations. This system operates at 11,000 volts. At each substation, the voltage is reduced by transformers of 4,000 kVA, and 1,000 kVA to 3,300 volts and 440 volts respectively. Smaller substations and large plants are supplied at 3,300 volts, and the 440 volt supply is used for all motors up to 50 h.p. and for all lighting.

The total connected load in Abadan is 120,000 kw., but to-date the highest load which has been recorded is 38,000 kw. The annual load factor at 75 per cent. is very high compared with many other supply authorities.

A new pump house has recently been completed for supplying water from the Shatt-el-Arab to the power station. It has three steam turbine driven pumps each with a capacity of 3.5 million gallons per hour. The power station was formerly supplied by No. 3 pump house, which has two pumps of 5 million gallons per hour capacity and three of 2.2 million gallons capacity, all steam turbine driven. This pump house will now feed other boiler batteries and services in the refinery. A third pump house houses six electrically-driven pumps each capable of delivering 0.3 million gallons per hour, and is maintained as a reserve source of supply.

In addition to these three pump houses drawing water from the river, other installations pump water over the four cooling towers each of which has a capacity of 1.8 million gallons per hour. The total water pumping capacity of the refinery is therefore 36 million gallons per hour.

Shipping Facilities

Abadan is situated on the Shatt-el-Arab, some 40 miles from its mouth. Navigation is controlled by the Port of Basrah Authority, but the AIOC maintains five modern dredgers to keep the channel open for ocean-going vessels.

There are 15 oil-loading jetties each of which is so equipped that two and sometimes three grades of oil can be loaded simultaneously. The loading rates vary from 500 to 750 tons per hour for white oils and 1,000 to 1,250 tons per hour for black oils. The total loading capacity is some 1,500,000 tons per month to some 150 tankers.

Two jetties are used for the import of general cargo averaging 15,000 tons a month. One of these jetties is also utilised for the export of bitumen, which is carried by a conveyor from the bitumen plant inside the refinery to the ship's side at the rate of 1,000 tons a day.

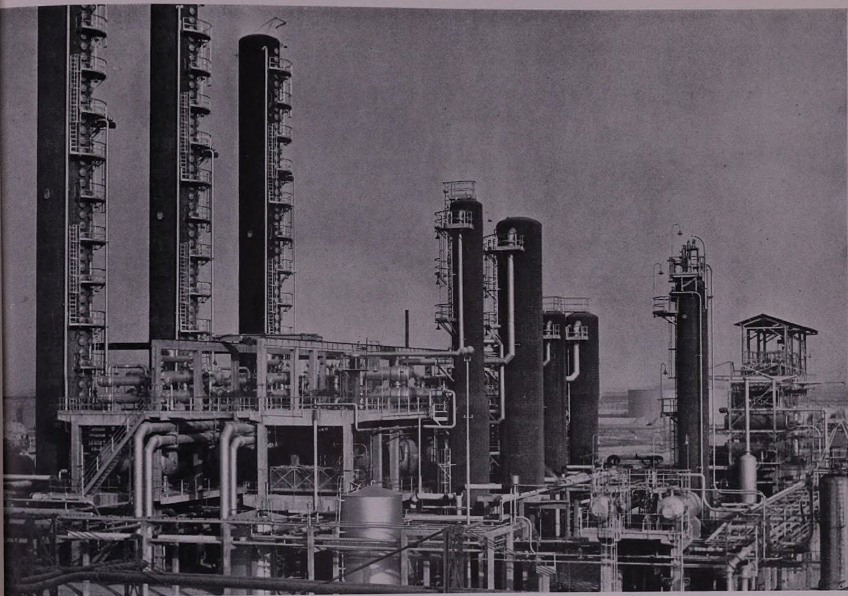
The company has twelve large modern sea-going tugs based on Abadan for servicing all shipping. Certain of these tugs are fitted with fire-fighting equipment and can also be used for salvage purposes. In addition to these large ones, there are 22 smaller diesel-engined tugs and approximately 120 barges, which are utilised for transporting imported goods and local materials to and from Ahwaz, Kut Abdullah, Basrah, etc.

For the maintenance of all craft based on Abadan, there are large modern engineering workshops where repairs of all descriptions can be effected to ocean-going vessels. There is also a floating dock capable of lifting 750 tons for the purpose of carrying out under-water repairs and for periodical dockings of small vessels. A larger floating dock will shortly be available.

The British Tanker Co.

This is not the place to review in detail the history and operation of the British Tanker Co., the wholly-owned shipping subsidiary of the AIOC, but no account of the Abadan refinery would be complete without brief reference to the tanker fleet which carries its products to Europe, India, Australasia and the Far East.

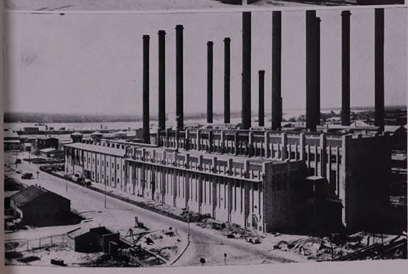
The foundations of the company were laid in 1915 and seven vessels were built in the next two years. The *British Emperor* was the first tanker built specially for the company. In early life she lightered cargoes from Abadan over the Shatt-el-Arab bar before it had been dredged to its present depth. Later she played her part in ocean-going service, before coming to a noble end on active service. By the end of World War I the fleet numbered 30 ships, including a number of vessels managed by the company for the British Admiralty. The cessation of hostilities brought an intensive building campaign and by 1924 the company had 60 ships with an aggregate capacity of over half a



One of the alkylation units

The bitumen conveyor

The cargo jetty at Abadan



The Abadan power station

AIOC Photos
by Raymond Wilson

million tons. Meanwhile, bunkering stations had been opened in Aden and Colombo in 1920, and at Port Said in 1921, and thereafter in Africa, Australasia and throughout the Far East. With these facilities and with the development of the parent company's trade in Europe—AIOC subsidiaries having been formed in Belgium in 1919, Norway and Denmark in 1920, France in 1921, and Italy in 1924—and with the opening of National Oil Refineries U.K. refinery in 1921, the fleet, which had been partially employed to transport oil from the Western Hemisphere to the U.K., was increasingly employed in trade between Western Europe and the Persian Gulf.

The year 1924 was also notable for the addition of the first motor vessels to the fleet. These were the pioneering days of the motor ship and with the *British Aviator* and *British Motorist* the company played its part.

By 1939 the fleet had grown to 93 vessels with an aggregate capacity of one million tons. In World War II the fleet added many illustrious pages to the annals of British maritime history: between September 1939 and August 1945, 46 million tons of petroleum products were carried to sustain the war effort of the United Nations, and large quantities of equipment and stores, including planes and gliders, were carried on temporary decks constructed over the oil tanks. In this service the fleet sustained grievous losses: 44 vessels were sunk; 657 officers and men were killed and 273, of whom 16 died in captivity, were taken prisoner. For their personal heroism, and as a tribute to the steadfast service of their comrades through years of peril, the names of 210 men of the fleet have appeared in the Honours List.

Despite the high building costs and the shortage of materials, good progress has been made in post-war construction. The war-time losses have already been made good but the building programme is not yet complete. When all the vessels now under construction and on order have been completed the tonnage will exceed the pre-war total by 30 per cent. Then a fleet of 1,300,000 tons will carry the House Flag of the British Tanker Co. to the four corners of the earth, with cargoes of oil from Abadan.

AIOC Photo] *The Bawarda oil jetties at Abadan* [By Hunting Aerosurveys Ltd.

A.I.O.C. Photo.] [By Raymond Wilson

Part of the Bahmanshir artisan housing estate

Amenities and Social Work in IRAN

The Anglo-Iranian Oil Co., with a total of some 55,000 employees of which 50,000 are Iranians, is by far the largest employer in Iran. The next largest employers are the railways with some 16,000 employees. In addition some 20,000 Iranians are employed by contractors working exclusively for the AIOC with the result that the company provides direct employment for 70,000. The company's wage bill in Iran amounts to approximately £1,000,000 per month.

The distribution by categories of employees and by areas of the company's Iranian employees is as follows :

	Abadan	Fields	Total
Iranian Employees :—			
Staff	3,700	800	4,400
Artisans	5,300	2,400	7,700
Skilled	15,100	4,900	20,100
Unskilled	9,700	4,600	14,300
Total	33,800	12,700	49,800*

* Includes 3,300 employed on distribution.

Forty years ago Abadan was an island swamp ; today it is the site of the largest oil refinery in the world and the home of a community of some 140,000 souls. To house, feed, and provide for the physical, social and spiritual needs of this community has been a major task confronting the company. This task has been rendered incomparably more difficult by the fact that expansion of the refinery and growth of the population has not been uniform. Between the wars the growth was a process of steady evolution, and the provision of houses, bazaars, hospitals and schools kept pace with the growth of the population. Just before the war the company undertook a housing scheme at a cost of £2 million, which in the normal course would have provided for all needs for several years. During the war, however, to meet the needs of the United Nations armed forces, the capacity of the refinery has been doubled and a large proportion of the increased capacity is for aviation fuel, which had not previously been made at Abadan. A result of this expansion is that the population of the island was doubled, at a time when construction work had to be concentrated on the refinery itself, when further substantial inroads were made on the company's resources of man-power and materials by the Aid to Russia programme, and when materials and shipping were in short supply.

As soon as raw materials and the ships to carry them could be made available the company embarked on an ambitious building scheme involving new housing estates, sanitary and medical facilities, shops, clubs, cinemas, sportsgrounds and schools, at an estimated cost of £15 million.

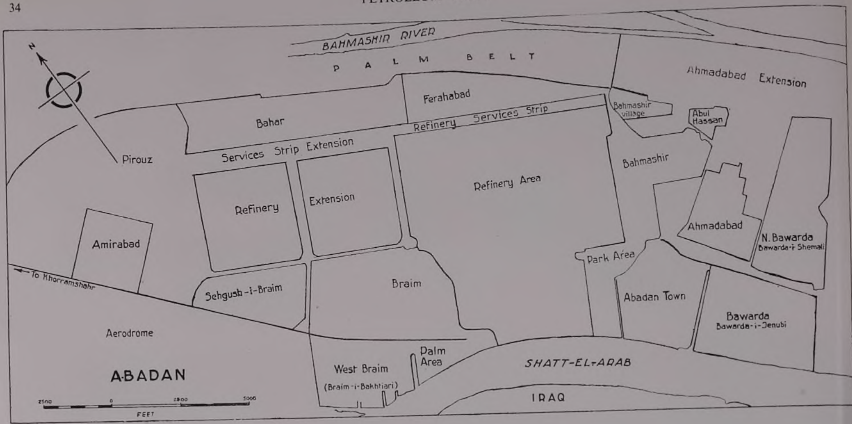
This scheme has involved the laying of 25 miles of new sewers and calls for the construction of 2,000 houses for British and Iranian staff and 8,600 houses for labourers. Since the inception of the scheme effort has been concentrated on housing for labour with the result that 2,500 houses have been built since 1945. All are of brick or stone and are equipped with electric light, water and sanitation.

There are at present four company housing estates for labour at Abadan, containing 5,400 houses and accommodating 21,300 people. Bahar, at the north-east corner of the refinery, has been built since the war and contains 465 houses of two or four rooms accommodating 1,120 people. Owing to shortage of equipment and craftsmen electricity is not yet available in these houses but will be installed as soon as fittings can be obtained. Another 400 houses are under construction in this area. The Farahabad estate contains 2,008 houses with another 1,500 under construction or to be added, and has a present population of 6,207. Built in the period of acute material and equipment shortages during and immediately after the war, most of these houses were built as two-roomed quarters, but are now being converted into three-roomed quarters with all services laid on.

Bahar and Farahabad are far from the bazaar and consequently the company has built and opened shops in these areas. These shops are leased to old service employees. More such shops are being built. In addition, a bus service is operated by a contractor between Farahabad and the bazaar, the fare being one rial (1.8462d.) per journey.

The Ahmadabad estate contains 886 houses with an approximate population of 3,500. This area is regarded by the company as a war time expedient only. The houses have two rooms, no electrical fittings, and the water supply is communal. When the housing situation has eased, this area will be demolished.

The Bahmanshir estate contains the best type of accommodation yet available. There are, in this area, three and four-roomed houses with electric light, fans and water supplied and also two-



roomed houses which have not, as yet, been fitted with fans but have all the other amenities. There are 2,357 quarters in this area, which houses a population of approximately 12,000. In this estate are housed long service employees who are, for the most part, high grade artisans.

The Bahar, Farahabad, Ahmadabad and Bahmanshir estates are for married employees and their dependents. For bachelors there are : a Nissen hut camp with accommodation for 603 men ; six hostels, each with 16 rooms holding four men per room, for artisans and skilled workers earning more than 50 rials per day (7s. 8d.) ; and bachelor quarters at Bahar reserved exclusively for recruits from Tehran.

The houses are allocated to employees on a points system, one point being awarded for every rial of daily pay and 2½ points for each year of continuous service. The different types of houses have varying points value according to their amenities. At present 58 points are necessary to qualify for accommodation but by the end of 1949 it is hoped that accommodation will be available for all employees who have 45 points, which in effect means for all skilled labour and long service unskilled labour.

In the oilfields approximately one-third of the employees are housed at present, there being 1,700 houses at MIS, where two new houses are being completed in every three days. In the other fields houses are being built at the rate of four per week. In the fields areas all new houses are built of stone and blend effectively with the rugged scenery of the Zagros foothills. All are provided with electric light and fans and water is laid on. The company also encourages employees to build their own houses and provides water and electricity for all such houses which are to approved standards.

In the Naftun area, in which most of the post-war construction at MIS has taken place, the company has built handsome and commodious club premises for its Iranian labour. It contains reading and card rooms, a bar, and an auditorium with seating accommodation for 600. The auditorium is equipped with a stage and cinema screen and projection room, and when not used as a theatre is used for table tennis and other indoor sports. There are 400 members, mainly senior artisans and the more athletic type of juniors, and an average nightly attendance of 120, excluding cinema nights when the auditorium is usually filled to capacity by members and their wives. The club is run by a committee of the members and meetings are attended by a senior member of the labour superintendent's staff who provides liaison with the company on matters of finance and acts in an advisory capacity.

Around the club a spacious park is being laid out containing playing fields and a swimming pool which in December 1947 was in an advanced state of construction and will be ready for the 1948 bathing season.

Other facilities provided by the company in the Naftun area are shops, a coffee shop, bakery, butchery, a school and a dispensary.

Education and Training

Second only to the provision of houses for its employees is the company's contribution to their education and that of their children which, we believe, compares favourably with that of any other commercial organisation in the world.

The company has built and equipped, and largely maintains, seventeen schools in the Khuzistan Province with accommodation for 7,280 pupils. In Abadan 3,672 of the 4,850 pupils attending school are accommodated in schools provided by the company. Another primary school in Abadan for 500 pupils and offices for the director of education and his staff will shortly be opened. In addition to this new primary school in Abadan the company plans to build, equip, and hand over to the Government further new schools during the next 10 years.

Three kindergarten schools are maintained for the children of the company's employees, where they receive curds in summer and hot milk in winter as well as vitamin tablets. Fifty per cent. of the children admitted to these kindergartens suffer from trachoma and duplicate classes are run so that they may be segregated from the non-infected children. Those suffering from trachoma receive daily treatment and, provided the complaint has no reached an advanced stage before admission, the majority are cured before passing from the kindergarten to the schools.

Apart from the trachoma clinics at the kindergartens the company provides two doctors and 25 clinical assistants who operate six clinics, the only functions of which are to attend to the health of the children. Sour milk and clothing are issued free of charge to children attending the clinics through the summer holidays.

There are 123 Government school teachers in Abadan, for many of whom the company provides houses, and pays rent for the others. It has provided fifty houses for teaching staff in its areas and intends to build many more. Teachers are also assisted by allowances, loans, and issues of ice.

There is no desire or attempt made by the company to introduce any sort of propaganda into the schools, which are organised and entirely controlled by the Iranian Ministry of Education. Teachers are selected and their salaries paid by the Government, although the company pays special allowances to certain teachers amounting to 600,000 rials (£4,615) per year. All that is hoped when rendering assistance is that the best teachers will be selected, and honourable, capable and healthy boys and girls turned out by the schools.

An index of the results obtained is the increase in literacy of the company's employees : in 1935 only 8 per cent. of the labour was literate : in 1945 over 14 per cent. was literate and it is hoped that by 1955 the percentage will have increased to at least 40.

In addition to the provision of school buildings and equipment and the assistance given to attract the best available teachers the company has seven separate schemes for training its employees so that they can improve their education and technical skills and thus become both better employees and better members of the community. These schemes enable employees to attend free night classes in their own time ; youths to learn a trade or profession ; and adult employees to improve their efficiency in company time. Today there are about 2,200 employees who participate in the training schemes at Abadan.

English classes for Iranians have been run by the company since 1931. They were first held in rooms at the labour office but in 1934 classrooms were provided in the new training centre at Bahmanshir. There now are 16 classrooms with a staff of 25 teachers paid by the company. Classes are open to all employees who are able to read and write Persian. Classes of an hour's duration are held on five evenings a week from October to June. The keenness of employees to learn English may be gauged from the steady increase in the yearly attendance, which has risen from 300 in 1938 to over 1,900 in 1947.

Housing estate built by the company for its employees in South Iran

A.I.O.C. Photo.] [By Hunting Aerosurveys Ltd.

Vocational training for youths is provided by the apprentice training shop. The aim of the scheme is to take a boy of about 14, who has had at least four years at school and give him a training which at the end of five years will turn him into a skilled man who can use his brains as well as his hands.

The apprentice training shop caters for two kinds of apprentices : the artisan apprentice who spends two years in the shop and the remaining three years in different departments in the refinery ; and the technical apprentice who spends one year in the shop, at the same time attending classes in the Technical Institute on one whole day and three evenings a week, and then goes to different departments in the refinery for three or four years. On completion of his course the artisan apprentice becomes a grade-two fitter, wireman or machinist and later on by ability, hard work and personality, can reach a staff position and become a foreman, while the technical apprentice ultimately becomes a junior foreman, draughtsman, or chemical assistant, etc.

In the apprentice training shop the first hour of the day is spent in the classroom and the juniors learn English four days a week and do physical exercises on one day. When a boy begins "English Reader 3," he also begins mathematics, engineering knowledge and machine drawing. On Thursday the boys do no classes but the apprentices working in the refinery come in and spend the whole morning in the classrooms.

All new entrants start from the beginning and learn how to use a footrule, read a simple blue print, mark out a job, chip and file. They are given 12 graded exercises to do, the last two being to make a pair of outside callipers and a try-square. At the end of six months a boy is given the choice of continuing fitting, or entering the machine shop, electrical section, or the instrument repairing section. As far as possible he is allowed to follow his own choice, subject to his instructor's approval and provided there is room for him in the section of his choice.

Subject to satisfactory reports on industry, conduct and progress the apprentice is paid at the rate of 30-33 rials per day for the first six months ; 33-36 during the second six months ; and 36-39 during the next year. During his three years in the refinery his pay rises progressively from 44 to 52 rials (6s. 9d. to 8s.) per day.

There is no lack of candidates for the training scheme and the numbers of trainees have risen from 150 in 1932 to 527 at the present time. They come from every Province and town in Iran but the local boy is most suitable as he is acclimatised and attuned to the general conditions of life, having in many cases parents or relatives working in the refinery. Isfahan, peopled by metal craftsmen, produces a very good type, the present generation having years of craftsmanship behind them. Kerman, on the other hand, being a carpet-weaving town, rarely produces a good fitter.

The acme of the company's educational work in Iran is the Technical Institute at Abadan.

The aim of the Institute, which is entirely financed and administered by the company but academically governed by the Iranian Ministry of Education, is to provide part-time training up to degree standard in specialised branches of industry and commerce. It is housed in a spacious and dignified building which must rank with the finest modern buildings in Iran. It was completed in 1939 at a cost of £100,000 and contains : a main hall which is used for public lectures, educational films, dramatics, examinations and indoor social activities ; a book-shop where students may buy text books, stationery, and drawing instruments ; a reading room in which are provided Persian, English and French newspapers and periodicals ; a library containing 1,035 Persian and 1,652 English books ; electrical and mechanical engineering laboratories and drawing office ; chemical, physical and petroleum testing laboratories ; typing and machine accountancy rooms ; and classrooms and lecture theatres.

The engineering and science laboratories are spacious and well equipped but, having regard to the wide scope and high standard of training, the library as at present constituted is deficient in standard works of reference and in journals of Learned Societies by means of which alone can students derive the inspiration which comes from consulting original sources of information.

A.I.O.C. Photo.] [By Raymond Wilson

One of the many types of houses built for the artisans at Bahmanshir

The following courses are at present offered by the Institute :

Secondary School Section in Engineering, consisting of four-year part-time courses, leading up to the Technical Institute Ordinary Certificate in Mechanical, Electrical and Boiler Engineering.

Secondary School Section in Commerce, consisting of one-year full-time and three years part-time courses leading up to the Technical Institute Ordinary Certificate in Commercial and Clerical Subjects.

Higher Introductory Section, consisting of one year full-time course leading up to the 12th Class Technical Certificate.

Intermediate B.Sc. Section in Petroleum Technology, consisting of a two-year part-time course leading up to the Technical Institute Higher Certificate in Petroleum Technology.

Final B.Sc. Section in Petroleum Technology, consisting of two-year part-time courses leading up to the Technical Institute B.Sc. Degree in Petroleum Chemistry and Petroleum Plant Operation.

Intermediate B.Sc. Section in Engineering, consisting of a two year part-time course leading up to the Technical Institute Higher Certificate in Engineering.

Final B.Sc. Section in Engineering, consisting of two-year part-time courses leading up to the Technical Institute B.Sc. Degree in Mechanical and Electrical Engineering.

The growth of the volume of work of the Institute has increased rapidly and class-hours and student-hours reached a total of 11,873 and 162,086 respectively during the academic year 1945-1946.

Most of the Institute courses, which are of four-year duration, only began to yield results in terms of qualified Iranian employees, for service in the company's technical and commercial organisations in Iran, after four years from the opening date. Up to now 142 apprentices and trainees have satisfactorily completed the Technical Institute courses and have been passed out to the refinery. Out of this number only 11 have since resigned, leaving a total of 131 in company employment.

All students receive a salary while they are undergoing training, in addition to free accommodation. The salary plus allowances received by students are : for the secondary school courses from 40 rials (6s. 2d.) per day on entry to about 3,900 rials (£30) per month on completing the course ; for the university courses from 2,200 rials (£16 18s. 6d.) per month on entry to 8,300 rials (£63 17s.) per month on completing the course.

Entry to the Technical Institute is open to qualified students from all over the country and selection is made each year by examinations and interviews held in Tehran, Abadan, and other important centres.

The total number of students attending the courses at present is 342.

A number of the best students are selected each year for practical and university training in the United Kingdom. The selection for practical training in various factories and firms in the United Kingdom is made from amongst the best students who complete the secondary school courses, whereas the selection for the university courses is made from amongst the best students of

A.I.O.C. Photo.] [By Raymond Wilson

One of several types of houses built by the A.I.O.C. for artisans at Bahmanshir

the first year of the Technical Institute university courses. The numbers undergoing training in the United Kingdom this year are: university training 37; technical training 30.

The Apprentices' Hostel

An apprentices' hostel was established in 1932 and at that time accommodated 30 students. The purpose of this establishment was to provide adequate accommodation for the apprentices who came to Abadan for commercial or technical training from the northern Provinces.

When the Technical Institute was opened, the number of these apprentices began to increase and as a result the hostel was expanded. At present 212 boys are comfortably accommodated in the hostel which has 10 bedrooms of 17 beds each, eight bedrooms of six beds each, three dining halls, three rooms for indoor games and entertainments and seven reading and study rooms.

The company supplies the hostel with all its requirements. Iranian meals are served: dinner consists mainly of rice and curry while luncheon is often soup, cutlet and roast meat. The charge for a full day is 13 rials per head for the juniors and 15 rials (2s. 4d.) for the seniors.

The hostel has an extensive sports organization and there are programmes of games for each season. It has three football grounds, two tennis courts, three volley ball and one basket ball court and three halls for the indoor games of badminton, table-tennis and weight lifting. In addition there are a large asphalted ground for physical training and a swimming pool which are exclusively for the use of the apprentices. Many apprentices have made excellent progress in their sports activities and have regularly taken part in the Iranian Olympic Sports. The hostel swimming team represented Abadan in last year's Olympic Sports and gained the championship.

Medical and Health Services

From the earliest days of the company's operations a medical service was set up for its employees, but from the beginning it has been extended to their dependents and, in areas where no other medical service exists, a very large number of non-employees receive treatment annually. The company's established centres also take in any kind of emergency case.

There are 70 full-time doctors at present on the staff including specialists in surgery, pathology and opthalmology and a large staff of fully trained sisters and nurses, dispensers, dressers and laboratory assistants.

Two fully equipped hospitals are provided—one at Abadan (350 beds) and one at MIS (86 beds) exclusive of 146 beds in isolation wings. Both have facilities for X-ray and laboratory work and well-equipped operating theatres. There are special departments for the treatment of heat stroke and heat exhaustion, in which the company's medical service are pioneers.

Abadan and MIS have had out-patient clinics—separate from the main hospitals—for many years. Every area of operation has medical facilities and the established small areas of which there are fourteen, have dispensaries with detention wards with a total of 50 beds. From all of these, there is an ambulance service to convey sick patients to the central hospitals and, in an emergency, serious cases are brought in by air.

Plans are in preparation for large-scale additions and improvements to the Abadan and MIS hospitals and also for new buildings, allowing for an increased capacity in the wards, at all the established areas.

Six years ago, a school of nursing was started and from small beginnings, it is now firmly established and a large extension is planned. More than twenty nurses have been fully trained and over thirty are at present passing through the school. The training scheme includes assistants in the pathological laboratory, the dispensing department and ward dressers.

Facilities for the treatment of venereal disease have undergone a large expansion and, in the special department in Abadan, which has been operating for the past three years, much experience has been gained in this direction. With the advent of modern drugs and when more liberal distribution of these in the world's markets is possible, this section of medical treatment will be extended considerably.

Ophthalmic diseases of every description are prevalent throughout the Middle East and, to control these, special clinics have been operating for many years. Eye diseases, especially conjunctivitis and trachoma, have received much attention and the company fully appreciates the necessity of treating them at an early age in children. It has, therefore, appointed a medical officer to the schools and equipped the school clinics of Abadan. The children are now thoroughly examined at regular intervals and, as a routine matter, receive treatment for all ordinary sickness as well as for eye diseases.

In recent years the radiography service has been greatly improved and the formation of a rehabilitation centre in Abadan has enabled great progress to be made in after-treatment of injuries. Here trained personnel supervise massage, exercises and electrical treatment.

For over twenty years a system of assessment of disability of the injured has been in operation. All assessments are recommended by a medical board and these have been accepted at all times by the management. The company's voluntary system, in which the company's doctors based their assessments on scales recommended by International Convention, has now been superseded by the Iran Insurance Scheme but, from the medical aspect, there has been no change.

In a single month last year 436 employees and 222 non-employees were admitted to the company's hospitals and remained there a total of 11,048 patient-days; 116 major and 1,151 minor operations were performed, 6,603 pathological and 434 X-ray examinations were made and 2,504 dental treatments given; 56,929 employees and 9,474 non-employees were treated in the Abadan hospital out-patients' department and 31,020 employees and 18,007 non-employees attended the company's dispensaries and received a total of 133,907 treatments.

A highly qualified medical officer, who has made a special study of public health and industrial diseases, controls the health organisation. He has on his staff six qualified health inspectors and twelve assistant health inspectors. There are also numbers of foremen and others specially trained in anti-malaria work, rodent control, food inspection and general sanitation. Altogether, there are over 1,400 labourers in the health department in all areas.

A continual warfare is waged against the malaria mosquito. Gangs of men are constantly seeking out breeding places, other gangs treat them to destroy the young forms and others still are engaged in catching adult mosquitoes.

"Prevention is better than cure" and, for many years the company has carried out very large-scale preventive measures. Whenever the need arises, mass vaccination and inoculation against infectious disease such as small-pox, cholera, typhus, etc., are undertaken. Anti-plague work includes the catching and examination for disease of large numbers of rats and mice. Last year more

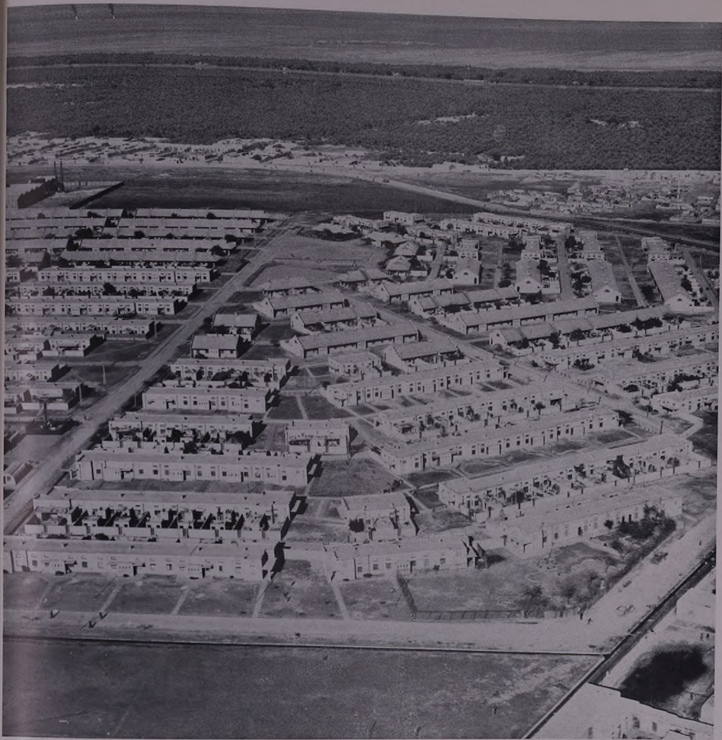
Air view of Farahabad housing estate for artisans

than 850 rats from Abadan and Khorramshahr were examined in a single month. A constant watch is kept to prevent outbreaks and special hospitals treat such cases and segregate contacts. All the company areas are provided with a treated water supply and bath houses are available to all. The latter are provided with warm water showerbaths and steam disinfectors for personal clothing. In 1945 over 500,000 persons passed through these baths on a purely voluntary basis.

The development of such a large industrial organisation has presented many problems concerning industrial occupational diseases. To solve these and to advise on methods for their prevention the company has organised a department under the direction of a specially qualified doctor to investigate and advise on these problems. Close co-operation is also maintained between the engineers of the safety department and the medical officers.

Many of the hazards that are encountered in a refinery are not confined to the normal type of accident that occurs to individuals working at a bench or machine, but are such that, by an unthinking or careless act, many persons may be involved and very costly and valuable equipment may be destroyed.

The safety measures that are applied can be divided into three distinct groups. The first and most important group is the mechanical safeguards. The second is the protection of personnel



A.I.O.C. Photos.]
By Hunting Aerosurveys Ltd.]

A section of one of the housing estates built by the company for its employees

in the form of special clothing for use where mechanical or other safeguards cannot be used and the third, education and propaganda. These safety measures are constantly pursued with the utmost vigour.

Experience has shown that almost 75 per cent. of accidents are due to failure of the individual to use safeguards provided. In consequence posters are made and distributed as constant reminders to personnel to become safety conscious and accident free. It is only by constant propaganda that the value of the safety regulations is appreciated. In order to make all employees alert to possible injury by accident, special safety classes are held, at which explanations of the regulations are given and the reasons why they must be adhered to. Each of these groups receive training for the particular trade or craft in which they are employed. Among the subjects that are discussed at the safety classes are road safety, taking care in the home and at play, and the care and use of protective clothing.

To cater for the needs of all the trades that are undertaken in the refinery, over a hundred different types of protective equipment and clothing have been adopted or devised. In the provision of this equipment, the greatest consideration has been given to the abnormal climatic conditions that prevail, and fabrics have been produced for the tropical heat of summer that are both light and durable and, at the same time, afford the fullest possible protection with the maximum of comfort to the wearer. Where eye protection is required, shields have been designed that give the fullest protection without discomfort from " steaming " or becoming obscured.

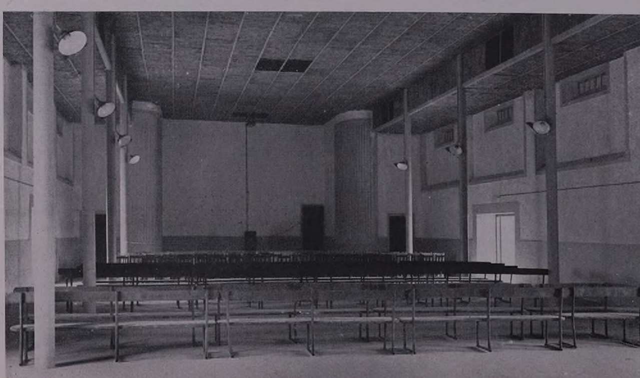
Agricultural Development in Abadan

It was foreseen during the early part of the war that every effort would have to be made to make Abadan Island as self-supporting as possible. To this end, the company encouraged local cultivators by installing and maintaining, free of charge, irrigation pumps, and by ploughing land in the initial stages, constructing drainage ditches and supplying imported fertiliser and vegetable seed. As a result of these efforts, it is estimated that some 200 acres of hitherto barren land have been cultivated, with a marked increase in the supply of produce to the people of Abadan.

Artisans' houses at the Pusht-i-Borj area at Masjid-i-Sulaiman oilfield

Swimming Pool at the Seamen's Hostel, Bawarda

A.I.O.C. Photos.]
[By Raymond Wilson

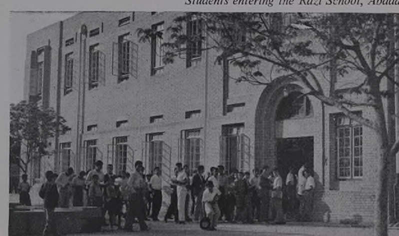


Concert hall and cinema for the artisans at the oilfield

Central Hall, used for social purposes at the Masjid-i-Sulaiman oilfield

The staff swimming pool at the Masjid-i-Sulaiman oilfield

Students entering the Razi School, Abadan



One of the seventeen schools built by the company in South Iran

In addition, some 175 acres are cultivated by the company, 100 acres of which are allocated for the growing of fodder crops for dairy cattle, and the remainder to produce and augment the vegetable supply to staff and labour, and to serve as a model for the local cultivators.

For the successful growing of crops in these areas, it was necessary, in the first instance, to construct drainage ditches for leaching and eradicating the high content of salt from the soil. These drainage ditches were extended to the river and had non-return flap valves installed to allow for the egress of salty drainage water and to prevent the ingress of tidal water. In some areas, it was necessary to carry out the leaching process daily for a period of from 18 months to two years, during which time, it is estimated that 80 to 100 tons of salt per acre were removed. Further, elements for plant life—in the form of compost—manufactured at the company's destructor, from town refuse and sewerage—were ploughed back into the land while lime was also added to lighten and break up the soil and to render it friable and amenable for tillage. As a result, the yield of vegetables and lucerne for cattle has increased considerably on the island. Production of vegetables of excellent quality has increased by 450 tons annually and today it is possible to obtain a variety practically all the year round—tomatoes, beet, turnips, spinach, carrots, lettuce, cucumber, brinjals, etc.—where spinach was once the only vegetable obtainable for five months of the year. Twelve irrigation pumps, each capable of delivering 60,000 gallons per hour, are being installed for the cultivators at various points on the island and there is every reason to expect that, shortly Abadan will have a regular self-supporting supply of vegetables and also that the cultivators will consider the planting of large areas with fruit trees.

In 1943 the company took over a dairy farm in which the herd consisted of about ninety cows of all descriptions local, Iraqi, Sindhi, crosses of all these and some Iraqi cows with Ayrshire blood. They were all in low condition and the yield of milk was only 80 litres, and all but a dozen calves and young stock had died off. Over 20 cows had to be killed as their productive life was over. Fair feeding and improved management increased the yield of milk threefold during the first year and all heifer calves were raised. The butterfat content of the milk also rose from 4½ per cent. to 5½ per cent. The incidence of disease became very low although mastitis and tick-fever had previously been common.

In 1944 daily production reached almost 300 litres but demand was growing more quickly than production, so forty head of Sindhi cattle were imported in 1945 from Karachi. After they had settled down, their equivalent in cows, calves, and heifers were sent to Dar-i-Khasine where a new farm was started to supply the fields areas.

The milk yield had now reached 400 litres but it became clear that there was a limit to the expansion of the herd as well as to the average production which could be expected from the available cattle. Ticks were well under control by this time but the risk of importing stock from any established dairy breed was too great owing to climatic conditions. A Lincolnshire Red pedigree bull was therefore imported from England in 1946 and within the next few years, a satisfactory herd should be established, able to meet the demand for milk. It should also be a valuable means of improving the strain of cattle for the local farmers.

During the past three years some 6,000 eggs from a good laying strain of poultry imported by the company have been hatched in the incubator at the dairy farm. The resulting distribution of more than 3,000 chicks on the island has greatly improved the local strain of poultry.

All these activities have revealed to local cultivators the possibilities of agriculture and poultry-keeping in this area. As an illustration of this, a farmer has started a piggery and a poultry farm on the Khosrowabad Road and intends to cultivate large areas of land in that district as soon as he can obtain a pump. Meanwhile, the company is helping as much as possible by providing him with swill from the two restaurants and with foodstuffs which, though condemned for human consumption, are suitable for pigs.

Food Distribution and Price Stabilisation

One of the most important war-time contributions which the Anglo-Iranian Oil Company made to the economic well-being of its employees was the stabilisation of prices at levels well below those obtaining in the neighbouring Provinces. Rationed food was issued free to all employees, and in the company's shops subsidised food and clothing were dispensed by a staff of 2,000 employees and at an annual cost to the company of £1 million. By these means the cost of living index in 1946 was 380 (1939 : 100) as compared with 550 in the neighbouring districts. During the same period wages of the company's employees were increased by over 300 per cent.

The company first undertook the responsibility of feeding its labour in 1941 when, because of short supply and consequently increasing prices, workers were finding great difficulty in obtaining bread.

During the early part of 1941, there was a serious shortage of wheat in Iran. Permission was obtained to import wheat from India for issue to employees in the company's areas. Subsequently the company undertook, at the request of the Iranian Government, the task of distributing bread (or flour) to all inhabitants of Abadan whether company employees or their dependents, contractor's employees or non-employees.

Realising that the supply and issue of foodstuffs would be an essential duty for some considerable time, it was decided to obtain data as to the population of the Abadan area and this was obtained in February 1943. This showed a total population of 109,000, including 24,000 adult male employees of the company and their 42,250 dependents. Based on this census, arrangements were made for the importation of flour, etc. from abroad and company shops were opened for the issue of foodstuffs and clothing materials to employees and their dependents.

In 1946 the subsidies by which the company had curbed war-time inflation were discontinued and an equivalent amount incorporated in the basic pay of their employees, but importation and rationed distribution of food and textiles at cost continues with the result that prices of staple commodities are from 30 to 50 per cent. lower than in the bazaar.

At the present time there are approximately 32,000 employees in Abadan area who purchase foodstuffs from company shops. In addition they purchase clothing at certain times and may also buy flour and tea for their dependents.

Social and Recreational Facilities

Recreation facilities provided by the company at Abadan include clubs, sports grounds, swimming pools, gymnasia and cinemas.

The principal club has 2,000 members and provides a well-stocked library ; billiard tables, badminton courts, table-tennis and volley ball ; football and hockey grounds, two swimming pools and an outdoor cinema. There are three other Iranian clubs with membership varying from 300 to 500 and another club has recently been opened with a membership equally divided between Iranians and non-Iranians.

For the time being the labour clubs cater mainly for sport. No fewer than 52 teams participate in the inter-departmental football competition and the 16 football fields are fully occupied. Athletics, hockey, volley ball, basket ball and table-tennis facilities are also provided and are keenly enjoyed by the workmen.

Cinemas are possibly the most important and popular of the recreational facilities provided by the company. There are 33 in all of which 12 are for labour, 10 for staff, 8 for staff and labour, two in the training establishments and one in the seamen's institute. The largest, opened in 1946, has seating capacity for 1,500 and offers three different programmes a week. A charge of 5 rials (9d.) is made for admission.

The Municipal Engineering Department

It has been the company's policy from the earliest days of its activities to assist the local authorities in municipal matters. A department has been formed solely for co-ordinating the joint efforts of the company and the local authorities in this direction.

Sufficient purified water has been put at the disposal of the inhabitants of Abadan and Ahmadabad to supply all their domestic needs, and river water is also laid on for gardens, etc. The chlorinated water which is used for drinking, bathing and other domestic uses in the town area is exactly the same as that used in the company's areas and is pumped from the same filtration plant. Private connections to houses consume about five million litres per day for which a charge is made at the rate of 0.45 rials (0.83d.) per 1,000 litres. There is also a free chlorinated water supply throughout the town by means of public water points for the use of inhabitants who have no private connections. The average consumption of this water is about 1,500,000 litres per day. All the water mains in Abadan and Ahmadabad have been laid and are maintained by the company.

Electricity is sold to the municipality at 0.08 rials (0.15d.) per kW, which is very much less than the cost of production to the company. As in the case of the water supply, the maintenance of the whole system is done by the company free of charge.

Three years ago the company agreed, at the request of the municipality, to take over the cleansing service on a contract basis for 100,000 rials (£769) per month. The actual monthly expenditure on this service in the municipal area exceeds 500,000 rials (£3,846). In addition the company has imported from the U.K. six special refuse lorries for removing refuse and six lorries for emptying the cesspits and one dragline for burying refuse.

A building surveyors' office has been set up to assist the public in modifying their buildings or in the erection of new ones. This service includes technical advice for bettering the standard of construction, sanitation, etc. and deals with an average of 40 applications per month.

One of the main functions of the municipal engineering department has been to investigate the needs of the town from a general sanitation and well-being point of view and to submit periodical plans for improvement. After approval by the Municipal Council the plans are put before the company with a request for their execution. The management usually not only undertakes their execution but so far has also contributed financially towards the cost. A recent scheme consisted of over 2 million sq. ft. of asphalting, some 60,000 ft. of drainage nullahs, the construction of a clinic and doctor's house, a meat and vegetable market, a new mortuary, a cemetery, the construction of public gardens, the construction of public latrines and a foreshore development project. Practically all these plans have been carried out at a cost of 29,900,000 rials (£230,000) of which the company contributed 16,600,000 (£128,000).

A.I.O.C. Photo.] [By Raymond Wilson

The Abadan Technical Institute


MIDDLE EAST
IRAQ FIELDS
TURKEY
SYRIA
IRAN
Kirkuk
Haditha
IRAQ
TRANS-JORDAN
SAUDI ARABIA
AINZALAH
Tigris
River
Mosul
River
Khazir
QASAB
Shura
JAWAN
NAJMAH
QAIYARAH
Quwar
River
Makhmur
Altun Kopru
Al Hadhr
Sharqat
Little Zab
KIRKUK
Kirkuk
Chemchemal
Sulaimaniya
Tauq
Al Fat-ha
Shuraimiya
Tuz Khurmatli
River
Tigris
Tikrit
River
Shatt al Adhaim
Tiaruq
River
Khanaqin
Samarra
Diyala
Haditha
River
NAFT-I-SHAH
Shahraban
Dilfawa
LEGEND:
Oil Fields
Refineries
Pipelines
Railroads
Towns
Roads

The IRAQ Petroleum Company and its Associated Companies

The first "oil concession" granted in Iraq, then the Vilayets of Mosul, Baghdad and Basrah of the Ottoman Empire, was to the German-controlled Baghdad Railway Co. in the last years of the nineteenth century when the right-of-way granted to them by the Turkish Government included all mineral rights for a distance of twenty kilometres on both sides of the projected line. The actual "concession" was limited to this strip on either side of the railway, but the Germans also obtained from the Turkish Government an expression of intent to grant them oil concessions over a wider area. None of these oil concessions to German companies became operative.

In the early years of the twentieth century the D'Arcy Exploration Co. became interested in oil concessions in Mesopotamia, but the promise of a concession made to them in 1904 never materialised. The "Shell" group, through the Anglo-Saxon Petroleum Co., were active in the area between 1906 and 1910 when the overthrow of Abdul Hamid's Government interrupted negotiations. The formation later that year of the National Bank of Turkey reconciled British and German interests and in 1911, African and Eastern Concessions Ltd., was formed to carry on negotiations with the new Turkish Government. In 1912 the name of the company was changed to Turkish Petroleum Co., in which the Anglo-Saxon Petroleum Co., was allotted a 25 per cent. interest. Early in 1914 the D'Arcy Exploration Co., came in by subscribing new capital equal to the existing capital of the company and the shareholding in the Turkish Petroleum Co., then became 50 per cent. by the D'Arcy Exploration Co., and 25 per cent. each by the Anglo-Saxon Petroleum Co., and the Deutsche Bank. Throughout the negotiations Mr. C. S. Gulbenkian played an active part and on the reconstitution of the company in 1914 the Anglo-Saxon Petroleum Co., and the D'Arcy Exploration Co., each held 2½ per cent. of the total stock for Mr. Gulbenkian as a "beneficiary 5 per cent. interest without voting rights." The agreement constituting the company on this basis was signed at the British Foreign Office on March 19, 1914, and contained a clause to the effect that none of the signatories would act independently "directly or indirectly in the production or manufacture of crude oil" within an area described as "the Ottoman Empire." In June, 1914, the Grand Vizer of Turkey promised the Turkish Petroleum Co., a lease of "the petroleum deposits already discovered or to be discovered in the Vilayets of Mosul and Baghdad."

On the outbreak of World War I the Deutsche Bank's share in the Turkish Petroleum Co., was taken over by the British Custodian of Enemy Property, but as Mesopotamia remained under enemy occupation for most of the war the company remained inactive. During the war seven unsuccessful shallow wells were drilled by the Germans in the Qaiyarah area, 37 miles south of Mosul.

By the San-Remo Agreement of April 24, 1920, the German 25 per cent. share in the Turkish Petroleum Co., was assigned to France, whereupon the American State Department on May 12, 1920, handed a Note to the British Foreign Office protesting against the exclusion of American oil interests from Mesopotamia. This was followed by protracted diplomatic exchanges between the two Governments on the so called "open door policy" and in 1928 the Turkish Petroleum Co., was reorganised to include a number of American companies whose interests were grouped in the Near East Development Corporation.

In the meantime, the Turkish Petroleum Co., obtained a concession in March, 1925, covering the whole of the Iraq Provinces of Baghdad and Mosul, and drilling operations were commenced in April, 1927.

Test wells were drilled at Palkhanah, Khasim Al Ahmar, Injanah, Qaiyarah, Jambur and Baba Gurgur (Kirkuk), culminating in the discovery of oil at Qaiyarah on October 13, 1927, and at Baba Gurgur two days later.

Thus it was not until after the discovery of the great Kirkuk oilfield that American interests entered the Turkish Petroleum Co. By this time only five of the American companies, who met in Washington in 1921 at the invitation of the U.S. Department of Commerce to discuss participation, remained interested. They were: The Atlantic Refining Co., Gulf Oil Corporation of Pennsylvania, Pan American Petroleum and Transport Co., Standard Oil Co. of New York (later Socony-Vacuum Co. Inc.), and Standard Oil Co. (New Jersey).

To provide the American share in the reorganised Turkish Petroleum Co., the D'Arcy Exploration Co. surrendered half its original holding in return for a royalty of 10 per cent. (reduced in 1931 to 7½ per cent.) on all the oil to be produced, and the ownership of the new company was as follows: D'Arcy Exploration Co., The Anglo-Saxon Petroleum Co. (Royal Dutch-Shell), Cie. Francaise des Petroles, and the Near East Development Corporation, 23.75 per cent. each; and Mr. C. S. Gulbenkian 5 per cent.

A group agreement was signed on July 31, 1928, providing that the participants act only through jointly-owned operating companies in all matters relating to the exploration for, and production of, crude oil within an area roughly corresponding to the former limits of the Ottoman Empire, and more precisely defined on a map by means of a red line. This so called "Red Line Agreement" provided also that the agreement be construed according to, and be governed by, English Law. Under it, all crude oil produced has to be offered at cost, plus a charge of one shilling per ton to each of the participants in proportion to their ownership in the company.

In June, 1929, the name of the company was changed to Iraq Petroleum Co. Ltd., and in 1931 the other American partners in the Near East Development Corporation sold their interests to the Standard Oil Co. (New Jersey) and Socony-Vacuum Oil Co. Inc., successors to Standard Oil Co. of New York. The American share in the Iraq Petroleum Co., is held equally by these two companies through their holding in the Near East Development Corpn.

Certain provisions of the 1925 concession proved unworkable and were modified by an amending agreement in March 1931 which limited the Iraq Petroleum Company's concession to the area east of the Tigris. A concession over the whole of Iraq lying west of the Tigris and north of latitude 33 was acquired in 1932 by the British Oil Development Co., a company formed in 1928 with 60 per cent. British and 40 per cent. Italian holding, but which in 1930 became an international company in which the capital was 45 per cent. British, 31 per cent. Italian, 12 per cent. German and 12 per cent. Franco-Swiss. In 1935, by which time German and Italian interests had gained control, this company was bought out by the groups forming the Iraq Petroleum Co., which organised the Mosul Petroleum Co., to operate the concession.

In 1938 the Basrah Petroleum Co., another company of similar constitution to the Iraq Petroleum Co., was granted a concession over the remaining portions of Iraq not covered by the Iraq Petroleum Co., and Mosul Petroleum Co. concessions.

Map of the area covered by 1928 "Red Line Agreement", under which participants in the Iraq Petroleum Co. undertook to act only through jointly-owned operating companies in all matters pertaining to the exploration for, and production of, crude oil within the area shown in white

In 1938 a concession (ratified in 1940) covering the whole of Syria north of the latitude of Damascus was granted to the Syria Petroleum Co., for a period of 75 years, and since that time other concessions or prospecting licences within the "Red Line" have been acquired by other companies of the IPC group. The areas now held by the group are as follows :—

Iraq Petroleum Co. Ltd.—The Provinces of Baghdad and Mosul east of the Tigris : 75 years from March 14, 1925.

Mosul Petroleum Co. Ltd.—All Iraq west of the Tigris and north of latitude 33 : 75 years from May 25, 1932.

Basrah Petroleum Co. Ltd.—All Iraq not covered by the IPC and MPC concessions nor the transferred territories (now held by the Kuwait Oil Co.) : 75 years from November 30, 1938.

Syria Petroleum Co. Ltd.—All Syria north of the latitude of Damascus : 75 years from March 26, 1940.

Lebanon Petroleum Co. Ltd.—Exploration licence covering 500 sq. kilometres : effective from March 7, 1938.

Trans-Jordan Petroleum Co. Ltd.—The whole of the Kingdom of Trans-Jordan : 75 years from May 10, 1947.

Petroleum Development (Palestine) Ltd. : Exploration licences covering 5,263 sq. miles : effective in part from February 24, 1939 and in part from July 21, 1939.

Petroleum Concessions Ltd.—Exploration permit over the Aden Protectorate (110,000 sq. miles) effective from January 1938.

Petroleum Development (Oman & Dofar) Ltd.—Two concessions from the Sultan of Muscat and Oman, covering some 52,000 sq. miles : 75 years from June, 1937.

Petroleum Development (Trucial Coast) Ltd.—Six concessions and one exploration permit from the Rulers of the Trucial Coast, covering a total area of some 45,000 sq. miles of which the boundaries are largely undefined : 75 years from various dates in and since 1937.

Petroleum Development (Qatar) Ltd.—The whole of the Qatar Peninsula (4,000 sq. miles) : 75 years from May 17, 1935.

Petroleum Development (Cyprus) Ltd.—Exploration permit covering 2,000 sq. miles : effective from April 1938, and renewable annually.

World War II caused a suspension of exploratory activities and where drilling and production obligations were prescribed, moratoria were granted by the Governments concerned. Another effect of the war was the suspension of deliveries of crude from Kirkuk to Cie. Francaise des Petroles after the German occupation of France in 1940. This occupation had a still more far-reaching result when, early in 1947, British legal counsel advised that the effect of the German occupation of France, where the French company was incorporated, and where Mr. Gulbenkian was resident at the time, was to dissolve the 1928 group agreement (the "Red Line Agreement"). The invalidation of the group agreement in 1940 was not held to affect the corporate existence of, or stock holdings of the partners in, the Iraq Petroleum Co., and in 1947 negotiations were commenced with the object of reaching a new operating agreement among the participants to the 1928 agreement.

Influenced by their need for greatly increased sources of foreign crude to enable them to satisfy their European markets with reduced drain on American production, the American partners in the Near East Development Corporation sought to reach a new agreement which would permit their independent participation in other companies' oil operations within the area prescribed by the 1928 "Red Line Agreement." This attempt was designed specifically to permit their participation in the Arabian American Oil Co., agreement to which was announced in December 1946. As a result of the 1947 discussions, French objections to such participation were withdrawn and in June of that year it was announced that agreement in principle had been reached by the major partners in the Iraq Petroleum Co. The new agreement has not yet, however, been concluded, and Jersey and Socony participation in the Arabian American Oil Co. awaits its formal ratification.

The Iraq Petroleum Co. is a unique example of international co-operation in oil. The reconciliation of the sometimes conflicting national as well as company interests has not always been easy. That an harmonious company policy has been successfully evolved and maintained is due in no small measure to the skill and patience of the managing director, Mr. J. Skliros, as well as to the forebearance of the British, French, American and Dutch groups in refraining from pressing national or company claims to the detriment of corporate interests.

EARLY EXPLORATION IN IRAQ

In 1927 the IPC embarked on a vigorous exploration programme, the discovery wells at Baba Gurgur and Qaiyarah being respectively the 5th and 6th tests to be commenced. The first two tests were started in April 1927 on the Palkanah structure, 45 miles SSE of Kirkuk. These were located on an elongated anticlinal complex some 70 miles in length lying 15 miles to the west of the south-eastward continuation of the trend of the Kirkuk structure. These borings were commenced in the Middle Fars and were abandoned at depths of 2,214 ft. and 1,892 ft. on account of mechanical difficulties and heaving formations without reaching the main limestone which is the reservoir rock at Kirkuk.

The third well, commenced in May 1927, was on the Khashim al Ahmar anticline, some 75 miles south of Kirkuk, which forms part of the Jabal Hamrin South complex, lying 30 miles west of the Palkanah axis. This well was commenced in the Upper Fars series and penetrated limestones probably correlative with the Transition Beds of the Kirkuk structure at a depth of 4,350 ft. Here high pressure gas was encountered and the boring was abandoned at this depth as a result of the mechanical difficulties accompanying the occurrence of heaving shales.

The fourth test was on the Injanah structure at the north of the Jabal Hamrin South complex on the same axis as the Khashim al Ahmar structure. This boring was also commenced in Upper Fars and was abandoned at a depth of 3,438 ft. in the Lower Fars salt zone on account of mechanical difficulties.

Then came the discovery wells at Baba Gurgur on the Kirkuk structure and at Qaiyarah, 37 miles south of Mosul, commencing respectively on June 27 and July 16, 1927.

Qaiyarah No. 1 well was commenced in the Lower Fars series and penetrated the Qarah Chauk Limestone at 760 ft. Strong shows of oil were encountered from 720 ft. onwards and on October 13, 1927, the well flowed 4,000 barrels of oil per day from a depth of 780 ft. Two days later Baba Gurgur No. 1 well came in as a gusher with an estimated production of 70,000 to 90,000 barrels per day.

In the meantime another test well had been started near Jambur on September 15, 1927, on an anticline lying 30 miles south of Kirkuk and pursuing a course parallel to and ten miles to the west of the south-eastward trend of the Kirkuk structure. This well which was commenced in the Upper Fars series encountered small shows of oil and gas and was abandoned at a depth of 4,824 ft. on account of mechanical difficulties.

Notwithstanding the discoveries at Qaiyarah and Kirkuk, exploration was vigorously pursued until shortly before the surrender of the area west of the Tigris in 1931.

A second well was commenced at Qaiyarah on March 20, 1928, which penetrated the main limestone at 890 ft. and was completed at 1,530 ft. on May 23. On test this well yielded 7,200 barrels per day of 11.4 Be. gravity oil, confirming the heavy non-refinable quality of the Qaiyarah crude.

In 1928 and 1929 two more wells were drilled at Palkanah to depths of 3,248 and 2,758 ft. encountering high pressure water and gas in the Qarah Chauk limestone. Three more test wells were also drilled on the Injanah structure to depths of 2,788, 2,439 and 4,048 ft. Injanah No. 2 was abandoned on account of mechanical difficulties associated with a bed of plastic bitumen ; No. 3 also on account of mechanical difficulties and, No. 4 was discontinued in February 1930 when exploratory activities were temporarily suspended.

In November, 1928, a test well was started at Kor Mor, an anticline some 40 miles south-east of Kirkuk and on the same anticlinal axis as the Kirkuk structure. This boring commenced in the Upper Fars and penetrated the main limestone at a depth of 6,335 ft. A swabbing test yielded a little oil and gas at 6,472 ft. and the well was abandoned at 6,530 ft. in January, 1930.

In 1929 two test wells were drilled on the Khanuqah anticline, a structure which lies on the west bank of the Tigris some 30 miles south of Qaiyarah. Khanuqah No. 1 well was commenced in Lower Fars and penetrated the main limestone at 628 ft. Small shows of oil and gas were encountered, and at 1,410 ft. gas ynder a pressure of 500 p.s.i. occurred and at this depth the well uielded 25 million cu. ft. per day. It was discontinued at 1,426 ft. Khanuqah No. 2 well, drilled down dip from No. 1, was completed at a depth of 1,940 ft. without encountering important shows of oil or gas.

In June, 1929, a test well was drilled near Quwair, 30 miles south-east of Mosul on an anticline running parallel to and six miles south-west of the northernmost portion of the Kirkuk anticline. This boring encountered the main limestone of the Kirkuk structure at a depth of 765 ft. and was discontinued at a depth of 1,767 ft. without encountering important shows of oil or gas.

The last test well to be drilled before the suspension of exploratory drilling was on the Chemchemal structure, an elongated anticline some 50 miles in length running parallel to and 25 miles to the north-east of the Kirkuk structure. This boring was commenced in the Middle Fars and penetrated a gas-bearing limestone correlative with a lower member of the Kirkuk Transition Beds at a depth of 1,394 ft. The boring was suspended at this depth in April, 1930.

The KIRKUK Field

THE KIRKUK STRUCTURE is an elongated anticline 60 miles long and with an average width of two miles, commencing 140 miles due north of Baghdad and pursuing a slightly sinuous course in a general north-westerly direction. The north-east flank is conspicuously marked by the 200-foot scarp of the Bakhtiari sandstones which forms a prominent feature paralleling the general trend of the Kurdish mountains. At the southern end of the structure in the neighbourhood of Kirkuk town the south-west flank is topographically ill defined. Approaching the Lesser Zab, a tributary of the Tigris which bisects the structure 24 miles north of Kirkuk, steeply dipping beds of gypsum convey an erroneous impression of pronounced asymmetry.

Looking north from a vantage point south of the Lesser Zab the combination of scarp and dip slope on both flanks of the structure and separated by an anticlinal valley is beautifully seen. Flying over the structure, the anticlinal valley with its rim rock of sandstones and conglomerates is seen to even better advantage—an unforgettable sight which provides only one of the many reasons why the Kirkuk structure should be in all geological text books.

Below the Bakhtiari sandstones and conglomerates some 2,500 feet of siltstones, sandstones and red shales are exposed which have been correlated with the Upper Fars of Iran. These are followed by red and grey siltstones and limestones with gypsum and anhydrite correlated with the Lower Fars of Iran and which constitute the lowest beds exposed in the Kirkuk structure.

At Baba Gurgur on the crest of the structure, five miles NNW of the town of Kirkuk, gas and oil seepages occur 400 feet below the top of the Lower Fars series. Except during the war when it was extinguished as an air raid precaution, gas from the principal seepage has burned continuously since the time of King Nebuchadnezzar and historians believe that these conflagrations are the " eternal fires " to which Shadrach, Meshach and Abed-nego were consigned. In daylight the fires are unimpressive ; a host of small faintly orange smokeless flames at the bottom of a small depression some 100 feet in diameter. Individual foci of flame can be stamped out and are occasionally extinguished by gusts of wind, and the principal memory of a daylight visit is the pungent smell of sulphur dioxide. But at night the scene is one of impressive and exotic beauty : dancing whisps of bright blue flame, like brandy burning on a huge Christmas pudding.

Detailed geological mapping has revealed that these seepages occur at the culmination of a local subsidiary dome, 29 to 30 miles long, with a maximum width of two miles and independent closure of 1,400 feet. To the north of this Baba dome and separated from it by a shallow saddle just south of the Lesser Zab is the Avanah dome, 20 to 21 miles long, approximately one mile wide and with an independent closure of 700 feet. Still further north and separated from the Avanah dome by a deeper saddle is the Khurmala dome 12 miles long, $1\frac{1}{2}$ miles wide and with an independent closure of 900 feet. These three crest maxima make up the Kirkuk structure, the total length of the closed area being 63 miles, with a maximum width of $2\frac{1}{2}$ miles in the Baba dome, and closure varying from 2,600 feet at Baba Gurgur to 900 feet at Khurmala.

Below the Lower Fars seepage beds which outcrop at Baba Gurgur 2,000 feet of Miocene to Eocene beds have been penetrated by the drill, the full Kirkuk succession being as follows :—

Age	Local Representatives		Lithology	Thickness in feet
Pliocene	Bakhtiari		Sands, gravels and conglomerates.	3,000+
Miocene	Upper Fars		Siltstones, sandstones and shales	2,400—2,500
	Lower Fars	Upper Red Beds	Red and grey siltstones and limestones with anhydrite and gypsum	900—1,200
		Seepage Beds / Saliferous Beds	Red and grey siltstones and marls with anhydrite, salt and thin limestones.	
		Transition Beds	Grey siltstones, marls, limestones and anhydrite.	
		Conglomerate	Limestone, conglomerate and grey siltstone.	
Oligocene to Eocene	Qarah Chauk Group	Miliola and reef limestones (120 ft.)	White fissured detrital and coralline limestone.	1,000+
		Nummulite limestone (up to 400 ft.)	Porous crystalline nummulite limestone	
		Globigerina limestone (up to 800 ft.)	Fine-grained Globigerina and marly limestones	
		Marls and shales	Grey to black marls and shales	

The Kirkuk structure from the Lesser Zab

Petroleum Times] [Photo.

An overthrust in the Lower Fars

The lower members of this series, not exposed in the Kirkuk structure, are well seen in the foot hills of the Kurdish mountains between Erbil and Shaqlawah where beds down to the Cenomanian are exposed in a series of deeply eroded anticlines. Here the sequence below the Lower Fars is dominantly calcareous, the Qarah Chauk group, the reservoir rock at Kirkuk, being partially represented by thin-bedded platey limestones with very subordinate shales. At outcrop the limestone is greyish white in colour and much of it is fine-grained and, unlike its equivalent at Kirkuk, apparently impervious.

In the Shaqlawah sections the Qarah Chauk limestones are underlain by a coarse conglomerate locally up to 10 feet thick, which is absent at Kirkuk, followed by red and blue Eocene shales with subordinate limestones passing downwards into black bituminous shales of Maestrichtian age. These are of considerable interest as they may be the source beds of the Kirkuk oil. For the most part silty and sandy bituminous shales, these beds contain stringers of compact fine-grained limestones with bitumen pebbles and residues. Below these shales thin-bedded Senonian limestones and massive Cenomanian limestones are exposed. The latter, known in Palestine as the Judea limestone, forms the magnificent craggy mountains of Sefin Dagh and Harir Dagh west and east of Shaqlawah and gives rise to characteristic rugged topography wherever it outcrops in the Middle East, of which it has been aptly described as the backbone.

As mentioned above, the almost vertical gypsum beds south of the Lesser Zab give a false impression of pronounced asymmetry. Elucidation of the structure by detailed mapping and the results of drilling indicate that these steeply dipping beds are the result of overthrusting in the saliferous beds of the Lower Fars. The salt beds act as an incompetent series during folding, gliding taking place in the salt with a consequent squeezing out of salt from the north-east, the direction of maximum pressure, and its piling up towards the west flank. Another result of this phenomenon is that the subsurface crest is displaced to the north-east of the apparent position of the surface crest, a feature which is even more pronounced in the case of some of the Iranian fields.

Actually the Kirkuk subsurface structure is slightly asymmetric, dips on the north-east flank being 45° as compared with 35° on the south-west.

Another interesting structural feature, which may have played an important part in the migration of oil is a series of NNW-SSE cross faults which traverse the Baba dome and with which are associated some of the fissuring which plays so important a part in oil production.

Development

Drilling was commenced on the Kirkuk field on June 30, 1927 on a site 4,000 feet north of the " eternal fires," and on October 15, 1947, Baba Gurgur No. 1 came in as a gusher at 1,521 feet. It was eight days before the well was brought under control and in this period it is estimated to have produced 700,000 barrels.

By 1932, 26 wells had been drilled and construction of 12-inch

Harir Dagh : A fine example of Judea limestone topography

[Photos Petroleum Times]

pipelines to the Mediterranean terminals at Tripoli and Haifa was commenced. The north line to Tripoli was commissioned in May, 1934 by which time 14 producing wells on the Baba dome and 12 exploration wells, two of which were on the Avanah dome, had been completed. In October, 1934, crude deliveries to Haifa commenced, and production from the field soon reached 90,000 barrels per day, equivalent to 4 million tons per year. By September, 1939 one more producing well was completed on the, Baba dome and 27 more exploration wells, 11 of which were on the Avanah dome and two on the Khurmala dome. Of the 39 wells drilled with the primary object of determining the structure 20 were operated as observation wells.

On the outbreak of war there was a three-weeks' shut down due to the suspension of all oil deliveries, but thereafter production was resumed at the rate of 90,000 barrels per day until June 1940, when, on the closing of the Mediterranean, it was severely curtailed. Early in 1941 all outlying wells were plugged as a precautionary measure leaving only seven wells, six on the Baba dome and a single observation well in edge water at the extreme south of the field. In May and June 1941, there was another complete shut down due to the Raschid Ali rebellion when the whole of the Iraq Petroleum Company's staff in Iraq was interned. Thereafter production slowly rose again to 90,000 barrels per day and has continued at this level until the present time.

In 1944 drilling was resumed in readiness for the expansion of production which will take place when two new 16 in. lines to Haifa and Tripoli, construction of which was started in the autumn of 1946, are completed.

Up to the end of 1947, a total of 80 wells had been drilled, including 48 wells plugged in 1941, 20 producing wells on an eleven-mile stretch of the Baba dome, six observation wells on the Baba dome, four observation wells on the Avanah dome, one exploratory well, and one suspended.

In November 1947, two steam-powered rotary rigs were in operation. Standard 136 ft. derricks are used, the travelling blocks, swivels and rotary tables and pumps being of British manufacture.

The normal casing programme is : a 16 in. conductor string set at 150 ft. ; an 11¾ in. string set in anhydrite near the top of the transition beds ; and an 8⅝ in. string set in the impervious Miliola limestone at the top of Qarah Chauk group. In view of the anticipated long life and high productivity of the wells each string is cemented to the surface and great care is taken to ensure that the wells are straight and in sound mechanical condition. Below the Miliola limestone no casing or liner is set and wells are sometimes drilled through the reservoir rock with blind circulation.

In the saliferous beds of the Lower Fars considerable difficulty has been experienced in maintaining stable suspensions of bentonite-treated mud fluids and the use of starch suspensions has been investigated but owing to supply difficulties has not yet been adopted. Circulation is usually lost in the porous nummulitic limestones and elsewhere in fissures throughout the producing formation, where water is used as the circulating medium in production wells and dead crude, gas oil or even kerosine in observation wells. From the time circulation is lost the wells are completed with blind circulation, in exceptional cases as much as 400 ft. of hole being drilled in this way. The bit is lifted off bottom at frequent intervals and the utmost vigilance and care exercised to prevent the collection of cuttings round the bit.

Petroleum Times Photos]

The Eocene section near Shaqlawah

Reservoir Characteristics and Data

Overlying the Qarah Chauk group which forms the main reservoir rock are the Transition beds which contain 13 limestone beds, some of which were originally oil bearing, separated by impervious beds of anhydrite with a total thickness of 450 ft.

J. M. Hudson, C. T. Barber and J. McGinty examine the Judea limestone

The base of this series is marked by a conglomerate lying unconformably on the relatively impervious Miliola limestones. These are followed by the porous nummulitic beds which attain a thickness of 300 ft. in the Baba dome thinning out in a north-westerly direction and passing downwards into fine-grained Globigerina and marly limestones. The thickness of the oil-bearing series averages 1,000 ft. throughout the structure and the whole is highly fractured.

The crude is appeciably undersaturated and there was no primary gas cap in the Baba dome. In the deeper Avanah dome, separated from the Baba dome by a shallow saddle, the crude is also appreciably undersaturated but in the Khurmala dome, separated from the Avanah dome by a deep water-logged saddle, the crude is saturated to hydrostatic pressure and there is a small primary gas cap. The specific gravity of the crude is 0.827 throughout the reservoir except in the Khurmala dome where it is 0.807. The oil is underlain by salt water, the level of which is practically uniform, giving in the Baba dome an oil column of 2,400 ft.

There is a high degree of communication throughout the reservoir, both vertically and horizontally, with the result that, although production has been confined to a nine-mile stretch of the Baba dome, pressure decline throughout the Baba and Avanah domes has been uniform. In the Khurmala dome a decline in reservoir pressure has also taken place as a result of production from the Baba dome but this decline amounts to only about a quarter of that which has taken place in the Baba and Avanah domes. It has been accompanied by a spilling of oil and gas through the saddle into the Avanah dome thus beginning the slow drainage of the Khurmala dome. The high degree of horizontal connection throughout the reservoir was strikingly illustrated during the war when fluctuations in the daily production rate correlated within 24 hours with pressure variations in the sole observation well in edge water 10 miles distant from the producing wells.

Free vertical communication has also been unequivocably demonstrated by the drainage of the oil-bearing limestones of the Transition beds by production from the main reservoir. Although separated from the main limestone by apparently impervious beds, pressure decline in the lower limestones of the Transition beds has kept pace with the decline in the main reservoir, and in 1937 an observation well in an oil-bearing middle member of the series went to gas. About the same time an improved channel of communication between this member and the main reservoir was uncovered and a transfer of gas took place which temporarily arrested the fall in the gas/oil level in the main reservoir. By the middle of 1939 pressure equilibrium between this member and the main reservoir was attained and a steady fall in the gas/oil level in the latter was resumed.

With a relatively negligible volume of free gas in the Baba dome, and none in Avanah, and with the oil in these domes under-saturated gas plays a subsidiary part in the replacement of oil produced. The major part of this replacement is by salt water, the rate of ingress of which, however, is not unrestricted as evidenced by the steady pressure decline in the reservoir and the development of a small secondary gas cap in the Baba dome. Like the pressure decline, the rise of edge water throughout the reservoir has been uniform. Despite the restricted area of production there is no evidence of any local effect and minor variations in the present water table are traceable to slight differences in the specific gravity of the water itself.

The sensitivity of the reservoir to changes in production rates was illustrated during the war. During the three-weeks' shut down in September 1939 there was a small rise in reservoir pressure followed by an abnormally rapid decline when production was resumed. From June 1940, to March 1941, when production was curtailed due to the closing of the Mediterranean there was a sunstantial rise and during the shut down in May and June of 1941 a further small rise of pressure took place. Thereafter gradually increasing offtake resulted in a resumption of pressure decline which by the end of 1943 again followed the curve of pre-war decline.

The total pressure decline has now reached a point at which wells at the highest ground elevations no longer develop a well head pressure when closed in and the gas beld off, but in the producing area this is not yet the case and all producing wells continue to flow in single phase with no evolution of gas from solution in the reservoir and no coning in of gas or edge water.

Wells in most parts of the field have extremely high productive indices exceeding 2,000 in some instances, their high productivity being due to the penetration of single major fissures which are fed by smaller ones and ultimately from the pore spaces of the rock. Productive indices have shown little change with time, such changes as there have been being improvements due to the removal of drilling cuttings from the flow channels.

The absence of primary gas caps in the Baba and Avanah domes and the under-saturation of the crude are probably attributable to the gas seepages at the culmination of the Baba dome. As a result of pressure decline consequent on production, evolution of gas from solution took place in the small crestal area where the reservoir pressure fell below the original saturation pressure but, being at the top of the dome and in tight Miliola limestones, the volume of gas represented by this expansion of the gas cap is small. The fall in the reservoir pressure, with an evolution of gas in the crestal portion of the structure, has however resulted in a decline in saturation pressure over a much wider area, due apparently to a gravitational interchange of oil between the crestal and lower portions of the structure.

Production Technique

The great extent of the reservoir, an oil column in excess of 2,000 ft., the low pressures associated with its shallow depth, the under-saturation of the oil, the high productive index and, above all, the high degree of communication throughout the reservoir endow the Kirkuk field with natural advantages which are comparatively unique. From the very beginning the production system was devised to make full use of these characteristics, some of which were already established beyond doubt, but others deduced from the incomplete data then available with an instinct which has since proved unerring in its recognition of principles and forecast of performance through the years which then lay ahead.

Taking advantage of the natural system of communication throughout the reservoir the original scheme for a production of 90,000 barrels per day was from 14 flowing wells covering a nine mile stretch of the Baba dome, thus concentrating production facilities and reducing gathering systems to a minimum.

The wells are sited to take production at an elevation as near as possible to the calculated ultimate gas/water contact, based on reservoir studies and the probable future production policy. In this way the maximum producing life of wells is ensured with the consequent economy of drilling effort and in surface installations. Thus the wells are located along structural contours. Subject to topographical considerations for both wells and flow lines, wells are evenly spaced along the two flanks and production from them is balanced to prevent the transfer of fluids from one flank of the structure to the other.

The concentration of producing wells in a nine mile stretch of this 60-mile structure necessitated the drilling of observation wells at strategic points throughout the structure to ensure that the encroachment of edge water is uniform. In 1939 there were 20 such wells, some of which were drilled originally to determine the structure and its fluid content but others were drilled expressly for the purpose of observing the movement of gas/oil and water/oil contacts and the determination of pressure decline throughout the reservoir. In drilling these wells elaborate precautions are taken to ensure that there is the minimum contamination of reservoir fluids, by the use of oil as the circulating medium. This is carried to a degree of refinement which calls for the use of oil as near as possible to the specific gravity of the reservoir crude, and dead crude, gas oil and kerosine, alone or in varying proportions, have been employed. To ensure that there is no local effect due to production, observation wells are never produced after an initial clean-out at relatively low rates of flow.

The discovery well at Kirkuk

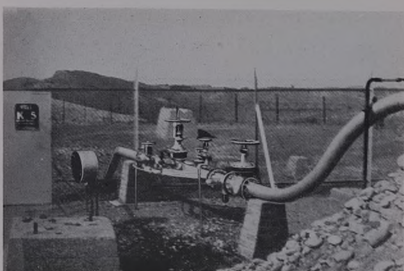
Determining fluid levels

Fluid levels in these wells are measured directly by a modified Halliburton measuring device to an accuracy of one inch while quick and sensitive determinations of reservoir pressure changes are made by direct measurement with a specially adapted dead-weight tester to an accuracy of one half of a pound.

So complete was the reservoir data accumulated by these refined methods during the six years from 1934 to 1940, and so fully in accord with the original conception of pressure equilibrium and uniform encroachment of water throughout the reservoir, that when all but six producing wells and a single observation well in edge water were plugged in 1941, the management had no hesitation in producing 90,000 barrels of oil per day from five wells as a temporary expedient.

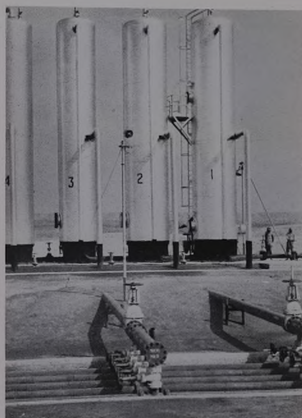
Second only in importance to the principle of control of the reservoir by means of observation wells is the concept that flowing pressures at the top of the productive interval shall be maintained safely above the saturation pressure of the crude so that no free gas is drawn into producing wells or released in the formation. Since, however, the replacement by water of oil withdrawn from the reservoir involves a considerable pressure decline, a secondary gas cap is forming in the Baba dome as a result of this decrease in pressure. All the gas so evolved from solution is retained in the reservoir since, with the high productive index, the draw-down of producing wells is much lower than is necessary to pull the gas cap down to the casing shoe of the nearest well. In these circumstances the gas/oil ratio of producing wells is constant at about 200 cu. ft. per barrel which is the volume of gas dissolved in the oil in the Baba dome at the reservoir pressure. So long, therefore, as the bottom hole flowing pressure is maintained above the bubble point it is quite unnecessary to bother about gas/oil; ratios and this freedom from preoccupation with gas/oil ratio problems is a result of the undersaturation of the crude. As a result of this freedom gas studies have been concentrated on saturation pressures and solubility curves which are of fundamental importance in relation to reservoir energy and development. Determinations on bottom-hole samples collected under pressure in special apparatus are made by simple methods in the laboratory from all producing and observation wells; accurate measurement of volume, together with complete analysis carried out with a Podbielniak apparatus and more fundamental pressure energy studies are carried out on selected samples by special apparatus.

Flow line and "harp" manifold



Surface Installations

Production of 90,000 barrels per day is at present taken from 10 wells connected to two degassing stations (Baba and Shurau), where separators are operated at a pressure in excess of 50 p.s.i. To ensure the maintenance of this system as long as



Shurau degassing station

Petroleum Times Photos

possible the margin of well head pressure for driving crude to the separators, which are situated on high ground, is conserved by carefully grading the flow lines.

At the well-head crude is taken vertically from the casing through a smooth swept bend to the flow line, connected through a system of by-pass controls consisting of $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., $1\frac{1}{2}$ in., 2 in., $2\frac{1}{2}$ in. and 6 in. lines arranged on a horizontal " harp " pattern. By selecting appropriate combinations of by-passes through this " harp " manifold the desired rate of flow can be obtained from the well at predetermined separator pressures. Curves have been drawn up for each well based on measured rates of flow at varying separator pressures so that the required " harp " combination for a specified rate of flow can be speedily determined.

Flow lines from north-east flank wells are 8 in. and from south-west flank wells where surface elevations are lower they are composite 8 in. and 10 in. The grading of flow lines minimises the pressure loss due to friction and gas pockets.

At each degassing station, to which three north-east and two south-west flank wells are connected, crude flows through a streamlined manifold into four 35 ft. by 7 ft. vertical separators operated at a pressure exceeding 50 p.s.i. These separators were built in Britain by Head Wrightson Processes Ltd., to the company's own design. The crude enters the separator tangentially and flows down a spiral tray which provides the maximum surface area for the evolution of gas, which escapes upwards through a central flume and is led off from the top of the separators to burning lines. The level of oil in the separators is controlled by a valve on the gas outlet line.

Of the 200 cu. ft. of dissolved gas in each barrel of crude about 150 cu. ft. are taken off at the degassing stations. The outlet line for the crude oil, with dissolved gas, from the base of the separators is free from restriction. The crude gravitates to a stabilisation plant where pressure regulators are so adjusted to maintain the required pressure of operation on the separators, and all flow is in the liquid phase. From the Baba degassing station there is a 14 in. graded line to the stabilisation plant and from the more distant Shurau degassing station a graded 18 in. line.

Prior to the plugging of outlying wells in 1941, a third (Hanjira) degassing station was in operation but when production was restricted to five wells, the Baba gravity line was used for the sole supply of crude to the stabilisation plant, the Hanjira line took

The Kirkuk stabilisation plant

[Photo

IPC]

surplus gas from the stabilisation plant for disposal without burning from a pipe carried 150 ft. above the ground, and a section of the Shurau line was used for the reinjection of surplus liquid products into the reservoir.

The Hanjira degassing station is about to be recommissioned and a fourth degassing station (Qutan) is under construction to cater for an increase of production to a potential of 300,000 barrels per day from 20 wells, when 270,000 barrels per day will be required on the completion of the new 16 in. pipelines to Haifa and Tripoli.

The a diagram opposite shows the present layout of the degassing stations and its adaptation for a future production of 300,000 barrels per day.

At the end of 1936 the stabilisation plant was commissioned with the objects of the recovery of butane and the removal of sulphuretted hydrogen from the crude. Since that time the production system has been operated as a closed circuit activated by the reservoir pressure. At the stabilisation plant crude is received in Hortonspheres which are normally operated at 50 p.s.i. and act as secondary separators from which a supply of gas can be obtained, if required for fuel in the stabilisation plant and the neighbouring power house, by raising the pressure on the primary separators.

The crude charge pumps take suction from the Hortonspheres, the crude being passed through heat exchangers, counter current with hot residuum, and then flashed at 340°F. into the first stage columns. Bottoms from these columns are recirculated through tube-stills to maintain the column base temperature of 450°F. necessary to drive off all the dissolved sulphuretted hydrogen. Overheads are charged to the second stage columns where close fractionation is carried out with a reflux of condensible distillate and venting of the gas. The bottoms from both columns are passed through heat-exchangers and blended to give the stabilised product which contains upwards of 90 per cent. of the butanes charged, representing some 75 per cent. of the reservoir butanes, and has a Reid vapour pressure of only 4 p.s.i.

The original stabilisation plant consisted of three units but a fourth was added in 1938 and four more are now under construction.

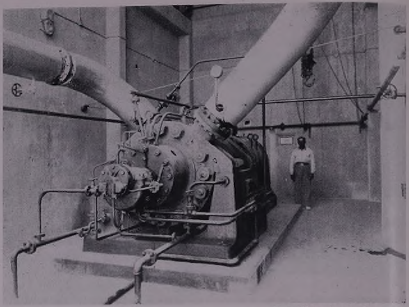
During the war part of the stabilisation plant was operated as a topping plant. Light fractions were removed from the crude to yield gasoline for the use of Allied forces in Iraq and a residual fuel oil, meeting Admiralty specifications, which was pumped through the northern pipeline to Tripoli for Naval use. Fluctuations in the demand for these products resulted in a surplus of distillate when Naval requirements were high and of residue when Army demands predominated, and these were returned to the reservoir via the Shurau line and one of the six remaining production wells. Fortuitously, but fortunately, the heavy and light products so returned to the reservoir were balanced so that there was no appreciable overall effect on the composition of the reservoir crude.

From the stabilisation plant oil flows by gravity to the tank farm at the main pump station (K-1) 1½ miles distant.

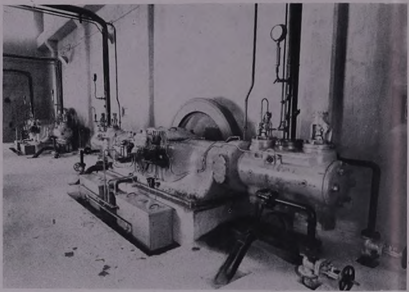
Oil Measurement

At the Kirkuk tank farm oil is *weighed* for royalty assessment. Royalty is payable on a tonnage basis and conventional methods of measurement by volume necessitate not only dipping, but elaborate sampling of tanks and determination of the temperature and specific gravity of the oil. The Iraq Petroleum Co. therefore concluded that determination of the weight of columns of oil by the use of a mercury column would give more satisfactory results than the dip tape method originally employed. They developed a special mercury column gauge which was manufactured by the London instrument firm of Negretti and Zambra and which the National Physical Laboratory certified to an accuracy within 0.005 in.; equivalent when weighing oil of density 0.845 to a head of oil of 0.08 in.

The gauge consists essentially of a cistern of internal diameter approximately 6 in., connected to a glass tube of approximately



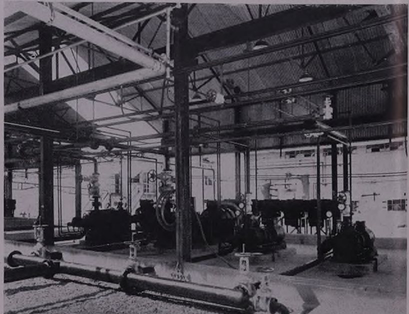
Hot oil recirculating pump



The gas compressor house

IPC Photos]

The stabilisation plant pump room



0.6 in. bore, with provision for measuring the length of the mercury column in the tube by scale and vernier. The upper end of the glass tube communicates with the atmosphere through a drying chamber containing silica gel. The gauge contains measured quantities of mercury (approximately 5 kilogrammes) and refined gas oil of average crude oil density (approximately 0.5 kilogrammes), the gas oil being placed in the cistern to serve as a sealing liquid over the surface of the mercury. In service, the upper end of the cistern is connected to the oil tank, and arrangements are provided to ensure that the connecting pipe and the upper part of the cistern, above the gas oil surface, are completely filled with oil.

The range of measurement of the gauge is 0 to 36 in. of mercury, reading to 0.002 of an inch.

A thermometer is provided for determining the temperature of the gauge, and two spirit levels are mounted on the instrument for levelling purposes. In service, the instrument is required to measure the quantity of oil above a fixed datum level in the storage tank for the purpose of determining the weight of oil despatched from the tank to the main pipelines. The datum level is chosen to be the plane containing the upper gas oil surface of the cistern when the gauge is connected to the tank and reads 0.000 at a temperature of 68°F.

Carefully fitted metal to metal joints are employed and arrangements are made to secure rigid mounting and accurate levelling, and special illumination is provided to ensure sharp definition of the mercury meniscus.

Readings of the gauge are corrected to standard temperature, 68°F., by means of a temperature correction table, furnished by the National Physical Laboratory. A second table is also supplied for converting gauge readings into equivalent heads of oil.

For each tank a table has been compiled based on the strapping of the tank for conversion of heads of oil into tons by multiplication of the weight of the oil column by the area of the tank at the appropriate level.

Remarkable accuracy has been achieved by this method as demonstrated both by the trial use of two gauges in service on the same tank and by comparison with refined conventional methods of measurement.

The New Power Station

A new power station is being constructed at Kirkuk in order to supply the greatly increased electrical power requirements of the area. This station, which is of particularly interesting design, consists basically of three building blocks connected by two double-decked bridges at the operating level, 22 ft. above ground, the lower parts of the bridges acting as cable ducts and pipe galleries.

The northern block contains the boiler battery consisting of six Spearing boilers each of 120,000 lbs. per hour M.C.R., generating steam at 450 p.s.i. and 750° F. final temperature. No building is provided to house this plant but the boiler structures are extended to carry a continuous umbrella roof 60 ft. wide by 230 ft. long, giving adequate weather protection to the plant.

The boilers are fired by refinery waste gas and/or oil, the firing zone being ingeniously extended to form a continuous firing aisle enclosed in steel and glass construction and giving complete all-weather protection to the operators.

The centre main block contains the turbine hall, auxiliary control room, offices, stores, etc., and is of steel framed brick-filled construction 88 ft. wide by 70 ft. high by 230 ft. long. In the turbine hall are three turbo-alternators of B.T.H. manufacture each of 23,450 kVA. generating at 11,000 volts and running at 3,000 r.p.m. There is also a small 350 kW. Diesel house set. The main turbo-alternators are provided with condensing plant and three-stage feed heating, evaporators, etc., of Metro-Vickers manufacture.

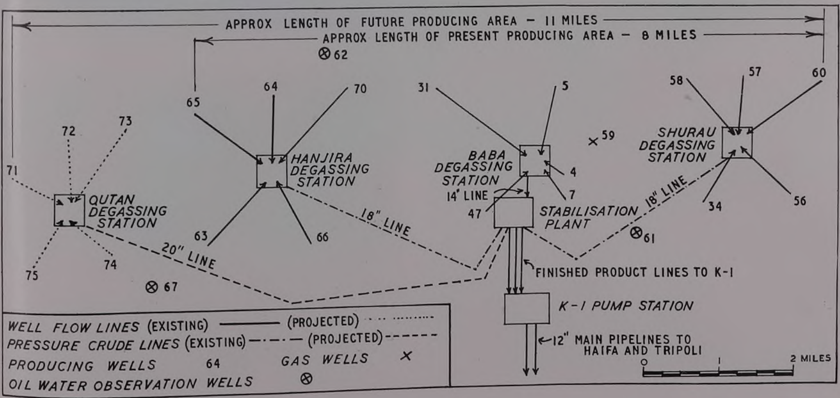
Washed and cooled air is continuously supplied to the main turbine hall, the maximum temperature being limited to 95° F. under hottest summer conditions.

Forming an annexe to the main hall is the auxiliary control room, 30 ft. wide by 80 ft. long, containing the 400 volt auxiliary switchgear and the remote control of the boiler battery which is operated from a special control desk elevated so as to permit a comprehensive view of the turbine hall and boiler battery through glass panels.

Beneath the auxiliary control room is a mezzanine floor space through which are distributed the various pipes and cables, while at ground level are staff wash-rooms, stores and workshop, etc. Immediately above the auxiliary control room are the general offices for the engineering staff, while on the topmost floor is the tank room containing the surge and feed tanks.

An electric lift gives access to all levels and the two main floors are fully air-conditioned to a maximum temperature of 80° F.

The southern block, which is also of steel framed brick-filled construction 56 ft. wide by 120 ft. long, accommodates at ground level the H.T. switchgear. This switchgear is arranged in two duplicate sections divided by a fireproof wall; it is of B.T.H. manufacture and is of the double bus-bar type rated at 500

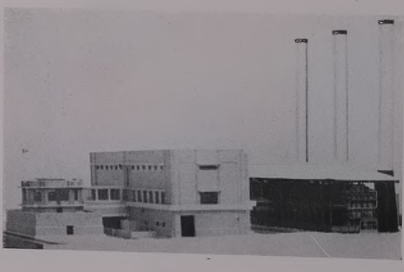


The water pump station area at the Lesser Zab

[IFC Photo

G. H. Herridge and H. W. Wheatley at the Kirkuk guest house

[Petroleum Times Photo



The new power station

M.V.A. rupturing capacity. The D.C. battery and switchroom, automatic fire extinguishing gear, electrical stores and air conditioning plant are also accommodated in this building underneath which are underground tunnels for the out-going feeders, etc.

Surmounting the flat roof of the H.T. switchroom is the main control room. This is of tower-like construction and octagonal in shape, being approximately 45 ft. square.

The control room floor is twenty-two feet above ground level, which is the operating level maintained throughout, and a further mezzanine space is provided between this and the switchroom roof. This space, together with the lower deck of the connecting bridge, forms a cable duct for the main phase cables and also the various control cables which are thus totally concealed.

The control room accommodates the main control board which is arranged to conform to the octagonal shape of the building. Indirect overhead lighting is provided through a large panelled overhead laylight. The control room is fully air-conditioned to a maximum of 80° F. and the pedestals of the control desk, situated in the centre, form the extraction ducts of the air conditioning system, thus ensuring a continuous supply of cool air in the region of the operator.

Particular care has been given to the design of this station to ensure the reliability essential to an isolated plant providing vital supplies.

In view of the peculiarly advantageous fuel situation it has not been necessary to strive for the maximum thermal efficiency and the designers have concentrated on the provision of trouble-free equipment, coupled with a simplified layout requiring the minimum of skilled staff.

The external appearance of the station, with its surrounding balconies and modernistic sun-shades rather like giant venetian blinds, is very pleasing, while the internal finish, which is carried out in cream and silver colouring with terrazzo tiled walls and panelled ceilings, gives an air of space and coolness.

Fluorescent lighting is provided throughout.

It is obvious that no necessary expense has been spared, but nevertheless we understand that the total installed cost of the complete power station including foundations will be not much more than £25 per kW.

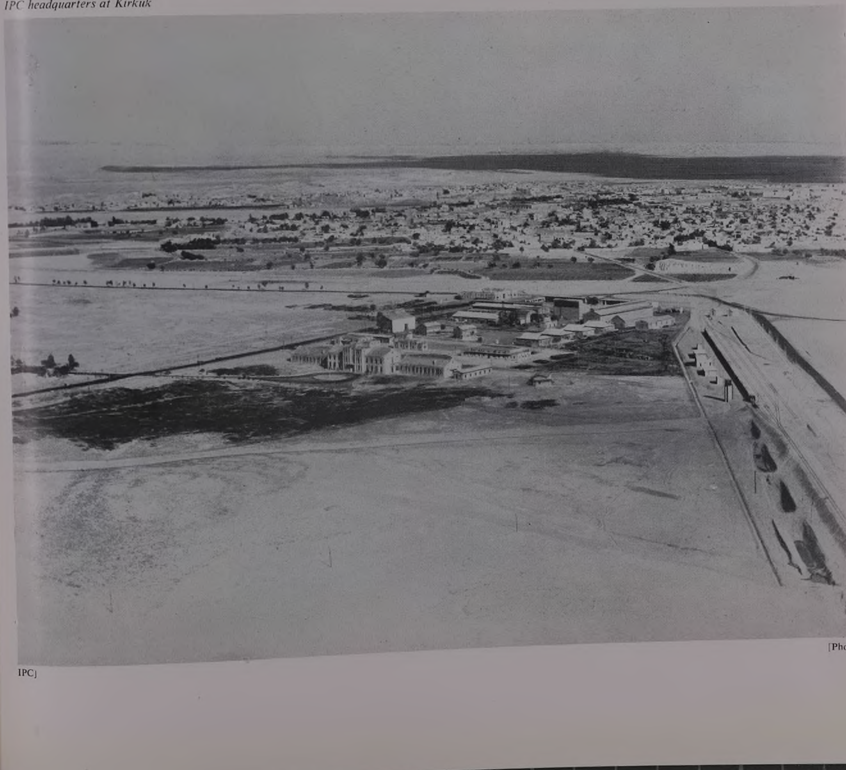
The design and engineering of this project have been carried out by Spearing & Co. Ltd., who are the main contractors for the complete station.

Amenities and Social Work

By reason of the geographical location of their producing operations on the eastern fringe of the desert, which stretches from the Jordan valley in the west to the Kurdish mountains in the east, the Iraq Petroleum Co. has to provide for every need of its European and American staff and a large proportion of the needs of its local employees.

From the dawn of history until the Mogul invasion in the 13th century irrigation from the waters of the Euphrates and Tigris made Mesopotamia one of the granaries of the world. But

IPC headquarters at Kirkuk



[Photo IPC]


IRAQ PETROLEUM COMPANY LIMITED
KIRKUK DEVELOPMENT
PROPOSED NEW HOUSING IN
THE ARRAPHA RIDGE AREA

during the Mogul occupation following Hulagu's capture of Baghdad in 1256 wanton destruction and subsequent neglect of the irrigation system caused this most fertile portion of the ancient " Fertile Crescent " to revert to desert. In *Four Centuries of Modern Iraq* Brigadier S. H. Longrigg gave the following epitome of this tragedy : " Most ruinous of Hulagu's acts had been the studied destruction of the dykes and headworks, whose ancient and perfect system had been the sole source of wealth. Disordered times, and the very fewness of the spiritless survivors, forbade repair ; and the silting and scouring of the rivers, once let loose, soon made the restoration of control the remote, perhaps hopeless, problem today still unsolved."

The plain of Erbil, between the hills of Bakhtiari sandstone which run along the north-eastern flank of the Kirkuk structure and the Kurdish mountains to the east, is the best wheat area in Iraq, but it is now dependent on the uncertain and inadequate rainfall. In 1947, when wheat was in short supply due to insufficient rainfall and the ravages of locusts resulting in the failure of the previous year's harvest, the best obtainable rice was purchased by the company and sold to its employees at the price ruling for the poorest quality rice in the bazaar. The shortage of wheat in the early months of this year sent bread prices soaring to heights never known before in Iraq. To assist their staff and labour, the company opened bakeries at Kirkuk and sold bread at approximately one-half the price in the local bazaar. Another scarce commodity, cooking oil, is also purchased by the company and sold at subsidised prices. In addition five canteens are operated by the company where employees can get meals which are subsidised to the extent of 45 per cent. The popularity of this service is evidenced by the fact that men go to the canteen for meals even on days when they have the afternoon off.

The cost of these food subsidies is equivalent to £1 7s. 6d. per month per employee, or 15 per cent. on the lowest salary rate of £9 3s. per month.

Clothes and textiles, which during and since the war have been in short supply, are also imported by the company and sold to employees at subsidised prices.

The policy of subsidising commodities has been adopted by the company as the only method of imposing a check on the spiral of inflation. In common with all Middle East countries war-time inflation has impinged with particular force on Iraq due to the presence of Allied forces, and the note circulation in 1947 was 39 million as compared with about 5½ million in 1938. With a population of some 4½ million this represents an enormous increase in purchasing power at a time of world-wide shortage of consumer goods, and in Iraq the inflationary effect is exaggerated by the fact that 50 per cent. of the population is nomadic, living on the products of their own flocks or on a barter economy in which money plays no part. The money is therefore concentrated in the towns, of which Kirkuk is the fourth largest with a population of 76,000. In these circumstances experience has demonstrated that salary increases are overtaken within one month by rising prices in the bazaar.

This ever rising spiral of wages and prices finds its most acute manifestation in the matter of rents. Early in 1947 the rent of four rooms with use of kitchen and bath in Kirkuk town had risen to £15 per month, and two rooms with similar facilities to £10 per month, while a single labourer could obtain lodging at £3 per month. To offset these costs the company gave a rent allowance, news of which rapidly spread in the bazaar with the result that in some instances rents rose by an equivalent amount before the allowance became fully operative and in all cases its total value was completely offset by higher rents in less than a month after its introduction.

The IPC pay roll at Kirkuk is 5,000 which, with an average of four dependents per employee, means that 25,000 out of the town's 76,000 inhabitants are directly dependent on the company's operations. Before the war the problem of housing had not become acute : rents in the town were moderate and the locally engaged labour preferred to make their own arrangements in the town rather than live in company quarters. With the expanding scope of the company's operations and the exorbitant cost of rents in the town the situation has entirely changed and the company is embarking on a housing project with the object of providing accommodation for the whole of their artisan employees. This will release accommodation in the town for labourers and with a reduction in demand should come a fall in rents. To provide accommodation for the whole of the employees at this stage is both impracticable and it is thought unnecessary : impracticable as a result of the shortage of building materials ; and undesirable as the laboureres still prefer to live in the town, the majority of them still having strong tribal attachments. They work for the company during the summer months but return to their tribes for the sowing and harvest seasons.

The immediate building programme calls for the construction in 1948 of 150 houses for daily-paid workers and 60 for monthly-paid workers ; 200 for daily-paid and 100 for monthly-paid workers in 1949 ; and 300 for daily-paid and 140 for monthly-paid workers in 1950, with another 150 for daily-paid workers in 1951. In the accompanying plan of the layout of the new Kirkuk housing estate, the existing Arrapha estate is shown in skeleton outline.

The houses for monthly-paid workers are all semi-detached and are laid out with a density of 1.86 houses per acre. They each have two bedrooms of 178 and 167 sq. ft. respectively. A living room of 224 sq. ft., dining room of 118 sq. ft., and kitchen of 98 sq. ft., together with store room, bathroom and w.c. The houses are surrounded by gardens and a feature of the design is the privacy which permits the traditional seclusion of Mohamedan women.

For daily-paid workers houses are built in blocks of not more than six houses with an average density of eight houses to the acre. Each house has two or three bedrooms of 176 sq. ft. each, a living room of 200 sq. ft., a kitchen of 87 sq. ft., a showerbath and separate w.c.

Houses for both monthly- and daily-paid workers have verandahs in front and courtyards at the back and are provided with access to the roof. Ample built-in cupboard accommodation is a feature of both types. Electricity and water are laid on and water-borne sewage disposal is provided. All roads are macadamised and have pavements and street lighting. In addition the layout includes a mosque, a savings bank, Post Office, clinic, bazaar, shops, laundry, police quarters, clubs, restaurants, schools, sportsgrounds, and an institute equipped with reading rooms and a debating chamber.

The site of this comprehensive town planning scheme has been graded, the roads laid out and the first batches of each type of house are under construction. A brick kiln with a capacity of 25,000 bricks a day, which has already produced more than 20 million bricks, is operated by the company.

Other building projects to begin this year are the construction of a sports pavilion on the existing Arapha sports ground on the outskirts of the new housing estate, a new canteen for workers at Baba Gurgur, and a new labour office and dispensary near the Baba Gugur railway station. The sports pavilion will have dressing and bathing accommodation for four teams concurrently, and a 50 ft. by 25 ft. central hall with a staircase to the covered flat roof. Kitchen facilities are provided for serving hot and cold drinks to players and spectators. The architect has produced a handsome as well as a functional design in which the players' entrances are so arranged to give direct access to the dressing rooms without detracting from the fine architectural lines of the facade.

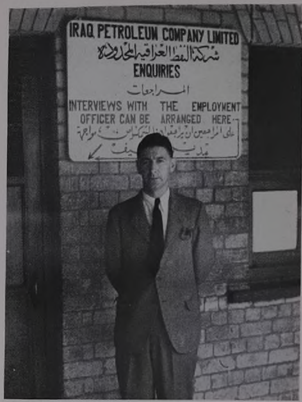
The new canteen is entirely self-contained with kitchens, stores, and its own refrigeration plant. It will serve 1,000 meals at a sitting and will provide breakfast in summer and luncheon in winter for daytime workers and meals at all hours for shift workers. In addition to the service of prepared hot meals, hot-plates are provided where workers who prefer to do so can heat up their own food. Rest rooms are provided for the kitchen staff, each of whom has a locker and will be expected to wash and change before handling food.

The new labour office and dispensary combines the functions

Houses under construction: top, for monthly paid workers; bottom, for daily paid workers
IPC] [Photos

of an employment office and a clinic. From the nearby railway station applicants for employment enter a courtyard where adequate covered space and toilet facilities are provided. They are interviewed in turn by the employment officer and then pass through the record room, where they are photographed and documented, to a waiting room. From here they go to the cleansing department where they have a shower while their clothes are disinfected, and from the dressing-room to the medical inspection room where they are examined. They then return to the employment office with their medical report. The building also houses consulting rooms where employees can see the company doctors, and a dispensary designed principally to cater for employees working in the Baba area.

At Kirkuk the company has one of the best equipped hospitals in the East. It has 96 beds and is staffed by European doctors, surgeons and a dentist and by British and Iraqi nursing sisters. It provides medical, surgical, radiological, dental, and opthalmic treatment, which are available both to the company's employees and to local inhabitants and tribesmen. Extensive additions are now being made to the wards and consulting rooms and the building of residential blocks for the sisters and nurses will commence shortly. In 1947 there were 2,600 in-patients, including 760 non-employees, while the company's out-patient clinics at Kirkuk treated 7,100 patients. The company's clinics in all areas treated 90,000 cases involving 220,000 attendances. The clinics specialise in public health, antenatal and child welfare, and preventative medicine. An incessant war is waged with bubonic plague, yellow fever, and malaria and the tribesmen come in increasing numbers for inoculation.



G. J. R. Tod, Labour Superintendent
Petroleum Times] [Photo

The existing camps at Arrapha and Baba Gurgur for the company's foreign staff include 83 permanent houses; a club with sportsground, tennis and squash courts, a swimming pool and indoor and outdoor cinemas; and a guest house presided over by a senior member of the staff, in which every want of the company's guests is anticipated. The camp is spaciously laid out with trees, shrubs and gardens and, by dint of irrigation, is a veritable oasis in the desert.

Water is pumped from wells sunk in the alluvium of the Lesser Zab, 24 miles north-east of the camp. The pump station there has a capacity of $2\frac{1}{2}$ million gallons a day, now being increased to 5 millions, and in addition to supplying the field and the camps supplies half a million gallons per day to the town of Kirkuk.

A large area has been acquired to the west of the pump station for a housing estate. It is hoped to build 16 houses for monthly and 48 for daily-paid workers this year, of types similar to those being built at Kirkuk, and in future years to develop the area with shops, canteens and other facilities.

The company's wage rates have always been higher than local or Government rates and in these respects the company anticipated the provisions of the 1936 and 1942 labour laws. The company has a provident fund for all employees on monthly contracts: employees contribute 10 per cent. of their wages, the company contributing a like amount and an annual bonus which last year was equivalent to $7\frac{1}{2}$ per cent.

The labour superintendent is responsible for a small safety department, whose activities are mainly directed to making all employees, from supervisory staff down to labourers, safety conscious. A tour of the oilfield and the workshops with the labour superintendent was an education in this respect: no piece of wire, no piece of wood with protruding nails, or other sharp object lying on the ground escaped his watchful eye; no act of reckless or negligent driving on the part of Iraqi or foreign employees but brought a stern reproof; no labourer stood with his foot under a suspended joint of pipe without receiving a demonstration of the danger to which he was needlessly exposed, and a kindly admonition; and all this on a tour not specifically designed to study safe practices, but to visit shops, clubs and canteens. Remarkable results have been achieved by friendly rivalry among departments whose accident rates are circularised in a monthly bulletin which contains notes on safe practices and avoidable risks. By these methods the incidence of accidents has been reduced by 50 per cent. in less than a year.

Other Areas in Iraq

TO THE WEST OF THE TIGRIS oil was discovered in the Qaiyarah area, 37 miles south of Mosul on October 13, 1927, two days before Baba Gurgur No. 1, in the Kirkuk field, blew in.

A total of 69 wells has been drilled on the four anticlinal structures of Qaiyarah, Qasab, Jawan and Najmah, which pursue a NW-SE course to the immediate west of the Tigris. Oil occurs in limestones of Miocene to Upper Cretaceous age at depths of from 700 to 1,800 ft., the shallower zones being correlative with the Qarah Chauk limestones of the Kirkuk field.

In the Qaiyarah structure itself substantial reserves of oil have been proved but the crude is of a heavy asphaltic type with a high sulphur content which it is uneconomic to refine at the present time, and all the wells are shut-in.

At Ain Zalah, 40 miles north-west of Mosul, oil was discovered in 1940 at a depth of 5,100 ft. The reservoir rock is limestone of Maestrichtian age, overlain by a thick series of shales, the complete succession being as follows :—

Age	Local representative	Lithology	Thickness in ft.
Miocene	Lower Fars	. . Shales and anhydrite . .	450+
		Limestone	550
Oligocene to Eocene	Qarah Chauk	. . Limestones with shales at base	2,300
Paleocene to Danian	Dohuk . .	. . Shales with sandstones	1,800
Maestrichtian . .		Limestone	1,000+

The Ain Zalah structure is an east-west anticline eight miles long and two miles wide with a closure of 1,000 ft. Unlike the Qaiyarah crude the oil is a light crude of the Kirkuk type but there is as yet no evidence of the high permeability and fracturing which characterize the Kirkuk structure, and none of the wells yet drilled has been a big producer.

By the spring of 1941, five wells had been drilled to depths ranging from 5,100 to 6,000 ft. but these were all plugged as a defence measure and the equipment moved to Basrah.

Operations were resumed in October, 1947, and three rigs are now in operation. In May, 1948, two new wells (Nos. 9 and 10) were drilling in the Qarah Chauk limestone at depths around 3,000 ft. and an offset well to the plugged well No. 8 had reached a depth of 460 ft. in Lower Fars.

Since the resumption of operations new drillers' quarters and a club with cinema have been built from local stone, roads to three well sites have been graded and the water pump station at the Tigris, four miles to the north of the field, recommissioned. In November, 1947, new drilling and production staff was arriving daily and there was every sign that the field was on the eve of intensive development.

EXPLORATION IN THE BASRAH AREA

At two sites near Zubair and Nahr Umr, 20 miles south-west and 30 miles north-west of Basrah respectively, exploratory drilling is in progress on broad flat structures located as a result of geophysical surveys. The first objective in these tests is the Rutbah Sand of Lower Cretaceous age, which is so prolific in the Burgan field 80 miles to the south. At Bahrah, half way between the Burgan field and Zubair, the Kuwait Oil Company's well No. 1 was drilled and here the Rutbah sand, which attains a thickness of 900 ft. in the Burgan field, had shaled out so that its presence in the Basrah area cannot be taken as a foregone conclusion.

If there is no sand development in the Basrah area, or if it should prove to be present but unproductive, the test borings at Zubair and Nahr Umr will be continued to explore the Jurassic sediments which are productive in Saudi Arabia.

Zubair No. 1 spudded in on February 14, and at the middle of May had reached a depth of 4,556 ft. Commencing in the Dibdibba formation, this well has drilled through the Lower Fars and the Kuwait Series, below which a predominantly limestone section has been penetrated to the present depth which may be at, or near, the top of the Cretaceous.

Nahr Umr No. 1 spudded in on March 25 ; the commencing formation was the Dibdibba and at the middle of May the well was drilling in Lower Fars at 1,758 ft.

British-built Ideal Consolidated rigs are being used at both locations.

The Dukhan Field, QATAR

The Qatar peninsula projects northwards from the Saudi Arabian coast between latitudes 24° 45′ and 26° 20′ N. Physically and climatically it differs little from the eastern littoral of the Saudi Arabian mainland : politically it is an independent Sheikdom under British protection. In 1932 the Sheik, His Excellency Sheik Abdulla Ben Qasim ath Thani, granted a concession to Petroleum Development (Qatar) Ltd., a member of the Iraq Petroleum Co. group, over the 4,000 square miles of his domain, for 75 years with effect from May 17, 1935.

Geology

The greater part of the peninsula is covered by wind-blown sand, but with numerous outcrops of Eocene limestone except in the dune country in the south-east. Structurally it is a broad anticlinorium with the well defined Dukhan anticline running along the western margin between latitudes 24° 50′ and 25° 30′, like the thumb of the right hand laid palm downwards on a map of the peninsula. Here surface elevations rise to 250 ft. in comparison with elevations of from 120 to 170 ft. prevailing over the remainder of the peninsula. Dips in the exposed limestones are very low but elevations taken on marker beds revealed the presence of a surface anticlinal structure some 50 miles long and up to five miles wide with some 300 ft. of closure. The geological succession established by drilling is as follows :—

Age	Local Name	Development	Thickness in ft.
Eocene	Bahrein formation . .	Limestone with shales	1,000
Maestrichtian . .	Tayarat limestone . .	Limestone	600
Senonian . .	Khatiyah formation	Limestones and shales	800
Cenomanian . .	Mauddud limestone	Limestone	200
Lower Cretaceous	Rutbah sandstone . .	Sands and shales . .	500
Cretaceo-Jurassic	Musandam formation	Limestones with subordinate shales . .	2,000
Middle Jurassic . .	Zekrit formation . .	Anhydrite	400
		No. 1 Limestone . .	35
		Anhydrite	30
		No. 2 Limestone . .	20
		Anhydrite	50
		No. 3 Limestone . .	84
		Anhydrite	60
		No. 4 Limestone . .	133+

The Zekrit formation, which is correlative with the Arab zones of Saudi Arabia, lies at a depth of 5,100 ft. at the crestal portions of the Dukhan structure. Southward and eastward thickening of the overlying Eocene, Cretaceous and Cretaceo-Jurassic formations reduces the size of the Zekrit reservoir in comparison with the surface Eocene structure.

Petroleum Times] [Photo
T. S. Cogan and Ben F. Zwick at the Basrah test

Development

An exploratory well was started at the north end of the Dukhan structure in October, 1938, and was completed in the No. 2 Limestone of the Zekrit formation in January, 1940, where it gave an estimated initial production of 5,000 barrels of oil per day at a wellhead flowing pressure of 367 p.s.i. A second well was drilled 10 miles south of No. 1 and in March, 1941 gave an initial production of 5,000 barrels of oil per day at a well-head pressure of 342 p.s.i. from the No. 3 Limestone. This well was deepened to the No. 4 Limestone which was gas-bearing and was subsequently plugged back to the bottom of the No. 3 Limestone. A third well, drilled 2½ miles east of No. 1 was completed in edgewater in both the No. 3 and No. 4 Limestones in May, 1942. Shortly afterwards operations were suspended for the duration of the war, the wells plugged and the equipment removed. On the basis of the two productive wells then drilled Dr. E. de Golyer in 1944 estimated the probable reserves of the Dukhan field at 500 million barrels.

Operations were resumed in 1947 with the immediate object of drilling five producing wells at the north end of the structure. Two producers (Nos. 4 and 5) have been drilled and No. 6 well is drilling below 3,000 ft.

Drilling

Two British-built Ideal 100 Consolidated rigs are in operation, powered by diesel engines, and a third is rigging up. Due to the acute shortage of fresh water, sea water is used for circulation, which in the dry porous Eocene limestones is blind. These are isolated by a conductor string cemented in the Tayarat limestone and drilling continued with overhead circulation using clay suspensions. The use of sea water and the saline content of formation waters cause flocculation of bentonite based suspensions. Starch suspensions, Zeogel, and soda ash have been employed, and Quebracho as a viscosity reducer. Fibrotex and Jelflakes are used as sealing media. A water string is cemented at about 4,000 ft. in the Musandam formation and an 8⅝ in. oil string in the 50 ft. anhydrite immediately above the No. 3 Limestone.

The Gathering System

Individual well-head separators are to be installed to operate up to 900 p.s.i., and from them crude will flow under pressure to a central multi-stage separation unit consisting of four separators operating down to atmospheric pressure. Adjacent to the separation unit, three 30,000 barrel storage tanks are under erection from which a 12 in. pipeline 25 miles in length is planned to a deep water terminal at Umm Said (south of Dohah) on the east coast of the peninsula. Export of crude is expected to start early in 1950.

Facilities

Apart from the small capital town of Dohah the Qatar peninsula is sparsely inhabited by nomadic Bedouin and the company has to provide for every need of its operating personnel, even to the extent of importing drinking water. An evaporation plant with a capacity of 100 tons per day will be in operation shortly and others are projected. The pre-war temporary camp has been reconditioned and enlarged and the site of a permanent camp has been selected and construction work commenced.

The IPC Group's Exploratory Programme

The complete dependence of the company's operations on facilities provided by itself is even more obtrusive in the case of its exploratory programme than at Kirkuk. There the Baba and Arrapha camps have an air of permanence that makes it difficult for the visitor to realise that the treelined avenues, the houses and gardens, the roads, and the water and electricity services are the creation of the company, and that twenty years ago the area they now occupy was nothing but " a strip of herbage strown that just divides the desert from the sown ". In the field area the gathering lines, the separators, the stabilisation plants, the workshops and the stores are easily recognised as the paraphernalia of a great oilfield, but in the camp, the club and cinema, the guest house, and the 24-hour laundry service are so reminiscent of pre-austerity Britain that one is apt to assume that they " have always been there." But at some of the group's outside tests, as on the pipelines, one comes up against the desert in the raw.

At Dolaa and Toual Abba, the sites of their test wells in Syria, the Syria Petroleum Co. has to provide for every need of its employees. The heavy drilling equipment, every ton of cement, every nut and bolt, has to be transported over many miles of desert " road," parched and dustry in the dry weather, and a sea of mud after the brief torrential rains. Houses have to be built for the employees ; offices, laboratories and workshops constructed, water wells drilled, ice and refrigerator plants, food, drink and recreation facilities provided. And provided they are, on a scale which mitigates in every possible way the rigours, discomforts and isolation of life in the desert.

In this type of operation the initial cost of road and camp construction and of installation of the equipment overshadows actual drilling costs and for this reason the group has adopted the policy of employing equipment capable of drilling to 10,000 ft.

SYRIA

Before World War II four deep and one shallow well were drilled by Petroleum Development (Syria and Lebanon) Ltd. to test oil potentialities of sediments ranging from Miocene to Devonian age.

Doubayat No. 1—was located on a WSW—ENE structure 46 miles ENE of Palmyra to test the Middle Cretaceous and Jurassic limestones. Having failed to obtain oil in these formations it was continued into sediments believed to be of Devonian age without obtaining production.

Cherrife No. 1—was drilled on a large closed structure parallel to the Doubayat structure and situated near T-4 pump station.

39 miles due west of Palmyra, with the same objectives as Doubayat No. 1. It was completed in Permo-Carboniferous strata without obtaining production.

Derro No. 1—located 20 miles north of Deir ez Zor was drilled to test the Bichri sand of lower Miocene and Oligocene age and the Middle Cretaceous limestones. In this well the Bichri sands, which at outcrop are heavily impregnated with oily residues, were absent, the Lower Miocene and Oligocene being represented by limestone which carried residual oil. No production was obtained from these limestones and the Cretaceous limestones were not reached due to mechanical difficulties.

Djibissa Nos. 1 *and* 2—were drilled on an east-west anticline 70 miles north-east of Deir ez Zor to test the Euphrates limestone of Middle Miocene age which is the source of the Qaiyarah oil in Iraq, and which is covered by Lower Fars sediments at Djibissa. Gas but no oil was obtained in Djibissa No. 1 which was continued into the Cretaceous limestones without obtaining production. No. 2 well was drilled down dip from No. 1 to explore the possibility that the gas-bearing horizon of No. 1 might be oil-bearing on the flanks of the structure, but no production was obtained.

Thus before the war, Doubayat and Cherrife were drilled to test the Palmyra area ; Derro to test the Bichri sector with its outcropping oily sands ; and Djibissa to test the Jebel Sinjar area on the borders of Syria and Iraq.

During the war a moratorium on prospecting obligations was granted and operations were suspended due to the difficulties in obtaining equipment and personnel. Recommencing exploration after the war, it was decided to test other areas without necessarily abandoning the idea of further examination of the areas in which unsuccessful tests were drilled before the war.

A test well was commenced at Bafloun, on a north-east—south-west structure, 30 miles NNW of Aleppo on May 31, 1947. The primary objective was the Middle Cretaceous limestones, with Jurassic limestones as secondary objectives.

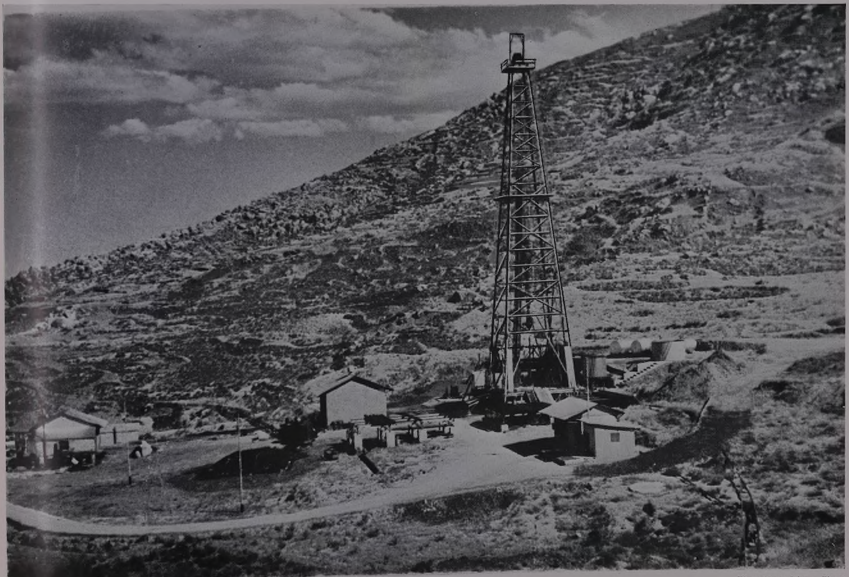
Early in May, 1948, Bafloun No. 1 had reached a depth of 6,696 ft. after penetrating the following geological boundaries : Lower Miocene/Upper Eocene 160 ft., Upper-Middle Eocene/Lower Eocene 2,530 ft., Lower Eocene/Cretaceous 3,530 ft., Upper Cretaceous/Middle Cretaceous 4,783 ft., and Middle Cretaceous/Lower Cretaceous circa 6,500 ft. After cementing 16 in. surface casing at 568 ft., the $11\frac{3}{4}$ in. was set at 3,080 ft. and the $8\frac{5}{8}$ in. at 6,522 ft.

A second test well was located at Dolaa, 95 miles south-east of Aleppo with the primary object of testing the Middle Cretaceous limestones. Dolaa No. 1 spudded in on December 6, 1947, and is now drilling at 5,383 ft. in Jurassic limestone. The following geological horizons have been penetrated : Upper/Middle Cretaceous 1,815 ft. Middle/Lower Cretaceous 2,255 ft., Lower Cretaceous/Jurassic 3,260 ft.

A third test has been located at Toual Abba in north-central Syria, 115 miles east of Aleppo, where a site has been graded and preparations are well in hand for the installation of the rig.

British-built Ideal 100 Consolidated rigs, capable of drilling to 10,000 ft., are being used for each of these tests in Syria.

The results so far obtained in Syria show that appraisal of the oil potentialities cannot be based on the mere counting of good anticlinal structures. This is not surprising since the formation of the anticlines took place at a late stage of geological history, long after the probable date of oil formation. The oil formed must therefore have had ample opportunity to disperse in the



[Petroleum Times Photo

The test well at Terbol, near Tripoli

meantime. The search for oil is therefore highly complex, calling for both regional and local stratigraphic studies with the object of locating primary stratigraphic traps. Prospects are good only where these coincide with subsequent anticlinal traps and it is therefore improbable that more than a small proportion of the known anticlinal structures will prove productive.

LEBANON

In May, 1947, a test well was commenced on the Terbol anticline which commences two miles east of the town of Tripoli and runs in a north-easterly direction parallel to the Mediterranean coast. Its objectives are to test the Cretaceous and Jurassic limestones which outcrop in the mountains of Lebanon.

The test well, known as Terbol No. 1, is situated in a natural amphitheatre 1,264 ft. above sea level on the limestone ridge which rises behind the town of Tripoli. It is reached by a road 4.8 kilometres long constructed by the Lebanon Petroleum Co. from a point on the coast road immediately north of the pipeline terminal. Winding at first through terraced olive groves, it soon reaches more rugged limestone country and rises steeply by a series of hair-pin bends. The location commands a magnificent view of the Mediterranean coast and of the westernmost portion of the town of Tripoli, with the twenty-seven 90,000-barrel tanks of the pipeline terminal immediately below, and tankers riding at anchor on the incredibly blue waters of the Mediterranean. Behind the 136 ft. derrick a limestone crag rises precipitously for another 600 ft. Well has this site been described as the most scenic well location in the world, a judgment which the Californian drillers do not hesitate to endorse.

The well was spudded in on May 7, 1947 and in May, 1948, had reached a depth of 6,267 ft., the 16 in. casing having been cemented at 745 ft. and the 11¾ in. at 3,503 ft. Starting in Middle Miocene limestones, circulation difficulties were encountered to the depth of 500 ft., below which a series of chalky limestones with occasional flints was penetrated. The Middle Cretaceous, or Judea limestone, was entered at 1,044 ft. and continued to 5,415 ft. when basalt of Albian age was encountered. This was penetrated to a depth of 6,080 ft. where Aptian limestones were entered. These Cretaceous limestones are dry and the next objective is the Jurassic limestone.

The derrick, crown and travelling blocks, rotary table, pumps and swivel are of British manufacture and the Ideal 100 Consolidated rig was the first of this type to be built by the Oil Well Engineering Co. Ltd. Of the 1,000 odd components in the whole outfit 550 were supplied by this firm, 350 are of American manufacture, and the balance is from other British suppliers. So successfully have these components been blended into a complete unit that a minimum of teething troubles has been experienced, and the drillers, all from California, speak highly of the performance and smooth operation of the rig and of the three Paxman 12 RPH 400 h.p. engines by which it is powered.

It is too early to speak of the prospects of Jurassic production at Terbol but should the structure prove productive it will be one of the most favourably located oilfields in the world, being less than two miles from the existing pipeline terminal on the Mediterranean coast. If there should be any success at Terbol there will be an intensified geophysical search for buried structures under the unconformable Miocene cover, there being no other obvious structures to test in Lebanon.

PALESTINE

On September 25, 1947, a test well was spudded in by Petroleum Development (Palestine) Ltd. at Huleiqat, eight miles north-east of Gaza in southern Palestine. Its first objective was the Judea limestone of Cenomanian age which it was thought would be covered by Upper Cretaceous marls. In fact, the Judea limestone was entered at 1,047 ft., the boring having passed through 415 ft. of Quaternary and Pleistocene sands, and 632 ft. of sandy marls which are assigned to the Neogene. Thus no Eocene or Upper Cretaceous beds were penetrated.

Soon after penetrating the Judea limestone circulation was lost at 1,102 ft. but was regained by pumping in 35 sacks of cement through the drill pipe. Circulation was again lost at intervals to 1,373 ft. and was regained by pumping in cement in quantities varying from 35 to 50 sacks and by the use of bentonite in the mud fluid.

At 1,386 ft. the bit penetrated a large fissure where circulation was again lost, the fluid level standing at 350 ft. Five attempts involving the use of 200 sacks of cement were made to seal off the fissure without success and the well was drilled to 1,390 ft. with blind circulation. A further 695 sacks of cement were pumped through the drill pipe or through the 16 in. casing, which was set at 600 ft., in four unsuccessful attempts to regain circulation. The fluid level still stood at 350 ft. but the well was deepened to 1,407 ft. with blind circulation. A further 1,895 sacks of cement were used in four unsuccessful attempts to regain circulation by pumping cement slurry through the casing, and 70 sacks in a single unsuccessful attempt through the drill pipe.

A novel experiment was then tried by lowering 35 bags of dry cement down the well. They were introduced in the form of "torpedoes" consisting of three sand bags sewn together and attached to the bottom of the drill pipe with string. The form of these "torpedoes," devised by Mr. R. H. Connor, drilling superintendent in charge of the well, is seen in the accompanying photograph. The first attempt was unsuccessful, the fluid level in the well still standing at 350 ft., but a second attempt using 64 sacks of cement introduced in the same way was completely successful.

Drilling was resumed but circulation was again lost at 1,422 ft. After an unsuccessful attempt to regain circulation by pumping 50 sacks of cement through the drill pipe in the form of slurry, it was regained by introducing a further 71 sacks in the form of "torpedoes" and drilling was resumed without further loss. Between 1,102 and 1,428 ft., 3,410 sacks of cement were used in attempts to seal off the formation.

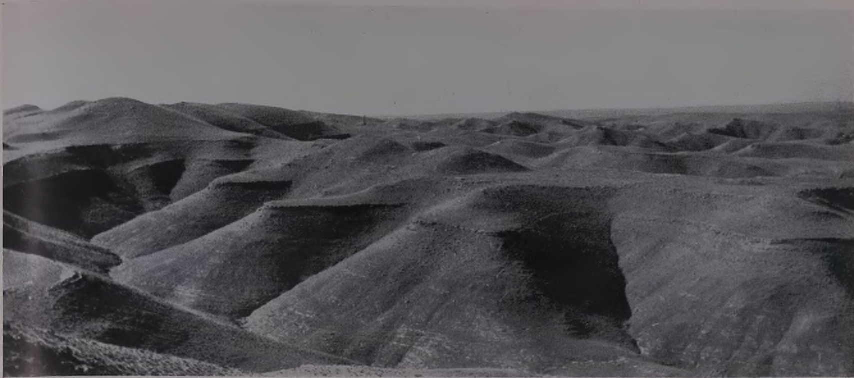
On February 7, 1948, drilling was suspended at a depth of 3,464 ft. where the 11¾ in. casing was cemented.

Having failed to obtain production in the Judea limestone the next objective in this boring is the Kurnub sandstone of Lower Cretaceous age. In Wadi Hathira, near Kurnub, 47 miles south-east of Gaza, 1,790 ft. of this formation is exposed and consists of quartzites, sandstones and shales. Below the Kurnub sandstone some 4,500 ft. of Jurassic beds are expected.

Another test well in southern Palestine is projected near Kurnub. It is located on a structure which must certainly rank as the most perfect "textbook" example of an anticline which the author has ever seen. It forms a range of hills rising some 2,500 ft. above the level of the surrounding plain, with the rugged, craggy outline so characteristic of the Judea limestone wherever it outcrops in the Middle East. On the north-west flank dips are from 5° to 10° and on the south-east, where there is a sharp "knee-bend," dips in the Cretaceous strata are as high as 60°, rapidly flattening out to horizontal without disconformity in the overlying Eocene strata.

At a point direct south of the Kurnub police post the steep south-east flank is breached by the Wadi Hathira forming a narrow steepsided V-shaped valley in which the complete succession from the Eocene to the Lower Cretaceous is exposed. Making his way along the dry boulder-strewn stream bed, the visitor at length emerges into a natural amphitheatre of breath-taking proportions : a perfect ellipse, nine miles long and four miles wide, entirely surrounded by precipitous limestone cliffs, 2,000 ft. in height ; a gigantic natural sports stadium which would accommodate with ease the combined populations of Great Britain and France. The limestone rim of this anticlinal valley is breached by the single narrow opening formed by the Wadi Hathira, a stream which is dry for nine months of the year but which has removed 2,700 ft. of sediment (weighing some 200,000 million tons) from the crestal portions of the structure.

As an example of geomorphology and of stream erosion the Kurnub structure deserves to become a classic. With over 3,000 ft. of closure it is also from the purely structural point of view ideal for the accumulation of oil. But here the Tertiary,



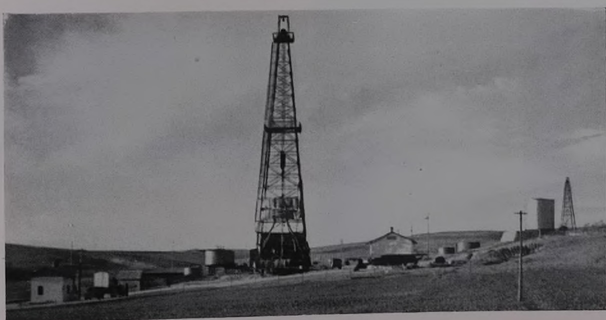
Typical topography in the Ain Zalah field

Cretaceous and Jurassic limestones, the principal reservoir rocks of the Middle East are either eroded or exposed by denudation, and the oil prospects depend entirely on the little known potentialities of the Palaezoics. Although carboniferous oil occurs in faulted monoclines, and where lenses of sandstone rest on the edges of the granitic rocks of the Arabian shield, in Egypt and Sinai, these occurrences afford little guidance to the prospects of carboniferous oil accumulations in typical anticlinal structures of the Kurnub type. With such a perfect structure it is, however, a reasonable speculative venture and the results of the Kurnub test will be awaited with great interest.

A road has been constructed by Petroleum Development (Palestine) Ltd. to a well site in the anticlinal valley near the foot of the central portion of the western wall. To reach it from the existing road from Beersheba it has been necessary to build a 16 mile road crossing the 2,500 ft. mountains forming the western flank of the structure and descending by a series of hair-pin bends to the bottom of the valley where Lower Jurassic strata are exposed. A camp has been built at the highest point on the road, where in summer the operating personnel will obtain some relief from the intense heat of the interior of the almost totally enclosed valley. Water both for the camp and the drilling operations will be provided from wells sunk near the bed of the Wadi Hathira.

Off loading a slush pump at Ain Zalah

Petroleum Times] [Photos



The test well at Huleiqat, near Gaza

The Port of Haifa

Lowering pipe into the ditch

The oil dock at Haifa

Bending pipe

The Tigris ferry

Welding pipe

Petroleum Times Photos.]

The Iraq–Mediterannean Pipelines

THE IRAQ PETROLEUM COMPANY'S concession of March, 1925, called for the construction of a pipeline of unstated capacity and to an unspecified port as soon as this should be commercially justifiable : it was further provided that in any case an order be placed for the pipeline within four years of the testing of the plots selected from its exploitation concession.

Alternative routes were surveyed between 1928 and 1930 and in the autumn of 1930 it was decided to lay two lines to the Mediterranean coast, following a common course from Kirkuk to the Euphrates and there bifurcating, with a northern limb through Syria and Lebanon and a southern limb through Trans-jordan and Palestine.

The modification of the IPC concession by the "Ameding Agreement" of March, 1931, provided that not later than August, 1931, the company should produce plans for a pipeline system with a minimum capacity of 3,000,000 tons per annum. It was also laid down that this system should follow an alignment from Kirkuk to the Euphrates between Hadithah and Hit, and thence, in respect of one trunk line, by way of Rutbah to the Bay of Acre, the company remaining free to construct another trunk line to any other Mediterranean terminal, provided the line to the Bay of Acre carry at least half the capacity of the whole system up to a limit of 4,000,000 tons. Work was to be completed by December 31, 1935.

Final surveys of the alignment were completed in the winter of 1931, and in the first half of 1932 water wells were drilled ; railhead depots constructed at Tripoli, Homs, Mafraq, Baiji and Hadithah ; and organisation of the transport system completed. Actual construction of the main pipeline commenced in August, 1932, with a labour force of 4,878 local employees and 182 foreign staff. Main construction of the north line to Tripoli was completed in July, 1934, and the first oil reached Tripoli on July 14. The southern line was completed in October, 1934, and oil was first delivered to the storage tanks of the Haifa terminal on October 14, exactly seven years after oil was first struck at Kirkuk in Baba Gurgur well No. 1.

The northern line is 532 miles long and the southern 620 miles, and both have a capacity of 2,000,000 tons of crude per annum. From the Kirkuk pump station (K-1), 1,000 ft. above sea level, there are 31½ miles of double 10 in. line followed by 34½ miles of double 12 in. line to the K-2 pump station at mile 66 which is 478 ft. above sea level. Thence to K-3 pump station, 453 ft. above sea level at mile 150, are 4½ miles of double 10 in. line followed by 79½ miles of double 12 in. line.

From K-3 on the northern line are 3½ miles of 10 in. and 56½ miles of 12 in. line to T-1 pump station at mile 211 (altitude 1,044 ft.). From T-1, 8½ miles of 10 in. and 60 miles of 12 in. lead into T-2 at mile 279 (1,273 ft.). From T-2 to T-3 at mile 360 (1,268 ft.) are five miles of 10 in. and 76 miles of 12 in. line. Thence to T-4 at mile 421 (1,086 ft.) are 4 miles of 10 in. and 57 miles of 12 in. line. Westwards from T-4 are 10½ miles of 10 in. followed by 57½ miles of 12 in. giving place to 20½ miles of 10 in. at mile 492½. Having increased the friction loss down the steep western slope of the Lebanese mountains by this stretch of 10 in. line, the diameter is again increased to 12 in. at mile 514 for the remaining 18 miles to the Tripoli terminal.

On the southern line 6 miles of double 10 in. pipe lead out of K-3, to be followed by 49 miles of 12 in. line to H-1 pump station at mile 205½ (1,343 ft.). From H-1, 4 miles of 10 in. and 54 of 12 in. lead into H-2 at mile 263½ (1,945 ft.). West of H-2 4 miles of 10 in. and 54 miles of 12 in. lead to H-3 station, the highest on the system, being 2,550 ft. above sea level. From H-3, 4½ miles of 10 in. and 91 of 12 in. lead into H-4 at mile 416½ (2,249 ft.), and thence 8½ miles of 10 in., 53 miles of 12 in. and 5 miles of 10 in. into H-5 at mile 483 (2,343 ft.). The highest point of the South line (3,167 ft.) is at mile 451 and a hydraulic control point in this section is at mile 456½ at an elevation of 3,160 ft. West of H-5 are 4½ miles of double 10 in. line, followed by 79½ miles of single 12 in., 8 miles of 8 in., 16 miles of extra-heavy double 10 in. and 29½ miles of single 12 in. to the Haifa terminal at mile 620, which is 20 ft. above sea level.

The variations in diameter between H-5 and Haifa are designed to enable crude to be pumped to a control point at mile 563 (2,580 ft. elevation) and thence delivered by controlled gravity flow to Haifa. The 8 in. line here inserted is to reduce the operating pressure as much as possible in the Jordan Valley, which at mile 581 is 885 ft. below sea level. The 8 in. line was carried so far down the eastern side of the valley that double 10 in. line was required across the valley to obtain a hydraulic gradient flat enough to clear the hills to the west.

The pipe employed was bell-ended seamless steel pipe in lengths of 36 to 40 ft., welded end-to-end over a chill ring. The 12 in. pipe had a wall thickness of 0.33 in. and a weight of 43.733 lb. per ft. the 10 in. a thickness of 0.307 and weight of 34.24 lb. ; the 8 in. a thickness of 0.322 and weight of 28.554 lb. The heavier pipe used for under-water work was plain-ended, with clamps over all submerged joints. The extra heavy 12 in. pipe was 0.5 in. thick, weighing 65.451 lb. per ft. and the 10 in. 0.365 in. weighing 40.483 lb. per ft.

The total weight of the pipe in the main lines was 123,000 tons.

The Pump Stations

The three pump stations K-1, K-2 and K-3, situated respectively 5 miles west of the Kirkuk oilfield, 10 miles west of the Tigris and 1½ miles west of the Euphrates, are double stations, each capable of pumping 85,000 barrels (11,200 tons per day). After the bifurcation of the line beyond K-3, the T stations on the northern line and the H stations on the southern line are each capable of pumping 42,500 barrels (5,600 tons).

The pump stations are equipped with 6¾ in. × 24 in. horizontal Duplex double-acting Worthington-Simpson pumps, working at 800 p.s.i. and directly connected to 500 h.p. diesel engines. There are six units at each of the K stations and three at each of the T and H stations. All the engines burn crude oil taken direct from the pipeline and pumps and engines are everywhere separated by gas-tight fire walls. Auxiliary equipment includes 8 in. by 10 in. piston-type suction pumps for emptying sections of the line in case of necessity, and 4 in. by 6 in. piston-type sump pumps for handling drainage oil.

The functions of the pump stations are not only to supply the power necessary to sustain the flow of oil at the designed through-put and to act as control points for checking the quantities passing through the line, but also to act as bases for line repair and maintenance. They are in fact miniature towns in artificial oases. Situated as they are in a desert inhabited only by nomadic tribesmen every need of the maintenance staff has to be provided by the company. At each station there are one or more houses with four main rooms for senior personnel ; six houses with three main rooms for married engineers ; and a mess block with servants' quarters, flanked on one side by a block of bachelor quarters and on the other side by a block of quarters for transients. At K-3 the bachelor accommodation is for six residents, each with his own bed-sitting room, and 12 transients ; and at the other stations for four residents and eight transients.

In the design of the quarters every effort is made to ameliorate the discomforts of extreme heat and cold and to exclude disease-carrying insects. In summer, shade temperatures of 120° F. are common and mid-day temperatures of 110° F. recur for weeks on end: in winter the temperature falls far below freezing. There is no natural shelter against the strong winds which sweep across the desert for a great part of the year and which in summer frequently become dust-storms which greatly increase the discomfort of desert life. As a protection from heat roofs are made as thick as the walls, and consist of earth carried by steel troughs; rooms all face north and south thus excluding direct sunlight in the summer and permitting it in winter; rooms are high and provided with cross-ventilation; and south windows are protected by verandas. Against the cold of winter, central heating is provided. All windows and doors are fly-proofed and the number of outside doors reduced to a minimum.

In addition to the housing, each station is provided with a service unit to accommodate departmental offices and stores and to act as a defence post in the event of disturbance. It is equipped with two-storey bastions at two corners and contains both high-level and low-level water storage. Apart from tankage and garage accommodation the service units contain 26 rooms including laundry, bakery, food store, canteen, cold storage, ice and soda plants; dispensary and sick rooms; and wireless equipment.

As some indication of the magnitude of the task of constructing the pipelines and transporting the necessary materials and equipment the following figures are of interest:

Between August, 1932 and May, 1934, 96,500 tons of cargo were landed at Basrah and forwarded to the Iraqi railheads of Baiji and Hadithah; 54,000 tons were landed at Tripoli and forwarded to the railhead at Homs; and 57,000 tons at Haifa and transported by rail to Mafraq or intermediate points. The total overseas tonnage of materials was thus 207,500 involving some 37 million ton-miles of rail transport in the Middle East. Local materials brought the total tonnage of materials and equipment handled up to 430,000 tons, made up as follows: stone, sand and gravel, 47 per cent.; pipe, 29 per cent.; engineering and station materials, 13 per cent.; petrol and water, 8 per cent.; pipe-protection materials, 2 per cent.; and transport stores, 1 per cent. The motor vehicle ton-mileage involved in transporting these materials exceeded 23 million.

The Mediterranean Terminals

The pipeline terminals at Haifa and Tripoli have been modified from time to time and at present contain respectively 36 and 27 tanks each of 93,000 barrels capacity.

At Haifa, crude from Kirkuk is fed direct to the refinery of Consolidated Refineries Ltd. but there is a relief line to the terminal tankage operated by a spring loaded valve, set at 90 p.s.i., in case the refinery should be shut down. The 29 crude storage tanks at the terminal are normally used for imported Kirkuk crude transhipped from the Tripoli terminal or tanker-borne Kuwait crude. The remaining seven tanks at the Haifa terminal are used for fuel oil storage. Off the terminal are four berths each served by a sea line, three of which are connected up. Two are used for unloading imported crude and one for loading fuel oil. Unloading rates depend on the capacity of the tankers' pumps but the maximum hose pressure of 75 p.s.i. limits the rate to about 750 tons per hour.

Products from the Haifa refinery are pumped to the oil dock in the harbour area through nine 12 in. pipelines to storage consisting of nine 93,000 barrel tanks, four 32,000 and three of 10,000 barrel capacity. The harbour installation, which is also operated by the Iraq Petroleum Co., has three pump houses handling: (1) diesel and gas oils; (2) motor spirit and kerosine: and (3) heavy and light fuel oils. Nos. 1 and 2 are equipped with three motor-driven Mather and Platt centrifugal pumps, and No. 3 by Stothert and Pitt screw pumps with a capacity of 500 tons per hour.

In the oil harbour are four berths at each of which loading can take place at rates of from 600 to 700 tons per hour at each berth.

At the Tripoli terminal, situated 200 ft. above sea level, crude is fed by gravity through three 12 in. sea lines to each of three berths situated 4,420, 4,400 and 4,470 ft. from the shore.

In 1941 a topping plant was built by French technicians on a site adjacent to the Tripoli terminal. It was constructed from materials locally available, using loco boilers from the railways, tube stills fabricated from line pipe and locally fabricated fractionating columns. After the occupation of the Lebanon by the Free French, instruments and other equipment were obtained from the U.S.A. with resulting increase in the efficiency and safety of operation. In 1945 the plant was taken over by the Iraq Petroleum Co. and a redistillation unit has been added. The present throughput capacity is 5,000 barrels per day, producing motor spirit, kerosine, gas oil and fuel oils for the local market with a surplus of fuel oil for export. Plans for doubling the capacity are in hand.

New Pipeline Construction

In the autumn of 1946 construction of a new 16 in. pipeline from Kirkuk to Haifa was commenced. With a scheduled capacity of 90,000 barrels per day this line was due for completion in early 1949, and it was to be followed by another 16 in. line from Kirkuk to Tripoli. Laying of the pipe on the Haifa line is complete except for some 40 miles at the western end where the disturbed conditions in Palestine have caused the suspension of operations. In the meantime work on the enlargement of the pump stations is in progress.

The alignments of the new line to Haifa and of the projected line to Tripoli follow those of the original lines, utilising the wayleaves negotiated in the early '30s.

At the end of 1947 a total of 9,000 construction labour was employed by the company on the pipeline, and a further 7,000 by contractors working for the company on pipeline construction. Ditching is done by contractors but the stringing, welding, doping and wrapping of the pipe is done by IPC personnel.

The pipe is laid in sections up to one mile in length which are tied-in when ready for laying in the ditch. Welding is done by truck-mounted portable welding machines supplied from the U.K. by Murex Welding Processes Ltd. or by Lincoln Electric Co. from the U.S.A., using Murex, Lincoln or Fleet welding rods. After welding the pipe is lifted and held in a cradle by side-boom tractors for cleaning, priming, doping and wrapping, all of which are done mechanically. Pipe dope is applied at 500° F. and the pipe wrapped immediately by a combination machine which performs both operations. The pipe is then lowered into the ditch with sufficient slack to ensure that there will be no tension in the line even at the lowest temperatures.

To cater for the increased throughput of the entire system, which will be 270,000 barrels per day when the 16 in. lines to Haifa and Tripoli are completed, the K stations are being enlarged and the existing reciprocating pumps replaced by motor-driven centrifugal pumps. At K-3, where construction is well advanced, the new pump station will accommodate six motor-driven Mather and Platt centrifugal pumps each of 156,000 barrels per day capacity at 500 p.s.i. to be operated in pairs in series. Two pairs will give the designed throughput capacity, with the third pair as standby. Each 1,800 h.p. motor will be supplied with current from its own diesel-driven 1,560 kVA alternator. The engines are Crossley Premier 16-cylinder horizontally opposed diesels of 2,000 h.p. The alternators, which are by the English Electric Co., will be housed in a new power house now under construction which will also accommodate five 875 kVA generators to supply auxillary power for station services.

Other new construction at K-3 includes: three new storage tanks each of 3 million gallons capacity, and six of 4½ million gallons: 50 houses for artisans and five for supervisory staff; cold store and oxygen plant; and five school buildings. The houses for artisans are built in blocks of five, each with three living rooms, w.c. and shower, store and kitchen.

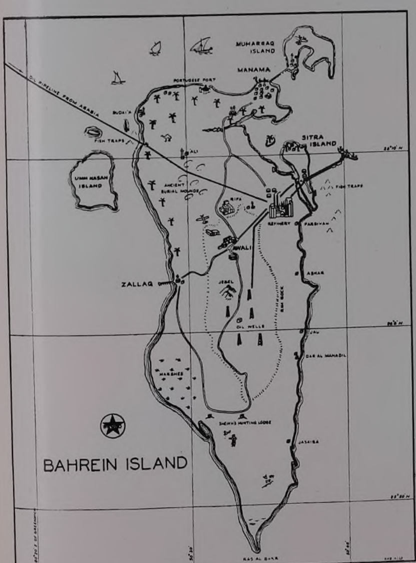
K-2 pump station will have similar equipment to that now being installed at K-3, and at K-1 electric power will be supplied from the field's central power station direct to the pump motors. The H and T stations will each have four reciprocating pumps each of 51,700 barrels per day capacity.

The total tonnage of pipe in the new 16 in. lines to Haifa and Tripoli will approximate to 170,000 tons, and is supplied by Stewarts and Lloyds and by Comptoir Franco-Belge des Tubes.

BAHREIN

THE ISLAND OF BAHREIN, situated in the Persian Gulf midway between the northern tip of the Qatar Peninsula and the Arabian mainland, is an independent Sheikdom under British protection. Relationships with Britain date back to 1820 when the East India Company established treaty relationships with the Sheik. The present relationship is based on agreements of December 22, 1880, and March 13, 1892, under which the Sheik undertook not to enter into any relationship with another foreign government without British consent.

A concession was originally granted by the Sheik in December, 1925, to a British group, the Eastern and General Syndicate. In November, 1927, an American corporation, the Eastern Gulf Oil Company secured an option from the British syndicate, and on December 21, 1928, the Bahrein rights were transferred to the Standard Oil Company of California. This transfer was the subject of discussion between the British and American Governments and did not become fully operative until six years later when the Sheik of Bahrein granted a mining lease to the Bahrein Petroleum Co., a wholly-owned subsidiary of the Standard Oil Company of California, registered as a British company under the laws of Canada. The original lease which dates from December, 1934, was for 55 years, and with later extensions is due to expire in 1999. It covered an area of approximately 100,000 acres in one block selected by the company on the main Island of Bahrein. A more recent concession has been negotiated covering what is known as the "Additional Area" which includes the Sheik's "present and future dominions."



In 1936 the base of the Bahrein Petroleum Company was widened by the inclusion of the Texas Company, and the concessions are now held by this affiliate of the California Texas Oil Company, Ltd.

The discovery of oil on Bahrein Island in June, 1932, had a significance which transcends the immediate importance of Bahrein production, since this was the first oil discovery in the southern Persian Gulf, and stimulated American interest in the Saudi Arabian mainland.

Due to travel restrictions arising from the cholera epidemic in the Middle East at the end of last year the writer was unable to visit Bahrein, and we are indebted to the Bahrein Petroleum Co. Ltd. for the following information as well as for the photographs appearing in this section.

Development

Development drilling was continued after the first well and producer was brought in. Storage tanks and a submarine loading line were installed. This was followed by the sale and shipment of the first crude oil products in December, 1934.

In 1936 a refinery was built, while shipping facilities and submarine pipelines were expanded.

The Bahrein Petroleum Company (BAPCO) did not have marketing facilities and on June 25, 1936, California Texas Oil Co. Ltd. (CALTEX) was incorporated to take over the existing storage, sales facilities and personnel of the Texas company, and to handle the marketing and distribution of BAPCO production in the areas of Africa, Asia and Australasia, known as "East of Suez."

On January 1, 1947, CALTEX acquired through purchase the marketing facilities and personnel of a company extensively distributing petroleum products in Continental Europe, the United Kingdom, Eire and the Mediterranean. This area is known generally as "West of Suez," and added to the East of Suez area, gives CALTEX wide coverage throughout the Eastern Hemisphere.

Geology

The geology of the main Island of Bahrein is simple and the structure of the field is apparent from the surface outcroppings, being a simple fold with the major axis lying in a north-south direction and with dips ranging from 3½° to 6°. Hard durable limestone strata near the surface have been eroded away in the crest of the field, leaving a rim-rock surrounding the entire field. The surface of the island from the rim-rock outward in all directions, is approximately a dip-slope. Mapping of strata exposed in outcroppings along the rim-rock and from exposure of these strata in water wells and washes parallels very closely the sub-surface structure.

Oil production is secured from three "Pays" known as the First Pay, Second Pay, and Fourth Pay, with the Second Pay divided into two zones for producing purposes. The Third Pay is not of commercial value. The largest portion of the oil production comes from the First and Second Pays while the Fourth Pay yields the balance of the oil together with high pressure gas produced mainly for gas injection into the upper Pays.

The total thickness of all the producing sections is approximately 500 feet with the First and Second Pays occurring between the depths of 1,800 and 2,300 feet from the surface. The initial reservoir pressure was approximately 1,200 p.s.i. The oil is undersaturated with gas at reservoir conditions and the bubble point is 250 to 350 p.s.i. There was no initial gas cap and the producing horizon in general operates under an active water drive.

Several years ago it was determined that, at the optimum production rate of 20,000 barrels per day, the pressure declined, showing that the water drive did not keep up with the crude oil withdrawal. This was offset with gas injection. An artificial gas cap was created by injecting gas in the main producing horizons of the First and Second Pays and the rate of gas injection is now controlled to balance oil withdrawal and water invasion so that the pressure is maintained at approximately the original levels.

In 1937 and 1938 six wells were drilled to a deeper horizon. This production is known as the Fourth Pay and is composed of a number of thick limestone members. Several of these members contain dry gas only and others contain oil and gas but are generally characterised by a thin band of black oil and a large gas cap area. The depth pressure of the dry gas members is 2,100 p.s.i. This gas is used for the gas injection operations to the First and Second Pays without the aid of compressors. Approximately 4 million cubic feet of gas is being injected daily. The producing wells flow to five tank batteries located at central points in the field where the crude oil is degassed and pumped to the refinery. The separated gas is used for fuel purposes.

Production

The oilfield on Bahrein is located in the centre of the Island, south of the village of Awali. About sixty-seven wells are producing a total of about 29,000 barrels per day, which is more than double the 1936 production. The average depth of Bahrein's producing wells is about 2,300 feet, while some are as deep as 4,700 feet. The wells in this field produce with a low gas-oil ratio so that the gas produced with the oil is relatively low in amount. This gas is used in the company's operations in Bahrein to the extent that it is economical to do so.

CRUDE PRODUCTION OF BAHREIN ISLAND

	Barrels
1934	285,072
1935	1,264,807
1936	4,644,635
1937	7,762,264
1938	8,297,998
1939	7,588,544
1940	7,074,065
1941	6,794,110
1942	6,241,135
1943	6,571,825
1944	6,710,810
1945	7,309,125
1946	8,009,925
1947	9,410,710
Total	87,965,025

Drilling was suspended late in 1940 and, due to war conditions, was not resumed until 1946, when a 12-well programme was instituted, designed to improve the drainage pattern, replace the production of wells captured by gas and water, redistribute the oil withdrawal from the various producing zones, and to provide for increased gas injection. At the present time, 11 of these wells have been completed, bringing the total to 67 producers as from October, 1947.

Preparations are actively proceeding on the drilling of a deep test well.

The Bahrein refinery, which was designed for a capacity of 10,000 barrels per day when it started operations in 1936, was extended during subsequent years, and in late 1947 was processing crude at the rate of 145,000 barrels per calendar day, which is about double the rate of 1945.

BAHREIN REFINERY CAPACITY

	Barrels per day
1936	10,000
1937	25,000
1940	35,000
1948	145,000

The refinery manufactures gasoline, diesel gas oil, power and illuminating kerosines, fuel oil and marine bunkers. The new asphalt manufacturing plant was started on trial runs in December, 1947, and a manufacturing rate of 50,000 tons annually was reached in April, 1948.

The crude of Bahrein has been thoroughly tested and evaluated and is considered eminently suitable for the manufacture of lubricating oil, but the present emphasis is on gasoline, kerosine, diesel oil, and fuel oil. Total plant investment on Bahrein is not far from sixty-five million U.S. dollars.

Pipelines

In 1944 a 12 in., 34-mile pipeline was laid from the Dammam field in Saudi Arabia to the Bahrein refinery. This pipeline is under water for 17 miles, which makes it the world's longest commercial submarine pipeline. During the year 1947, the land portions of this line were looped with an additional 12 in. pipeline. This line, with a capacity of approximately 100,000 barrels per day, carries Saudi Arabian crude under the waters of the Persian Gulf to be processed in the BAPCO refinery on Bahrein Island. Oil was initially started through this line on March 2, 1945. It is expected that the maximum capacity will be increased to 115,000 barrels per day by the middle of 1948.

Thirteen oil lines varying in size from 6 in. to 18 in. run three miles from the shipping tank farm on Sitra Island to a deep water pier. This tank farm is about two miles from the refinery which is located inland on Bahrein Island.

Six tankers can be accommodated at one time at the new four-berth wharf and the older two-berth island wharf. The new wharf is located in 6 to 7 fathoms of water and is capable of handling the largest tankers. It is connected to the shore by a two-lane causeway and trestle. Its design allows for the handling of packaged products and miscellaneous freight as well as bulk oil shipments.

The present loading rate is approximately 5,000 barrels of petroleum products per hour, but plans are being considered to increase this rate by adding several larger lines which will probably be of 20 in. diameter.

Housing Schemes and Social Welfare

The company, from the very beginning of its operations, realised the importance of helping in educational and social projects designed to improve these conditions on Bahrein Island. Working in conjunction with local Government Agencies and members of the ruling family of this independent Sheikdom, the company has assisted in various projects for the welfare of the native population. This assistance has ranged from the direct contribution of cash to the performance of various engineering and technical tasks involved in civic projects such as the construction of roads and bridges, drilling water wells, malaria control, and other projects in the interest of hygiene.

Standard of Living

The company provides free bachelor housing for Bahreini employees who wish to utilise them. Electricity and other utilities for this housing are supplied free of charge. The houses are of masonry construction. The bulk of these employees, however, prefer to live in the native villages and towns and are transported to and from the company's premises.

A building boom by private individuals on the Island currently exists and can be expected to continue. It is the policy of the company to encourage local private enterprise in this and other ventures in Bahrein so that the local employees of the company are housed in housing of their own choosing at reasonable cost to them. It is also the policy of the company to foster civic improvements in the various villages and towns.

Recreation and other facilities are provided for the Bahreini employees who live in company quarters. However, privately organised club-houses and recreational facilities are being constructed by various groups in the principal town of Manama. The company gives assistance to such ventures.

Left, top to bottom: BAPCO club and messhall; The Awali hospital; Front entrance of club; Batchelor quarters in the BAPCO camp; Aerial view of Awali. Right, Distillation units; Catalytic cracking unit; Loading packed products; The Cargo wharf; Bahreini mason at work; The Manama primary school.

As to income of the company's local employees, it is worthy of note that their wages have more than doubled in recent years and as they become more proficient, they are advanced to higher paying positions. The average wages paid by the company are considerably higher than the average of the Island. In addition to this, the company provides continuity of service to the bulk of its employees, free hospitalisation and medical care, vacations with pay, sick benefits and severance benefits, as well as a thrift fund.

Public Health

The company has two modern, well-equipped hospitals as well as outlying dispensaries for its employees, and staffed with skilled surgeons, doctors and nurses. Free medical care is provided for all employees including local employees.

Other hospital facilities on the island are :

(*a*) Bahrein Government Hospital—constructed and operated by the State.

(*b*) American Mission Hospital—maintained by the Dutch Reformed Church of America.

Both of these hospitals provide free medical care and hospitalisation to the poor to the limit of their facilities.

One of the hospital buildings of the Mission was donated by the company as well as X-ray and other equipment. The company subsidises, to a varying extent, the Mission Hospital.

The Mission Hospital has been in operation for many years and has been very instrumental in creating good will toward Westerners among the local inhabitants.

The company works in close co-operation with the Government medical personnel in all matters of public health, sanitation, mosquito control, etc., and renders assistance as necessary.

The company maintains a qualified entomologist and sanitation experts. An extensive mosquito abatement programme is maintained, covering not only the company area but the adjacent native villages and gardens.

The city of Manama is soon to be provided with a modern domestic water supply and a sewer system.

As a result of the medical facilities provided by the company and others, and the general prosperity of the island resulting in large measure from oil royalties and employment provided by the company, the health, sanitary conditions and standard of living of the native population is steadily improving. It is to be expected, now that the effects of war are receding, that conditions will continue to improve more rapidly.

Employment

Considerable progress has been made in the training and utilisation of Bahreini employees and many phases and units of the company's operations are manned almost entirely by these employees.

The company's training programme was curtailed during the war years and somewhat disrupted by the large construction programmes carried on almost continuously during the past several years. The company is now instituting a comprehensive programme of training of its employees and has sent to Bahrein several experienced instructors. It is hoped that, as a result of this training programme, many additional positions can be filled by Bahreinis, resulting in increased employment of Bahreinis and higher salaries due to their increased productivity.

At the beginning of 1948 the company had 6,078 employees in Bahrein, of which number, 11.8 per cent. were British plus some Americans, Canadians, South Africans and Europeans, 12 per cent. are British Indians and Iraqis, and 76.5 per cent. Bahreinis and other locals.

The policy of the company is to employ as high a percentage of Bahreinis as possible and they far outnumber all other employees.

Education

During recent years, a creditable system of Government-operated primary and secondary schools, including a technical school, has been developed. The company's aim is to foster and aid such a development of public schools.

The company has established several scholarships in these schools for worthy students.

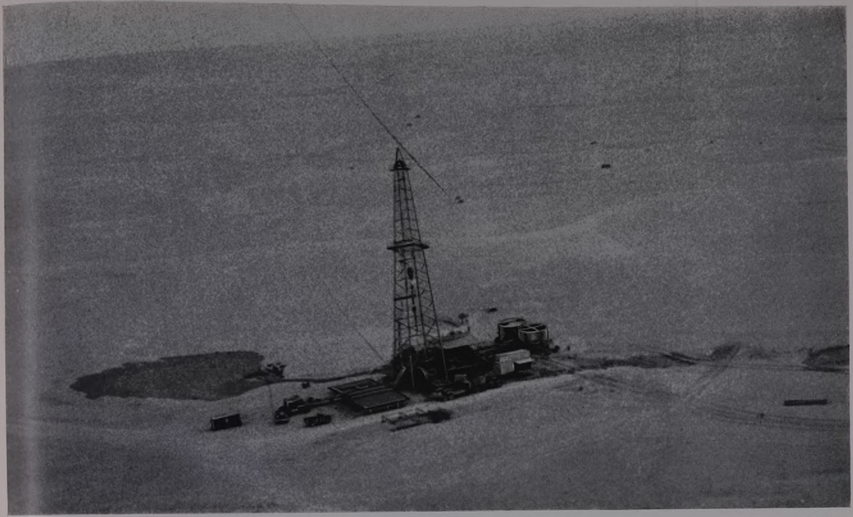
The company does not, as yet, operate company schools for its local employees in the usual sense of the word. It does, however, conduct training classes in such crafts as welding, etc. Most of these employees are trained on the job. Careful study is being given to this question at the present time and the company may possibly set up in the future more elaborate and systematic methods of training devised to meet its needs, and at the same time not supplant the State schools.

The company does not, at present, have in effect scholarships in Middle Eastern and Occidental universities, although just before the war a start was made in this direction.

Agriculture

The agricultural possibilities of Bahrein are rather poor, most of the area being desert, the soil even in the cultivated areas being very poor. The company assists in the development of irrigation wells and attempts whenever possible to encourage the conservation of the water resources of the Island. The company regularly imports and distributes, at cost, seeds to interested parties and distributes literature concerning modern methods to the more enterprising farmers.

The Government operates an experimental farm and is quite interested in improving agriculture and animal husbandry.



Petroleum Times] [Photo

The discovery well at Buqqa from the air

SAUDI ARABIA

STIMULATED BY THE DISCOVERY of oil on Bahrein Island in 1932, Standard Oil Company of California officials turned their attention to the neighbouring portions of the Saudi Arabian mainland and in May 1933 obtained a concession from H.M. King Ibn Saud covering 318,000 square miles and extending over the eastern Arabian littoral and along the northern borders of the country to the Iraq frontier. In May 1939, the concession was modified and extended and now covers approximately 440,000 square miles which, together with an area of some 177,000 square miles over which the company holds preferential rights, covers the whole of Saudi Arabia north and east of the ancient granitic rocks which occupy the greater part of the Najd Province. The company also holds concessions on Saudi Arabia's undivided half interest in the Neutral Zones lying to the south and west of the Sheikdom of Kuwait. The term of the original concession is 66 years from July 15, 1933, and of the supplemental concessions, including the interest in the Neutral Zones, 66 years from July 21, 1939.

In 1936, the Texas Company acquired a half interest in the Arabian operations and the company became the California Arabian Standard Oil Co. On January 31, 1944, the name was changed to Arabian American Oil Company, still owned jointly by the Standard Oil Co. of California and the Texas Company, to which the concessions and properties in Saudi Arabia were transferred. In 1946 " Jersey Standard " and " Socony-Vacuum," who through their partnership in the Near East Development Corp. hold a 23.75 per cent. interest in the Iraq Petroleum Co., and its associates, entered into negotiations for participation in ARAMCO with the object of securing increased supplies of crude for their established markets in the Eastern Hemisphere, with reduced drain on Western Hemisphere resources. On December 26, 1946, it was announced that agreement in principle had been reached for the reconstruction of ARAMCO to provide for 30 per cent. ownership by the Standard Oil Co. (N.J.) and 10 per cent. by the Socony-Vacuum Oil Co., the remaining shares to be held equally by the Standard Oil Co. of California and the Texas Co. Consummation of this agreement was delayed by objection of the French participants in the Iraq Petroleum Co., who held that the proposed agreement was incompatible with the 1928 " Red Line Agreement " which provided that the participants in the Iraq Petroleum Co., act only through jointly-owned operating companies in all matters relating to the exploration for, and production of, crude oil within an area roughly corresponding to the former limits of the Ottoman Empire. Early in 1947 British legal counsel advised that one effect of the German occupation of France, where the French company was incorporated, was to dissolve the 1928 Group Agreement and negotiations were commenced with the object of reaching a new agreement among the participants which would permit their independent participation in other companies' oil operations within the area prescribed by the 1928 " Red Line Agreement." In June 1947, it was announced that agreement in principle had been reached by the major partners in the Iraq Petroleum Co., but the new agreement has not yet been formally concluded and " Jersey " and " Socony " participation in ARAMCO awaits its formal ratification.


MIDDLE EAST
SAUDI ARABIA, BAHREIN, & QATAR FIELDS
IRAN
PERSIAN
GULF
LEGEND:
Oil Fields
Refineries
Roads
Towns
Pipelines
Manifa
ABU HADRIYA
Hinnat
Winan
Jubail
Ras Tanura
Salwa
Qatif
QATIF
Dammam
DAMMAM
Hanidh
Dhahran
Al Khobar
Manama
BUQQA
ABQAIQ
Arai'ra
BAHREIN
BAHREIN
SAUDI ARABIA
Oqair
Dohat al Husain
Hofuf
DUKHAN
Doha
QATAR
IRAQ
IRAN
TRANS-JORDAN
DAMMAM
SAUDI ARABIA

Geology

The oilfields of Dammam, Abqaiq, Buqqa, Qatif and Abu Hadriya lie between latitudes 25° 50′ and 28° N. on the eastern coastal plain of Saudi Arabia. From Permian to Cretaceous times this area formed part of a deep and continually sinking geosyncline. Lying to the east of the ancient granitic land mass which forms the western half of the Arabian Peninsula, this geosyncline embraced the areas now occupied by the eastern Arabian littoral, the Persian Gulf, the valleys of the Tigris and Euphrates, the oilfield belt of SW Iran, and the Zagros Mountains to the east. From late Cretaceous to Pliocene times the great thickness of dominantly calcareous sediments laid down in this geosyncline was compressed by the Alpine folding movements which produced the great mountain arcs which stretch from the Alps to the Himalayas. During this compression the eastern Arabian littoral acted as a stable foreland on which a series of gentle brachyanticlines were developed which are in strong contrast to the steeply folded anticlines of great magnitude and amplitude which characterise the oilfield belt of SW Iran.

Between the coastal plain and the granitic rocks of the Najd the complete succession from the Eocene to the Lower Jurassic is exposed in a gentle easterly dipping monocline where the structure is well brought out by a series of steep westerly scarps and gentle easterly dip slopes. Resting on the granitic rocks of the Arabian shield, the lowest sediments exposed are Ordovician limestones and shales between which and the Tuwaiq Mountains, Triassic limestones and sandstones are exposed. West of Riyad, Lower Jurassic limestones and shales (the Tuwaiq Group) form the 400 ft. western scarp of the Tuwaiq Mountains and are overlain by the Riyad Group consisting of alternating limestones and anhydrites of Upper Jurassic age on which the capital city of Riyad is situated. The Cretaceous consists of a basal limestone, known locally as the Thamma Group, followed by the Wasia sandstone Group which is probably correlative with the Rutbah sand of Iraq and Kuwait, and this in turn by a limestone series of Upper Cretaceous age forming the Aruma scarp and plateau.

There is an important unconformity at the base of the Eocene, the lowest member of which is a persistent bed of anhydrite. This is followed by alternating limestones and anhydrites of Lower Eocene age and these by Middle Eocene limestones, marls and shales.

In the north of the Hasa Province the Miocene consists of marine limestones and anhydrites, but in the area around Dammam, where the lowest member is a hard cherty limestone, it is partly non-marine.

Surface deposits of wind-blown sand over much of the area, and the important discordance accompanying the unconformity at the base of the Eocene, preclude the location of the Cretaceo-Jurassic structures by geological mapping alone except in the case of the Dammam, and to a lesser extent the Abu Hadriya field, which are possibly salt dome structures. The remaining structures of Abqaiq, Buqqa, and Qatif were located as a result of structure drilling to the base of the Eocene anhydrite. Up to the end of 1947 some 175 structure holes were drilled to an average depth of 600 to 700 ft. In many of these, particularly in the Abqaiq area, potable waters with less than one thousand parts per million of dissolved solids were found in the lower Miocene and Eocene limestones. As the shallow waters in this area are saline, these potable waters are of great value in this arid region and many of the structure holes were completed as water wells for the benefit of the local inhabitants and travellers.


The Abqaiq Field

The Dammam Field

The Dammam field is situated on a broad gentle dome structure $3\frac{3}{4}$ miles long and 3 miles wide with its longer axis striking north-west—south-east. Its almost circular form, and the fact that it coincides with a negative gravity anomaly, suggests that it lies above a buried salt dome. Here a surface anticlinal structure is clearly recognisable, an inlier of Eocene rocks, largely covered by wind-blown sand, being surrounded by a rim rock of splintery Lower Miocene limestones which form low craggy hills rising from the gently undulating coastal plain.

There are unconformities at the base of the Eocene and at the top of the Wasia and Thamma Groups (Middle and Lower Cretaceous) but the Cretaceo-Jurassic structure coincides with the surface Tertiary structure.

The reservoir rock consists of oolitic and dolomitic limestones of Upper Jurassic age, known locally as the Arab Zone, which are divisible into four groups (A, B, C and D) separated by anhydrites. Here the top of the Arab Zone lies at a depth of approximately 4,500 ft. and the total thickness of the zone is some 300-400 ft. There is considerable lateral variation in the individual members but the following thicknesses may be taken as representative: A, 60 ft.; B, 25 ft.; C, 120 ft.; and D, 240 ft. There is some 300 ft. of closure at the top of the Arab Zone which is overlain by a thick bed of anhydrite which forms the cover rock.

In contrast to SW Iran, where the intensity of the folding is such that fracturing of the anhydrites permits the upward migration of oil, in the more gently folded structures of Saudi Arabia the Jurassic and Cretaceous anhydrites form an effective seal. As Dr. Lees has pointed out, these techtonic differences may account for the preservation of Jurassic and Cretaceous oil accumulations in Saudi Arabia and Bahrein, whereas in SW Iran vertical migration has taken place throughout the Jurassic, Cretaceous and Eocene sediments. There the impervious cover to the Asmari limestone structure is not the anhydrite "cap rock" but the plastic salt and salty marls of the Lower Fars, and no commercial accumulation of oil has yet been found below the Asmari limestone.

The Abqaiq and Buqqa Fields

The Abqaiq structure, situated in the sand dune country 40 miles south-west of Dammam, is an elongated anticline 14 miles long and 5-6 miles wide with 1,400 ft. of closure at the top of the D horizon of the Arab Zone. Here the surface geology is obscured by wind-blown sand and the field was located as a result of structure drilling to the base of the Eocene. The A and B members of the Arab Zone are water-bearing and the main productive horizon is the D member which here lies 6,000 ft. below the surface at the culmination of the structure.

The axis of the Abqaiq structure strikes east-north-east, and 20 miles to the east-north-east on the same axis is the Buqqa field, where oil was discovered in the D horizon at a depth of 7,200 ft. in 1947. The limits of the Buqqa field have not yet been determined but it may eventually prove to be an important extension of the Abqaiq field.

Recent gravity surveys and structure drilling to the south of Abqaiq indicate the possibility of the existence of a large extension to the field or of an independent structure in this direction also.

The Qatif Field

The Qatif field, which is covered by wind-blown sand, was located as a result of structure drilling to the base of the Eocene anhydrite. Production is obtained from the C and D zones of the Arab limestone, the top of which here lies at approximately 7,000 ft. With only three deep wells drilled in the area the size and shape of the reservoir are not yet fully known.

The Abu Hadriya Field

The Abu Hadriya structure, 100 miles north-west of Dhahran, was located by seismic survey, and it is thought that, like Dammam, it may be a salt-dome structure. One well has been drilled to a depth of 10,200 ft. and proved a pronounced thickening of the Cretaceo-Jurassic strata as compared with Dammam and Qatif. At Abu Hadriya all the Arab Zones are waterlogged but oil production was obtained from lower limestones of Jurassic age. These limestones, which lie some 3,000 ft. below the Arab Zone, have been named the Hadriya Zone.

Reserves

In 1944 Dr. E. de Golyer estimated the reserves of Saudi Arabia at 5,000 million barrels. Very little was then known about the extent of the Abqaiq field, but on the evidence gained from the drilling of a further 20 wells on that structure and as a result of the discovery at Buqqa, some observers believe that the reserves of these two areas alone are as great as Dr. de Golyer's estimate for the whole of Saudi Arabia.

Development

Exploration started in Saudi Arabia in September, 1933, and test drilling in 1934. The discovery well in the Dammam field, near Dhahran in the Hasa Province, was completed at a depth of 2,109 ft. in December, 1936. The productive horizon in this well was the Cenomaman limestones which are correlative with the producing horizons in Bahrein Island, and known locally as the Bahrein Zone. A number of wells were drilled to this zone in the Dammam field but results were discouraging and No. 7 well was drilled to test lower horizons. In March, 1938, it was completed as a flowing well with an initial production estimated at some 5,000 barrels per day from a depth of 4,727 ft. The producing horizon is in the Zekrit formation of Jurassic age, known locally as the Arab Zone, which is divisible into four members separated by anhydrites. No. 7 well was completed in the third or "C" member, but the A, B and D members have since proved productive in the Dammam field. In the early years of the war operations were severely curtailed but in 1944 they were intensified with the object of providing additional supplies of petroleum for the war in the Pacific. By the end of 1947 a total of 40 producing wells had been drilled and the daily average production was 85,000 barrels per day and the cumulative production from the field some 115 million barrels.

The next discovery in Saudi Arabia was at Abu Hadriya, 100 miles north-west of Dhahran, where oil was discovered at 10,200 ft. in March, 1940. Here the Arab Zones of the Dammam

Petroleum Times] [Photo

The gathering unit and stabilisation plant at Dammam

The refinery and terminal at Ras Tanura

field were water-logged and the productive horizon is the Hadriya zone some 3,000 ft. below the top of the Arab Zone. A second well $1\frac{1}{2}$ miles south-west of the discovery well was suspended in October, 1940, at a depth of 4,700 ft., and operations at Abu Hadriya have not been resumed due to the availability of shallower crude in areas more conveniently situated to the Ras Tanura refinery and terminal.

The discovery well in the Abqaiq field, 40 miles south-west of Dhahran, was completed at a depth of 6,180 ft. in February, 1941. The producing horizon was the fourth or D member of the Arab Zone which is here 200 ft. thick. The A and B members of the Arab Zone are wet at Abqaiq but the C member yields a heavy oil which is used for road dressing. Production from the field commenced in January, 1946, and the daily average production was 200,000 barrels from 25 wells at the end of 1947, and the cumulative production 75,000,000 barrels.

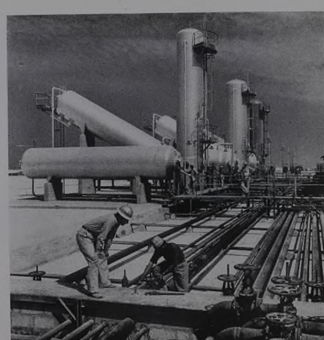
In February, 1945, the discovery well in the Qatif field was completed at 7,300 ft. and yielded 5,000 barrels of oil per day from the C and D members of the Arab Zone. At the end of 1947 two producing wells had been completed in this field which is situated midway between the Dammam field and the Ras Tanura refinery.

The most recent discovery in Saudi Arabia was at Buqqa, 15 miles east-north-east of Abqaiq, in May, 1947. Here the productive horizon is the D member of the Arab Zone which was penetrated at a depth of 7,200 ft.

Drilling

Casing programmes are designed to protect the potable waters which occur in the Lower Miocene and Eocene strata. At Dammam a 16 in. string is set at about 1,700 ft. and cemented back to the surface. Below this, circulation difficulties are experienced in the Bahrein Zone in which cavernous limestones occur. In drilling through these formations ARAMCO have adapted a technique developed by the Bahrein Petroleum Co. When circulation is lost the bit is lifted off bottom and heavy mud is pumped into the annulus between the drill pipe and the casing. Drilling is then continued with blind circulation of water below the floating mud column. The cuttings are carried into the formation by the water and help to seal it, but in case they should accumulate above the bit, cutters are welded on the top of the bit so that they may be dislodged by "drilling upwards." An $11\frac{3}{4}$ in. string is usually cemented below the cavernous zone, at or around 2,500 ft. An $8\frac{5}{8}$ in. string is set at about 3,200 ft. and a $6\frac{5}{8}$ in. oil string at the top of the productive zone.

Wells are drilled in with mud fluid circulation but are given three acid washes of 20 minutes duration to remove the mud sheath from the walls of the hole. The acid is pumped in through tubing and drawn off through the annulus, thus producing the swirling effect necessary for thorough washing of the formation.



A view of the refinery

Petroleum Information Bureau Photos

At Abqaiq 11¾ in. casing is set at 2,700 ft. ; 8⅝ in. at 4,200 ft. ; and 6⅝ in. at the top of the productive zone, at or about 6,600 ft.

At the end of 1947, seven strings were in operation, five of which were at Abqaiq and one each at Buqqa and Qatif.

Production

In the Dammam field production is obtained from all four members of the Arab Zone which although separated by anhydrites are in approximate pressure equilibrium and have a common oil/water level. In addition wet and dry gas is obtained from the Bahrein Zone. In many cases two members of the Arab Zone, particularly A and B, are produced together, but where variations in thickness or pressures, or the proximity of gas/oil or oil/water levels make it advisable they are separated by packers. In some cases production is taken from the A, B and C members, in which case the C member is produced through the tubing and the A and B members through the annulus between the tubing and the casing. Other dual completions are made in the C and D members, the C member being produced through the annulus and D through the tubing.

The reservoir pressure is approximately 2,150 p.s.i. and the oil is saturated, with small primary gas caps in all four members of the Arab Zone. At the current production rate of 80,000 barrels per day from 31 wells the gas/oil ratio is 350 cu. ft. per barrel, and for short periods the field has been produced at the rate of 100,000 barrels per day without any appreciable increase in the gas/oil ratio. The oil produced is partially replaced by water but the evidence does not suggest that the field is subject to a natural free water drive.

All wells are connected to a central multistage gas separation unit where the flow lines discharge into a horizontal 60 ft. mist extractor from which crude flows to the first stage separator operated at 320 p.s.i. and thence to the second stage separator operated at 130 p.s.i. The separation unit also includes a test separator in which gas/oil ratios are determined of three or four wells per day, and, in addition to the 60 ft. by 4 ft. 6 in. horizontal separators, a number of vertical separators which were used before the installation of the horizontal vessels and which are now maintained as standby capacity.

From the separation unit the crude goes to a central gathering unit which handles 80,000 barrels per day from the Dammam field, 200,000 barrels from Abqaiq and 5,000 from Qatif. From

An aerial view of the ARAMCO camp at Dhahran

Petroleum Times] *A general view of Dhahran* [Photo

this gathering unit some 100,000 barrels per day are switched to the stabilising plant where it is stabilised for export and the balance to the Ras Tanura or Bahrein refineries.

At the stabilisation plant export crude passes through steam reboilers where it is heated to 230-240° F. and thence through weathering columns. The overheads pass through heat exchangers to a rectifier from which the vapour line is held at 135 p.s.i., thus recovering condensible hydrocarbons which are mixed with crude for delivery to the refineries. The present maximum capacity of the stabilisation plant is 125,000 barrels per day but extensions now in hand will increase the capacity by 18,000 barrels.

At Abqaiq 200,000 barrels per day are produced from 25 wells, all from the D member of the Arab Zone except one dual completion in the C and D members which produces heavy oil used for road dressing. The crude is saturated at the reservoir pressure of 3,300 p.s.i. but there is no evidence of the existence of a primary gas cap. The producing formation is dolomitic and oolitic limestone with an average porosity of 20 per cent. but without pronounced fracturing. There is no water production and the gas/oil ratio is 900 cu. ft. per barrel at the current rate of production. Production is to primary horizontal traps operated at 500 p.s.i. and thence to Hortonspheres maintained at 5 p.s.i. From these the crude is pumped to the central gathering unit at Dammam where it is stabilised for export or switched to the Ras Tanura or Bahrein refineries.

The current Qatif production of 5,000 barrels per day is obtained from two wells producing from the C and D members of the Arab Zone. The crude is saturated at the reservoir pressure of 3,300 p.s.i. and the producing gas/oil ratio is 400 cu. ft. per barrel.

Pipelines

A 10 in. pipeline from Dammam to Ras Tanura was completed in 1939. This line follows the land route via Qatif and is 39 miles long with a daily capacity of 63,000 barrels. In 1945 a 12 in. overland and submarine line was laid from Dammam to the Bahrein refinery. It is 34 miles long and has a daily capacity of 110,000 barrels. A second line was constructed from Dammam to the Ras Tanura terminal in 1946 taking the direct overland and submarine route. It is 12 in. in diameter, 23 miles long and has a daily capacity of 115,000 barrels. In 1946 also a combination 12-14 in. line was laid from Abqaiq to Dammam, being 40 miles long and having a capacity of 210,000 barrels per day. A second 14 in. line from Abqaiq to Dammam was completed in 1947, and a 20-22 in. line with a capacity of 200,000 barrels per day is now under construction from Abqaiq direct to Ras Tanura, a distance of 65 miles by the overland route.

Construction has already commenced on a 1,100 mile 30-31 in. pipeline from Abqaiq to the Mediterranean. With a capacity of 300,000 barrels per day, this line was due for completion in 1950, but the disturbed conditions in Palestine and the neighbouring Arab States, and the pipe shortage in the U.S.A. may delay its completion.

The Ras Tanura Refinery

Construction of a refinery with a designed capacity of 50,000 barrels per day was commenced in September, 1944, and completed in October, 1945. The plant includes two distillation units each of 25,000 barrels designed capacity, with atmospheric and vacuum columns ; two reforming units each of 7,000 barrels per day designed capacity ; and a naphtha re-run unit.

By augmenting pumping and charging equipment the capacity has been progressively stepped up to 125,000 barrels per day and at the end of 1947 the cumulative throughput was 70,000,000 barrels. The principal products are : Motor spirit (72 and 70 octane), kerosine, diesel oils (black and white) and Naval fuel oil.

The Loading Terminal

A loading terminal at the tip of the Ras Tanura spit, 5 miles south-east of the refinery, is fed by the 10 and 12 in. crude lines from Dammam and by product lines from the refinery. It is equipped with one T-head jetty with two inside and two outside berths, and with one sea loading line of 9,000 barrels per hour capacity. The total loading capacity of the terminal for crude and refined products is 300,000 barrels per day.

Amenities and Social Work

The progress so far made by the Arabian American Oil Company in sponsoring the advancement of education and social welfare in the area of its operations in Saudi Arabia should be considered in the light of the limited span and the war-time interruption of its operations. From the beginning of its operations in 1933 until 1938, when oil was first discovered in commercial quantities, the company's operations were purely of an exploratory and "wildcat" nature. From 1938 until the beginning of the war manpower resources were concentrated upon the building of pipelines and terminals to enable oil to be exported. During the war until the beginning of 1944 operations were necessarily greatly curtailed and American and other personnel were reduced to an absolute minimum. During 1944 and 1945 the company's available manpower resources were taxed to the limit in the construction of the pipeline to Bahrein, and the Ras Tanura refinery which had been considered as essential projects for the prosecution of the war.

Since the war there has been a rapid development of the Dammam and Abqaiq fields and an intensive exploratory programme so that the company's operations have barely reached a stage of consolidation. In the four years since the resumption of active operations local resources of labour and materials have been absorbed in the provision of housing, hospitals, transport and other services for the company's 1,700 American and 15,000 Arab employees, so that the development of educational and welfare facilities for the Arab communities is still in its early stages.

Education and Technical Training

From the beginning of its operations in Saudi Arabia the company has been keenly aware of its duty to contribute to the greatest practical extent to the training, education and improvement of the living standards of the local population and particularly of its employees. The company embarked upon the development of a country in which the local population was not only illiterate, but without any knowledge of modern mechanical equipment or of Western methods. The company's earliest efforts during the first few years were devoted almost entirely to the training of the local Arabs in mechanical crafts. In spite of the relatively short period of the company's active operations, the results of this training have been most gratifying and thousands of Arabs who were hitherto totally unskilled have been trained to do semi-skilled and skilled mechanical work. A small percentage of exceptional individuals have been developed to a point of remarkable proficiency.

Schools for education other than craft training have been introduced in Al Khobar and at Dhahran. In view of the general illiteracy of the population, the only subjects so far offered have been English, written and oral, Arabic writing and grammar, hygiene and arithmetic. The company schools have been open to the public, to employees and non-employees, of all ages, and the size of the classes has been determined largely by the numbers who have wished to attend.

The schools were started with local Arab teachers under the supervision of the company personnel department. In 1943 the company engaged an American educator, to act as superintendent of schools and to take charge of the educational programme. Additional schools were opened in the refinery area at Ras Tanura during 1944.

During 1944 also the company introduced a programme for the training of local Arab office workers by offering boys, who had reached the age of 14 or over and who had progressed to a certain point in the company schools, full time employment consisting of half a day as errand boys in the offices and half a day in company schools for which regular wages are paid. These boys are being given more advanced education in their English, Arabic, and arithmethic, plus some accounting and training in the operation of office equipment.

A similar system has been introduced in trade schools for the training of artisans. In these schools students who qualify by having studied Arabic for three years, with one hour's tuition in English per day, are trained as fitters, machinists or welders. Hostels are provided for their accommodation and students who devote full time to their studies receive subsistence pay. Those who spend half their time in the schools and half time in the shops receive half the subsistence pay plus the rate for their job.

The results obtained in the company schools as well as in vocational training up to date have been gratifying. A large number of the Arabs have taken advantage of the opportunities offered and the literacy rate at Dhahran has risen to 20 per cent. The company has endeavoured to develop a sense of integrity, character and loyalty, as well as an improvement in education and mechanical skill. Encouraged by the successful results to date and of the importance of this work in the future, the programme envisages a great improvement and enlargement of the present school system as rapidly as the demand develops, as suitable teaching staff can be obtained and proper facilities constructed. The company intends to supplement its vocational training with class work which will give those in the mechanical trades a better understanding of the work that they do.

Housing

The company has followed a practice of providing housing for employees in the vicinity of its operations. The type of housing provided varies from the native " Barasti " variety for the lower paid workman to more permanent stone or cement structures which provide a room for each two men. In all cases, the employees are provided with ample water, bathing and sanitary facilities. It is the company's intention to replace the " Barasti " type of dwelling by the more permanent type of structure but shortages of materials and craftsmen have limited the construction of permanent buildings.

Nevertheless, standards of accommodation in the company's temporary camps compare favourably with those in the neighbouring oasis towns of Qatif and Hofuf, while in the matter of sanitation they are infinitely superior.

With the possible exception of the Syrian pump stations on the IPC pipelines, the area of ARAMCO's operations is the most barren and inhospitable of all the oil areas of the Middle East, and climatically the worst.

Apart from the oases of Hasa, Hofuf and Qatif the desert is all pervading. Around Dhahran and between there and the coast the terrain is barren, slightly undulating sand, relieved only by the splintery limestone crags which form the rim rock of the Dammam field. For a few months around Christmas the climate is pleasantly hot, but for the rest of the year the atmosphere is either charged with the steaming vapours which rise from the Persian Gulf, or choked with dust from the sand storms which blow in from the dune country to the north and west. At Abqaiq we are already in the Jafura country—a belt of moving sand dunes projecting northwards from the Rub al Khali or " empty quarter." Here there is nothing but a sea of sand: sand dunes up to 100 ft. in height rising in wave after wave and, although migratory—swallowing up roads, derricks and installations—still and lifeless to the eye. The searing monotony of endless repetition is relieved only at sunset when the changing light endows the dunes with a rare but transient beauty. Drab yellow sands turn to richer shades of brown, lengthening shadows steal down the steep south-east flanks and the tips of the dunes are suffused with amber and gold. But in the morning, this fleeting beauty has vanished like a dream and the pitiless sun again beats down on a petrified ocean of khaki sand.

It is in these surroundings that 1,700 Americans, one of the largest American communities outside the United States, live and work. But the company has done everything that lavish expenditure and engineering skill can contrive to make life tolerable. Dhahran is a modern American city with paved streets; timber, brick and masonry air-conditioned bungalows; clubs, mess-halls and cinemas; laundries, barbers' shops and beauty parlours; swimming pools, baseball grounds and flood-lit tennis courts. There is a branch of the U.S. Post Office with batteries of individual post boxes, each with its own combination lock for every household, a company-operated weekly air service to Beyrouth, 1,100 miles away across the Great Arabian Desert, and a fortnightly one to the United States. Schools are provided where employees' children receive education to American standards up to the age of 14, and it is proposed to extend this up to high school standard, so that family separation, so frequently an inevitable consequence of service abroad, may be avoided.

Imported cold stores, fruit and fruit juices, ice creams and breakfast cereals in every appetising variety and form, baked Virginia ham and grilled pineapple, corn-on-the-cob, and fried chicken Maryland sustain vitality and persuade the visitor to the air-conditioned mess-hall that he is back in Bartlesville or Bakersfield, in Tulsa or in Taft.

An Arab refinery worker

The new camp, aptly called American City, at Ras Tanura has similar facilities and its proximity to the ocean with its bathing beach is a distinct advantage. Being entirely of post-war construction, American City lacks the trees and gardens which relieve the glare and impart a homelike atmosphere to the older-established camp at Dhahran but, with copious supplies of water, these will come and add greatly to the attractions of this modern town.

The drilling camp at Abqaiq, where construction materials are absent and all supplies have to be carried in by camel, consists of temporary buildings but by air-conditioning they are made as comfortable as possible. Now that a road has been constructed from Dhahran, the temporary buildings will be replaced by permanent ones as soon as the supply of craftsmen and materials permits.

Hospitals and Clinics

For several years a hospital has been maintained for Arab employees in the company's camp at Dhahran. Medical attention is provided for all employees free of charge. A gradually increasing number of non-employees have also been availing themselves of the company's medical facilities. A nominal charge for medical care is made to non-employees although the charge is waived in the case of individuals whom the Government certifies as indigent.

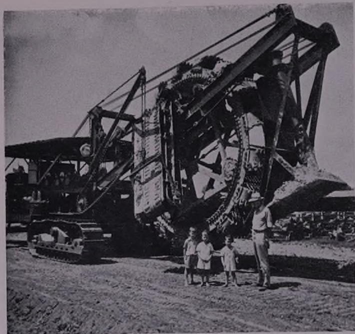
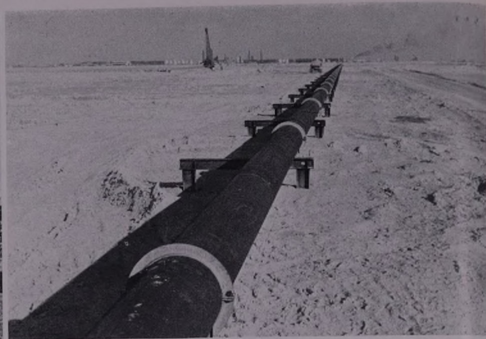
Prior to the company's operations the Saudi Arabian health service was oriented to deal with the pilgrim traffic from Jidda to Mecca and the first hospitals in the Hasa Province were built by the company at Dhahran and Ras Tanura. Impressed by the benefits of the company's medical work in the immediate area of their operations, the Government have asked the company to establish clinics over a wider area of Hasa Province at Government expense.

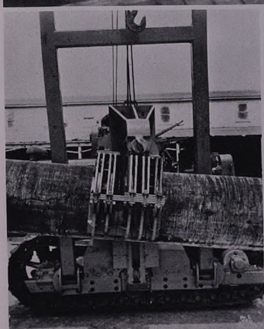
The company doctors make constant efforts to reduce disease through the education of employees and for several years have been carrying on a campaign to eliminate malaria in Dammam and El Hobar, the two towns nearest the Dhahran camp.

An entomologist and sanitary engineer employed by the company act as consultants to the Local Government in their efforts to extend this work over a wider area.

Part of the residential area at Dhahran

Petroleum Information Bureau Photos.


Williams Brothers Overseas Co] [Photos

Top: Pipeline ditching machine; A surface line in the desert. Centre: Pipeline equipment for TAPLINE stored at Beyrouth; Tractor and pipe bending shoe Bottom: A close up of the bending shoe; Another view of TAPLINE equipment at Beyrouth

Public Projects

The company has given assistance to the Government in the development of water supply and of agriculture.

The most notable project in which it has participated has been the Al Kharj project, about 50 miles south-east of Riyad. This was started by the Government themselves and carried forward by them until 1941 at which time they appealed to the company for technical advice in the enlargement of the project. In the spring of 1941 company engineers made a complete survey followed by recommendations for increasing the water supply and placing additional land under cultivation. The recommendations were followed and the company placed orders in the United States for additional pumping equipment. During 1942 and in 1943 company engineers and construction men took over complete supervision of the project, with the Government supplying the labour.

The project was completed at the end of 1944. The work consisted of the installation of modern centrifugal pumps at the edge of large pits formed by the collapse of the limestone surface. The pits are filled to approximately 100 ft. below the ground level with water fed from a source some 600 ft. below the surface. The pumps are installed in 36 in. wells drilled into an over-hanging wall of the pits. It also involved the construction of an 11-mile canal and the levelling and grading of some 2,000 acres of land as an initial unit of the new area to be placed under cultivation. Now, nearly two thousand acres of formerly dry desert are green with luxuriant crops of wheat and alfalfa, or planted with water-melons, cantaloups, squash, eggplant, tomatoes, lettuce, onions, carrots, broccoli and cabbage.

Water wells were drilled and are being maintained by the company at Maagala, at Rhauda al Hani, at Khobar, Dammam, Qatif and Jubail. At many other points good water wells discovered in the course of structure drilling and seismograph work have been completed by the construction of masonry or concrete tops and are maintained for the benefit of the local Bedouin.

At the request of the Government the company has undertaken the construction of a deep-water port at Dammam on the southern shore of Ras Tanura Bay and of a railway from there to the capital city of Riyad. This is to be financed by the Government out of oil royalties, but the company will be responsible for the construction and technical supervision.

The company's participation in these engineering projects is typical of the co-operation with the Government on which the management places such emphasis. No effort is spared to cultivate good relationships with the Government and the local people. While this is the primary responsibility of a large "relations" organisation under a resident vice-president of the company, it is impressed on all employees that their conduct must be such that no offence will be given to Arab religious or social susceptibilities.

One of the responsibilities of the Relations Branch, through its agency, the Arab Industrial Development Department, is the encouragement of Arab contractors. Three years ago there were only one or two Arab contractors doing haulage work with camels; now there are 70 employing a labour force of three to four thousand on company contracts. The majority are ex-employees of the company and the work on which they are engaged includes welding, trucking, building and electrical work (wiring). The Abqaiq-Ras Tanura pipeline was strung and welded by Arab contractors under the supervision of company personnel.

The help given to these contractors includes assistance in the procurement of equipment such as vehicles and welding sets, with the object of making them as independent as possible. They are even given assistance in preparing tenders, and on more than one occasion when tenders have been received at rates which the company knew to be unremunerative, contracts have been given at higher rates. To enable the contractors to increase their efficiency technical booklets are being prepared in Arabic, dealing with welding, vehicle operation and maintenance, etc.

The emergence of independent Arab contractors as a result of the company's efforts has had a far-reaching effect on building standards in the neighbouring towns and on transport facilities in the Province. Fifteen years ago the wheel was unknown in Arabia except as a water wheel: today fleets of lorries operate in the Hasa Province carrying dates from the oases of Hofuf and Qatif to the neighbouring towns and even to Riyad.

The HAIFA Refinery

Construction of the Haifa refinery of Consolidated Refineries Ltd. was started in 1938, but was interrupted at the beginning of the war when most of the American construction staff were repatriated. Consolidated Refineries' own staff were able to commission the first topping unit themselves in December 1939. With a throughput capacity of 1,000,000 gallons per day of stabilised Kirkuk crude, this unit was operated to produce motor spirit and Admiralty fuel oil.

Construction continued, but it was not until the Spring of 1941 that a second topping unit was completed, but shortly afterwards the refinery was shut down for lack of crude during the Iraq rebellion of May and June 1941. On the resumption of crude supplies from Kirkuk in the summer of that year the refinery operated at the designed capacity of 1,600,000 gallons per day, equivalent to 2,000,000 tons per annum. Several air raids were experienced at that time, and although fires were started, and some stores and tanks destroyed, output of the refinery was not affected.

At the end of 1941 bitumen manufacture was commenced to meet the great military demands for road and airfield runway construction. At first the bitumen was filled into discarded 4-gallon petrol tins until a drum plant was improvised from salvaged equipment from obsolete plants in Egypt. Over 2 million 4-gallon tins were filled to meet emergency military demands and thereafter the drum plant, with a capacity of one hundred 24 gauge drums per hour, was operated for the remainder of the war by Consolidated Refineries on behalf of the Army.

Throughput of the refinery was progressively stepped up to meet military needs to 3½ million gallons per day by the construction of a third topping unit of similar capacity to Nos. 1 and 2 and by revamping the wax cracking sections of these units to process additional crude.

The original design of the refinery included two 300,000 gallon capacity reforming units with the object of improving the octane rating of the finished gasoline. Since however this would have reduced the yield of finished products at a time when maximum output was essential for military purposes these have not yet been operated, and straight-run motor spirit is brought up to the required specification by leading.

The 600 h.p. Mather & Platt totally enclosed, flame proof motor driving the charging pump to the reformer furnace was the largest of its type in the world at the time of its installation.

From August 1944, when the throughput of the refinery reached an annual rate of 4 million tons, 2 million tons has been received from Kirkuk by the Kirkuk-Haifa pipeline, and two million transhipped from the Tripoli terminal of the northern Kirkuk-Mediterranean pipeline. In 1945, when French refineries recommenced operation, supplies formerly drawn from Tripoli by transhipment were gradually replaced by Iranian and later by Kuwait crude. The annual throughputs of the refinery and sources of the crude from 1939-1947 are given opposite.

War-time and Present Operations

The first two units were designed by M. W. Kellogg Co. as topping-reducing units and the third as a simple topping unit. To increase capacity the wax cracking sections of the first two units have been operated as two subsidiary units for crude distillation and the viscosity breaking sections as two vacuum units for asphalt production, giving with the third main distillation unit a maximum input capacity of 3.5 million gallons per day of stabilised crude and an actual average throughput of 3.2 million gallons.

The fractions and yields obtained are: motor spirit up to 145° C. (23 per cent.); kerosine up to 235° C. (14 per cent. of which 5 per cent. is blended with fuel and gas oils, leaving a net kerosine yield of 9 per cent.); and gas oil from 235° C. to 360° C. (22 per cent.), leaving a residue of from 40 to 41 per cent. Some 40 per cent. of this residue is vacuum distilled to yield a waxy distillate equivalent to 22 per cent. of the crude charged to the primary units, and the residue from vacuum distillation is air blown to give several grades of bitumen, both solid, with penetration of from 80 to 100, and liquid, cut back with kerosine. The waxy distillate is blended with the remainder of the residue from the primary units to yield two grades of fuel oil: Admiralty grade of 210 seconds viscosity Redwood No. 1 at 100° F.; and commercial grade of 900 seconds viscosity.

Chemical Refining

Gas oil is treated with salt to remove water and to clarify, and kerosine is washed with sodium hydroxide followed by doctor treatment.

A panorama of the Haifa refinery, with the development area in the foreground.

Motor spirit is refined in two streams—light, boiling up to 100° C. and heavy from 100 to 145° C. The light fraction is stabilised in two Badger units each of 5,750 barrels capacity for butane removal and to yield a specific vapour pressure product, and is then soda treated for H_2S removal. The heavy fraction is also soda treated and then washed with sulphuric acid for further sulphur removal. The two cuts are then combined for doctor treatment and redistilled to improve the lead response. From the re-run operation 97 to 98 per cent. overheads are obtained leaving 2 to 3 per cent. bottoms. The octane rating of the finished motor spirit is 59 clear ; 70 with 1.1 ml. of tetraethyl lead and 79 with 3.6 ml. of tetraethyl lead.

Butane recovered from the stabilisers is soda washed and sold as "Shell Butagaz" in the local market and exported to Mediterranean countries. Other by-products are special boiling point products boiling at 60° C. to 90° C. for dry cleaning and the extraction of olive and ground nut oils.

Sulphuric acid is manufactured from imported sulphur in a contact plant using vanadium pentoxide as catalyst and producing 30 tons a day of 98 per cent. acid. This is the only source of sulphuric acid in Palestine and in addition to providing its own needs for the refining of motor spirit the refinery has supplied substantial quantities through the Palestine Government Controller of Heavy Industries for other industrial use. Acid tar from the washery is delivered to manufacturers of superphosphate fertilisers and alkaline wastes are supplied to manufacturers for the tanning industry.

Expansion Programme

Work has already started on a construction programme with the object of increasing the refinery capacity to 7.5 million tons per annum. It involves the installation of one more distillation unit of 3 million gallons capacity per day, and of a lube oil plant of 125,000 tons per year capacity. Additional equipment will also be provided for production of numerous grades of bitumen and of white spirit and solvents. When complete the refinery will be able to produce all grades of products, with the exception of aviation fuel, called for by modern markets.

HAIFA REFINERY CRUDE OIL INPUT

Year	IRAQI		IRANIAN		KUWAIT		TOTAL		PROGRESSIVE TOTAL	
	Gallons	Tons	Gallons	Tons	Gallons	Tons	Gallons	Tons	Gallons	Tons
1939	19,335,308	72,794.99	..	..	..	..	19,335,308	72,794.99	19,335,308	72,794.99
1940	221,602,270	847,044.71	..	..	..	..	221,602,270	847,044.71	240,937,578	919,839.70
1941	306,771,218	1,165,096.33	..	..	..	..	306,771,218	1,165,096.33	547,708,796	2,084,936.03
1942	540,574,772	2,005,997.69	..	..	..	..	540,574,772	2,005,997.69	1,088,283,568	4,090,933.72
1943	724,192,228	2,723,792.11	..	..	..	..	724,192,228	2,723,792.11	1,812,475,796	6,814,725.83
1944	871,610,255	3,281,714.24	..	..	..	..	871,610,255	3,281,714.24	2,684,086,051	10,096,440.07
1945	1,061,783,586	4,000,066.29	2,593,061	9,939.75	..	..	1,064,376,647	4,010,006.04	3,748,462,698	14,106,446.11
1946	817,920,043	3,080,587.48	138,584,328	530,378.90	106,861,668	410,531.85	1,063,366,039	4,021,498.23	4,811,828,737	18,127,944.34
1947	778,129,465	2,937,136.24	..	..	259,309,375	997,482.09	1,037,438,840	3,934,618.33	5,849,267,577	22,062,562.67

The administration building

Although of American design, a great part of the new equipment is being manufactured in the United Kingdom. The distillation, vacuum and SO_2 plants are designed by the E. B. Badger Co.; the furfural solvent extraction and MEK solvent dewaxing plants and the clay treatment plant by The Lummus Co. and the de-asphalting plant by the M. W. Kellogg Co.

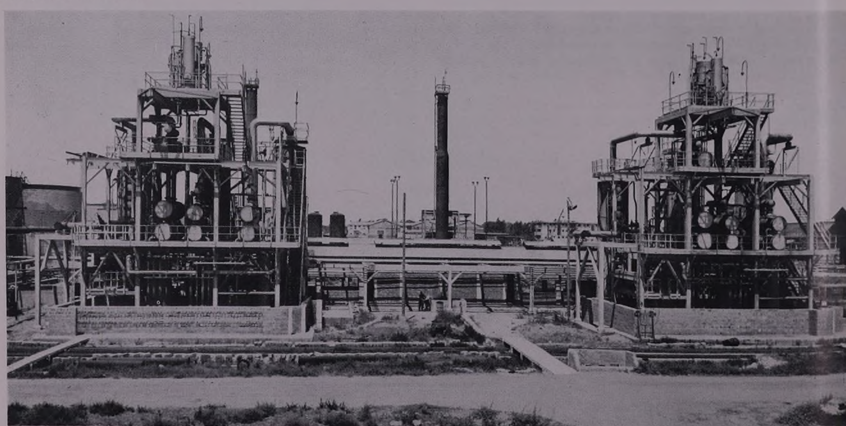
The existing services include four Spearing boilers with maximum ratings of 150,000 lb. per hour at 500 p.s.i., of which two are normally in operation. To cater for the expansion of the refinery five more similar units are to be added. All water for the boilers is treated with lime-soda, followed by zeolite and conditioned by adding sodium sulphate and sulphite, tannin and Calgon. Three to five parts per million of Calgon are also added to circulating water with a great reduction of scale. Circulating water is cooled from 117° F. to 85° F. in two towers of the parabolic type, each with a capacity of 2 million gallons per hour, having evaporation losses amounting to from 2 to 2.5 million gallons per day. At the time of their construction these towers were the largest in the world. Two more towers of similar capacity are under construction as part of the extension scheme.

Power is provided by three turbo-alternators each with a capacity of 6,250 kW. They are operated by 500 lb. steam from the boilers and steam at 200 lb. is bled off and used for process purposes. Two units are normally in operation with one standby, and two more units are to be added.

The expansion of the refinery also calls for a large increase in product storage to maintain the requisite minimum storage capacity of each product; and extensions to the existing oil docks and installations. It is estimated that the peak labour requirements of the construction programme will reach 5,000 as compared with the normal force of 1,600 labour and 400 supervisory staff.

Towards the end of 1947 mounting racial tension in Palestine made operation of the refinery precarious: there were several attempts at sabotage, and strife between Arab and Jewish employees. Throughout this difficult period the British personnel, whose morale was magnificient, succeeded in maintaining output only a little below maximum capacity. Early this year the deterioration of the Palestine situation, culminating in civil war on the termination of the British Mandate on May 25, restricted operations at the refinery and ultimately caused their suspension on April 25. Thus, not only are the 4 million tons of products produced annually by the existing refinery temporarily cut off but the expansion scheme, so vital to European recovery, is indefinitely suspended.

Two of the distillation units



The Times] [Photo
The City and harbour of Kuwait

KUWAIT

THE SHEIKDOM OF KUWAIT, situated at the head of the Persian Gulf, has an area of some 6,000 square miles. Its population is estimated at 100,000, of whom some 80,000 live in the ancient walled town of Kuwait. On January 23, 1899, the Sheik of this Arab State signed a treaty with Great Britain in which he undertook not to alienate any portion of his territory to a foreign Power, except with the express authorisation of the British Government. In return the Sheik was assured of British support and assistance in case of need. For his promise of assistance against the Turks during World War I, the British Government, in a Note dated November 3, 1914, recognised Kuwait as " an independent State under British protection." All British subjects and non-Moslem foreigners are subject to British jurisdiction.

Negotiations between the Gulf Oil Corporation of America and the Anglo-Iranian Oil Company led to the creation in 1933 of the Kuwait Oil Company in which both were associated on a partnership basis. On December 4 of the following year Sheik Sir Ahmad al Jabir as Subah, the present Ruler of Kuwait, granted a concession to this new company. The Kuwait Oil Company is registered in London ; its concession covers the whole of Kuwait's territory and is for a term of 75 years.

Exploration History

After geological surveys had been completed, the first exploration well, located in the Bahrah area north of Kuwait Bay, was drilled to a depth of 7,950 feet where drilling was suspended. The results of this well were sufficiently encouraging to justify extensive geophysical surveys, following which a second exploration well was located in the Burgan area on a " high " 28 miles south of Kuwait Bay and 14 miles inland from the coast, and after four months of drilling this well had reached a depth of 3,672 feet, where the present producing horizons of the Burgan field were first penetrated in February, 1938. Subsequently, eight additional wells were drilled in the Burgan field between the years 1938 to 1942 when all operations were suspended and the wells plugged with cement as a war measure.

Outside the Burgan area, in addition to the Bahrah well, one other exploration well had been commenced in the Madaniyat area, approximately 15 miles to the north of Burgan, on a seismic r flection high on the same general north-south line as the Burgan high.

Operations were resumed in October, 1945, under a wartime programme for developing additional sources of petroleum in the Middle East. Under this programme all the original nine wells—except No. 1 which is still idle owing to mechanical conditions—were cleaned out, gun perforated and placed on production and the first commercial crude oil shipments from Kuwait were made on June 1, 1946, when, at a ceremony held at Fahaheel, His Highness Sheik Sir Ahmad al Jabir as Subah, K.C.S.I., K.C.I.E., opened the main valve at the loading terminal to load the tanker


IRAQ
IRAN
TRANS-JORDAN
SAUDI ARABIA
IRAN
Abadan
Euphrates River
IRAQ
Al Batin River
BAHRAH Ø
Kuwait
PERSIAN GULF
MIDDLE EAST
KUWAIT FIELD
Madaniyat
Magwa Camp
Fahahil
BURGHAN
LEGEND:
Oil Fields
Refineries
Pipelines
Roads
Towns
Ø Dry Wildcat Test

British Fusilier with the first cargo for Grangemouth. In reply to a speech of welcome in which the managing director, Mr. C. A. P. Southwell, M.C., B.Sc., F.Inst.Pet., referred to the happy blend of British and American technical skill and resources embodied in KOC, His Highness emphasised the importance of this event, which he said would enable him " to carry on the various improvements which we desire for the happiness and welfare of my State and people." Since then, under a programme for development of the field, nine new wells have been completed, making eighteen in all to May, 1948. Work on the Madaniyat well has not yet been resumed owing to the necessity for concentrating actively in the Burgan area.

KOC] [Photo

Mr. C. A. P. Southwell receiving the Sheik of Kuwait at the opening ceremony

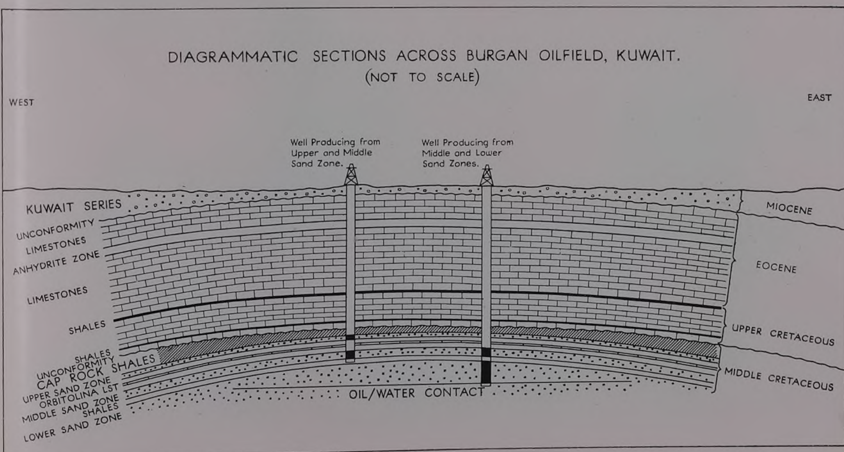
Geology

The greater part of the Sheikdom of Kuwait consists of desert windblown sand and outcrops are rare except in the Burgan Hills where Miocene sandstones are exposed at elevations of from 250 to 300 feet above sea level, some 28 miles south of the town of Kuwait. Here there is a bitumen seepage, where hard bitumen-impregnated sandstones were worked on a small scale for road metal during World War II. There are gas seepages at Madaniyat, 14 miles north of the Burgan Hills and at Bahrah 37 miles further north.

In the Burgan Hills dips are so low as to be scarcely determinable, although with the knowledge that one of the greatest oilfields of the world has been proved there, and with the benefit of the guidance of a Kuwait Oil Co. geologist, some suggestion of a structure was discernible.

The present proven productive area of the Burgan field is pear-shaped, narrowing to the north and covers approximately 30 square miles, while the structure is a broad anticline having a major axis running north and south. The producing formations are of Middle Cretaceous age and, with the exception of one limestone band, are sand reservoirs. The cap rock is a shale development with a proved maximum thickness of about 220 feet, but the thickness of shale preserved below the Upper Cretaceous unconformity (which truncates the shale group) is generally less than this. The depth of the first productive horizon on the top of the structure is approximately 3,600 feet, and drilling results have shown this to increase to at least 4,000 feet as the periphery of the field is approached. At the centre of the field the productive section is approximately 1,100 feet thick and consists of three major sand bodies with a limestone band (the Orbitolina limestone) below the first sand. The producing horizons are separated from each other by intervals which are predominantly shaly but contain thin sandstone bands.

The lowest sand at the crest of the structure has approximately 500 feet above the water table and at least 400 feet of this is probably productive; the thickness of this productive zone decreases to zero as the top of the sand section approaches the water table. The middle sand, which contains the greater proportion of the known reserves, varies in thickness between about 200 and 300 feet and appears to average about 175 feet of good



producing sand. The upper sand averages approximately 85 feet in thickness, at least half of which is good producing sand, and the Orbitolina limestone is about 25 feet thick. The Orbitolina limestone is the most consistent geological marker in the producing section as the sands and shales vary in thickness.

The upper sand zone is composed of fine grained, glauconitic, calcareous well-cemented quartz sand interbedded with medium grained sandstone and siltstone. The two lower sand zones are interbedded, coarse grained unconsolidated sand grading to a very fine grain unconsolidated sand with thin laminations of siltstone and shale. The Orbitolina limestone is a brown. oolitic, argillaceous limestone of variable hardness and porosity,

The two lower sand zones are the most productive, but to date little information is available regarding the permeability, porosity and connate water content of the reservoirs. The reserves of the field have been variously estimated between 9 and 12 billion barrels (12,000 million) but knowledge of the reservoir is still far too limited for any accurate estimate to be made.

The generalised geological section according to present information is as follows :—

Age	Local Development		Approx. thicknesses in ft.
Miocene	Kuwait sands		200 max.
Unconformity			
Middle Eocene	Limestone		635 max.
	Anhydrite zone		300
Lower Eocene	Limestone		1600
Upper Cretaceous	Shales		10
	Limestone		750
	Shales		25
	Limestone		100
Unconformity			
Middle Cretaceous	Rutbah Sand	Shale (cap rock)	220 max.
		Sand	100 ,,
		Shaly interval	100 ,,
		Orbitolina limestone	30 ,,
		Shaly interval	100 ,,
		Sand	300 ,,
		Shaly interval	150 ,,
		Sand	500 plus

There are unconformities below the Miocene and Upper Cretaceous limestones. There is no evidence of thinning over the structure below the cap rock shale, below which the only definite marker bed is the Orbitolina limestone.

Production and Reservoir Data

The individual well production rates have been controlled to 5,000 or 6,000 barrels per 24 hours to ensure sand-free production. However, this is only a portion of the possible theoretical well potential as the pressure differential across the sand face to produce the above volumes of oil is only between 50 and 100 pounds while the wells are produced against 500 to 650 pounds surface pressure.

The original reservoir pressure was 2,075 p.s.i. at a depth of 4,000 feet below sea level. Surface elevations of the wells vary between 200 and 280 feet above sea level. Petroleum engineering studies for the middle sand indicate that the oil and accompanying gas, 475 cubic feet per barrel, have a saturation pressure of the order of 1,630 p.s.i. at a reservoir temperature of 132°F.

The specific gravity of the oil produced from the various sand zones increases with depth, which is unusual but not unique. It also appears that the specific gravity of the oil increases with depth in each individual sand zone. The specific gravity of the oil produced varies from 0.845 (36.0° API) for the upper sand to 0.876 (30.0° API) for the lower sand.

From June 1, 1946, when the field was re-opened, the total production to the end of April, 1948, has been 30,745,000 U.S. barrels from 17 wells, well No. 1 being closed in for mechanical reasons. Of this total, 20 per cent. was from the upper sand, 72 per cent. from the middle sand, and 8 per cent. from the lower sand. The current production is in the neighbourhood of 100,000 U.S. barrels per day.

Of the 17 wells now producing, 10 are completed as dual producers from the two upper sands and four from the two lower sands. By the installation of packers the production from each sand is segregated up to the surface in order that the gas and oil may be measured separately to determine the relationship between volumetric extractions and reservoir pressure performance of each zone. Wells recently completed, as well as a proportion of future wells, will be brought in as dual producers from the two

KOC] [Photo

Derrick being skidded over typical Kuwait terrain

Petroleum Times] [Photo
The manifold of the production unit

KOC] [Photo
An Arab production worker

lower sands. The present programme is to develop the field on a 600-acre spacing, with intermediate wells as may be necessary to meet production requirements.

The average porosity of the sands is indicated to be as high as 30 per cent. and the productive indices are: Upper sand, no accurate data, but has produced 1,500 barrels per day; the middle sand, 75 barrels per pound differential pressure at 5,000 barrels per day; and the lower sand 45-50 at 4,000-4,500 barrels per day. The producing gas/oil ratio is approximately 475 cubic feet per barrel and there is no evidence that this ratio is sensitive to decreases or increases of oil production. The bottom hole temperature is from 132°-134°F. and no temperature changes are noticed as a result of production. As mentioned previously, the gravity of the crude increases with depth not only in succeeding zones but within each zone. The gas is sweet although the oil contains from 2 to 2½ per cent. sulphur. The analysis and physical characteristics of the Kuwait crude are as follows:—

Data on Crude

Gravity, °API	33.2
Viscosity, S.U.S. at 100°F.	49.9
Viscosity, S.U.S. at 130°F.	44.3
Colour, NPA	8+Dil.
Cast	Brownish black
Flash point, °F. T.C.C.	Below 35
Pour point, °F.	−10
Carbon residue, per cent.	4.27
B.S. and W., per cent.	0.10
Neutral No.	0.01
Acid heat	20
Aniline point, °F.	161
Ash, per cent.	0.01
Sulphur, per cent.	2.06
Distillation (D 285-41)	
I.B.P.	80
2 per cent.	123
5	170
10	230
20	326
30	429
40	524
50	588
60	621
70	635
80	641
87 (cracked)	646

Base of Crude

Key fraction No. 1
B.P. 482-572°F.
Gravity, API − 39.3
V.O.P. char. factor
K = 11.9
Base of fraction—Intermediate

Key fraction No. 2
B.P. 747-800°F.
Gravity, API − 23.9
V.O.P. char. factor
K = 12.2
Base of fraction—Intermediate

Base of Crude—Intermediate

	Pod. Analysis of Crude per cent. by wt.
Propane	0.3
Propylene	0.0
Isobutane	0.2
N-Butane	1.0
Isobutylene	0.0
Butene 1 and 2	0.0
Isopentane	0.5
N-Pentane	1.5
Pentenes	0.0
Hexanes plus	96.5

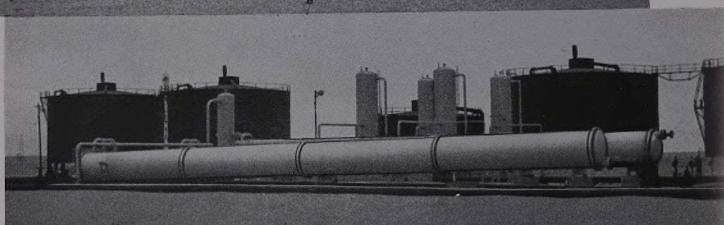
When operations were resumed in October, 1945, production pipelines, separators and tanks were installed, and a pipeline laid to the shipping depot at Fahaheel, 10 miles distant, on the Persian Gulf.

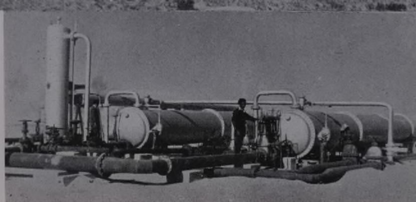
Drilling

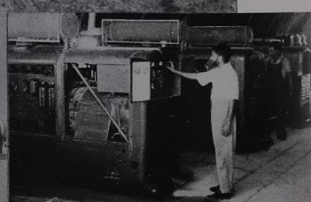
In April, 1948, there were seven rigs in operation, three more being erected while two more were in transit from the U.S.A., and a heavy rig for a deep test well has been placed on order.

Standard 136-foot derricks with a 30-foot base are employed and these are erected on a substructure 14 feet high which obviates the necessity for a cellar. Because of the flat nature of the terrain, the derricks, complete with their substructures, can be moved

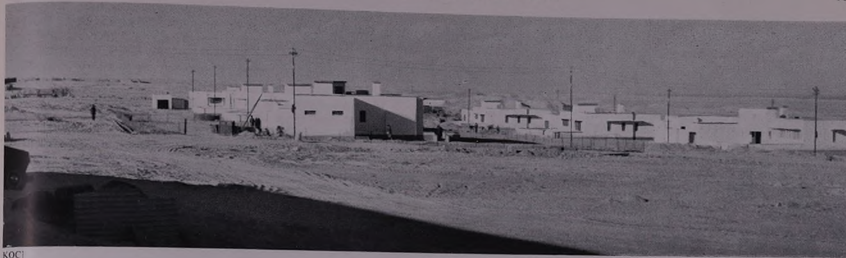
KOC] [Photo
Submarine loading line being launched







Top to bottom: The KOC Viking service plane; A tanker loading at Fahaheel; The Burgan gathering centre; Housing construction at Ahmadi; Separators at the gathering station; The interior of the pump-house



KOC] [Photo

The housing estate at Ahmadi

intact to new locations by skidding. This is carried out by eight D 8 Caterpillar tractors, and the distances covered often extend over several miles. The drawworks are "Ideal" Type-50 consolidated rigs driven by two duplex General Motor diesel engines of 250 h.p. each, and the pumps are two National Type C-250 which are driven by similar diesels.

A 16 in. string of conductor casing is set at 260-400 feet, a 11¾ in. or 10¾ in. water string is carried to or slightly above the cap rock shale (between 3,250 and 3,800 feet below surface) and an 8⅝ in. or 7 in. oil string is cemented into the producing sand usually just below the oil/water contact or slightly above it (that is, approximately 4,700 feet below surface).

Wherever possible, each string of casing is cemented from the shoe to the surface and, as an additional protection the present procedure is to gun perforate and squeeze cement between each sand horizon after normal cementation to ensure separation of producing zones. The casing opposite the zone or zones which are to be exposed for production is gun perforated with six ⅝ in. diameter holes per foot and the wells are then completed with 3 in. tubing and packer. Each third well is cored continuously through the productive zones to obtain geological and reservoir data. At the present time all drilling operations in Kuwait are confined to the development of the Burgan area.

Gathering System

The wells when completed are connected to the Burgan "gathering centre" by 4 in. flowlines with composite 4-6 in. or 6 in. lines from the more distant wells. The original wells were connected to a 4-stage separation system with vertical separators maintained at 300 p.s.i. at the wells. Second and third stage separation was carried out at the Burgan gathering centre and the fourth stage to atmospheric pressure in the storage tanks. The vertical separators are now being replaced by horizontal ones, and subsequent gathering centres will have 6-stage separation with no initial separation at the wells.

In November, 1947, the Burgan transit pump station was equipped with three reciprocating "Oilwell" pumps. Extensions to the pump house have been carried out to accommodate two more units, but as equipment becomes available, reciprocating will be replaced by centrifugal pumps. From the Burgan transit pump station there is at present a single 12 in. pipeline to the main tank farm situated at Ahmadi which is 140 feet higher and at a distance of 10 miles. These lines will be paralleled by two additional 20 in. lines in the near future.

At Ahmadi six 135,000 barrel and two 168,000 barrel storage tanks have been erected, and provision has been made for an additional thirty of 168,000 barrel capacity each. From Ahmadi the crude flows by gravity through two 22 in. diameter pipelines to the loading terminal at Fahaheel, five miles distant. Three more pipelines of 24 in. diameter are to be laid from Ahmadi to Fahaheel. From the terminal at Fahaheel ten 12 in. lines with 8 in. hoses extend to five marine loading berths ; each of these berths is capable of loading at the rate of 1,140 tons (8,500 barrels) per hour. A six-berth loading jetty presently under construction is expected to be completed in 1949.

Markets

In June, 1947, an agreement was concluded between Shell Petroleum Co. Ltd. and the Gulf Exploration Co. for the Shell Petroleum Co. to purchase "increasing annual quantities of crude oil to be produced from the Kuwait fields over the period of the agreement," which is stated to be considerable.

It is assumed that these purchases by the "Shell" are to satisfy their Far Eastern markets, formerly supplied from the British and Netherlands East Indies, and possibly their European markets, with reduced drain on their Western Hemisphere production.

With its favourable location on the Persian Gulf, expansion to meet the increasing demands of the Far Eastern markets, which for geographical reasons must remain tanker-borne, will probably be limited mainly by tanker availability and refining capacity. Until the Middle East pipeline is built from the head of the Persian Gulf to the Mediterranean, tanker availability will probably retard the expansion of Kuwait crude in European markets also, but, assuming the planned Middle East pipeline is constructed, then a further retarding factor may well be the shortage of European refining capacity.

Magnitude of Development

An impression of the magnitude of the development now taking place at Kuwait may be gained from the following figures :—

	1947 Jan.	1947 April	1947 July	1947 Oct.	1948 Jan.	1948 April
PERSONNEL						
Anglo-American staff	90	159	201	289	670	846
Other staff	153	204	279	341	446	618
Skilled labour ..	389	601	864	1,635	3,189	3,801
Unskilled labour ..	1,269	1,597	2,405	2,665	3,573	3,929
Total ..	1,901	2,561	3,749	4,930	7,878	9,194
FRESH WATER SUPPLY						
Gals/day	16,000	27,000	61,300	69,000	60,500	156,750
IMPORTS (Engineering and other cargo)						
Tons/month	6,701	5,400	5,500	9,300	12,114	16,426

One of the main administration problems which has to be faced is that of feeding the rapidly increasing number of personnel, since practically all foodstuffs have to be imported from abroad.

Construction work, on which for the next few years a large proportion of the company's personnel will be engaged, presents a formidable task. For the development of the company's main residential and industrial centre, a site situated on a low ridge some 14 miles south of the town of Kuwait and five miles from the coast has been selected. On the eastern slopes of this ridge, facing the sea, will be situated the residences of the company's permanent staff. In the main, houses will be of the bungalow type, designed to reduce to a minimum the unpleasant characteristics of the Persian Gulf climate. Within the residential estate, schools, clubs and shops for the various communities are also to be constructed and plans have been completed for the building of a hospital, to incorporate the most modern features in both design and equipment. For Arab employees the construction of a new village is contemplated in which not only good housing, but all forms of community and administrative needs will be provided.

The company's main industrial area comprising workshops, store yards, air-conditioning plant, bakeries, laundries, flour mills, mineral water factories and many other facilities is being built on the western slope of the same ridge. Careful thought has been given to the planning of the whole area so as to provide the company's employees with the most satisfactory conditions possible for their work and life.

A second industrial area, to include a power station, a 20,000 barrels per day topping plant, loading facilities and harbour management, is to be constructed on the coast at Fahaheel. The loading jetty, with berths for six 25,000 tankers and two cargo ships, will be the biggest of its type in the world. As there are no natural inlets on this part of the coast, a small harbour for tugs, barges, launches and other craft required in connection with loading operations is to be developed.

Middle East Refinery Capacity

Middle East crude production is discussed and summarised in the first article in this Review : for convenience Middle East refinery capacity and the characteristics of Middle East crudes are summarised below :

Middle East Refinery Capacity

Country	Location	Capacity Barrels per day
Iran	Abadan	495,000
Iran	Kermanshah	2,100
Bahrein	Bahrein	145,000
Saudi Arabia	Ras Tanura	125,000
Palestine	Haifa	90,000
Iraq	Khanaqin	6,900
Lebanon	Tripoli	5,000
	Total	869,000

Plans are in progress for doubling the capacity of the Haifa refinery in Palestine and the small refinery at Tripoli in Lebanon. Construction has also commenced on a topping plant in Kuwait with a capacity of 20,000 barrels per day.

Characteristics of Middle East Crudes

In a recent paper* L. C. Strang (Anglo-Iranian Oil Co., Ltd.) gave the following assessments of Middle East crudes by Hempel distillations (U.S. Bureau of Mines, Bulletin 207) :

	Haft Kel, Iran	Gach Saran, Iran	Kir-kuk, Iraq	Damman, Saudi Arabia	Ku-wait
Sp. gr. at 60°F.	0·836	0·866	0·844	0·852	0·860
Sulphur, per cent.	1·2	1·6	2·0	1·6	2·2-2·5
Hempel Distillation	Volume per cent.				
Light gasoline	10·1	9·7	11·3	8·0	9·1
Gasoline plus naphtha	33·6	28·2	32·8	30·0	28·7
Kerosine distillate	11·5	9·0	15·7	11·8	8·3
Gas oil distillate	19·9	16·5	14·0	21·8	16·6
Non-viscous lub. distillate	10·5	9·3	9·9	11·4	9·5
Medium lub. distillate	3·2	3·4	2·6	4·4	3·6
Viscous lub. distillate	..	..	..	..	..
Residue	20·8	32·4	23·8	20·4	31·9
Loss	1·5	1·3	1·2	0·7	1·4

* *Institute of Petroleum Review*, Vol. II, No. 16, April, 1948.

Acknowledgments

This review of Middle East oil is based on a two month's visit to the Middle East at the end of 1947. PETROLEUM TIMES is indebted to all the oil companies operating in the area, for their hospitality and for the facilities, so amply afforded, for my study of their operations.

An evening at the Kirkuk guest house with the discussion ranging from music to machinery, a night at a desert pump station, with a photographic motif ; lunch on the terrace of the St. George Hotel, Beyrouth, with the table cloth finally covered with geological sketch maps and sections ; "pot-luck" with the American drilling superintendent at Gaza ; and a curry party at Basrah ; a drive across the desert near Dhahran, and the discussion on British planned economy and American free enterprise continued until midnight in the bunkhouse of my American host ; an evening with old colleagues in the "biblical" atmosphere of the City of Kuwait ; the courtesy of my Iranian guide at Abadan ; and reminiscences of the pioneer days of Iranian oil, at MIS : All these are cherished memories.

My thanks are due to oil company geologists, technologists and managerial staffs also, for countless discussions of their problems, and to their London colleagues for checking data and for many helpful suggestions.

We are indebted to the Arabian American Oil Co., for permission to reproduce the maps appearing on pages 3, 8, 44, 74 and 88, and to the Royal Geographical Society for facilities for the reproduction of our cover design which is based on an historical map taken from *A Prospect of the Most Famous Parts of the World* by John Speed (1631). A photographic reproduction of this 300 year old map is reproduced on page 106. This early cartographer describes what is now Saudi Arabia as "Happie Arabia." It has since passed through many vicissitudes, but recent and impending oil developments can bring to this area, and to the whole of the Middle East, a prosperity which it has never known before.

Finally, the management of PETROLEUM TIMES joins me in gratitude to my Editorial colleague, C. W. Wood, for supporting the burden of regular publication during my preoccupation with this Review.

C. T. BARBER

The Oilfield Province of the Middle East

by G. M. Lees, M.C., D.F.C., F.R.S.*

In this *Petroleum Times* Review of Middle East Oil the individual fields which together constitute this great oilfield province are described. Their various structural types and their reservoir characteristics are discussed but it may reasonably be asked what are the governing factors which have caused accumulation of oil into pools of such phenomenal size. In the world as a whole the average recoverable oil-content of individual fields is about 5 million tons whereas in the Middle East the average probably exceeds 100 million tons. The two oldest fields, Masjid-i-Sulaiman and Haft Kel, have both produced more than 100 million tons and Kirkuk has yielded nearly 50 million tons to date. Only seven other fields in the whole world have passed the 100 million ton figure.

The exceptional size of the individual units in the Middle Eastern oilfield province is the consequence of an unusually favourable conjunction of all the factors which control oil accumulations—original richness of source rocks, good reservoir rock conditions, large anticlines with extensive drainage areas, and good cover-rocks to prevent the escape of oil to the surface. Of these factors, probably the first is the most important as, given a sufficiency of original oil, it can usually find some circumstances to effect an accumulation.

Source Rocks

In the Middle East there is difficulty in recognizing the source rocks of the oil by reason of an embarrassment of possibilities. Polybituminous rocks, that is rocks, mostly marls and marly limestones, having a primary bituminous content, occur at intervals throughout a continuous stratigraphical sequence ranging in age from Permian to Lower Miocene, and even Lower Palæozoic beds may, locally, have claims as possible source rocks.

The Iranian and Iraq fields extend along a steeply folded foothill zone in front of the Zagros mountain belt. They produce from reservoir limestones of Lower Miocene-Palæogene age. Test-wells drilled to the Middle Cretaceous limestone at Masjid-i Sulaiman and Haft Kel have found these rocks to be water-bearing although cores contain significant traces of free oil. It would seem that, under the conditions of steep folding along this foothill zone, the marls and marly limestones of Oligocene, Eocene and Upper Cretaceous age are too brittle to function as cover-rocks and their oil content has leaked upward to find a lodgment in the Asmari limestone where it is firmly sealed from further escape by the excellent cover-rock series--the anhydrites, salt and shale of the Lower Fars. It may be that the oil in the Asmari reservoir has had a multiple origin. Vertical migration has certainly taken place through thousands of feet of strata and perhaps the great accumulations have received contributions from source rocks distributed at various levels through ten thousand feet or so of dominantly brittle rocks—limestones, marly limestones and limy shales. Many of these polybituminous rocks still have an adsorbed bitumen content of up to 10 per cent., or exceptionally up to 20 per cent., and if they had evolved oily vapours of only a fraction of one per cent. during the course of geological time the amount thus liberated would have been sufficient to account for the vast oil accumulations which we now find.

The oilfields on the Arabian side of the Persian Gulf occur in a zone of very different structure and, although they have many differences in detail of stratigraphy, there is also here a continuous sedimentary sequence of dominantly calcareous strata, ranging from Permian to Eocene. The folds here are broad and flat, and dips of five degrees are accounted steep. In consequence, fracturing of the strata has been much less and opportunity for vertical migration much more restricted. Oil accumulations have been found at various levels—in Cenomanian sands in Kuwait, in Cenomanian limestone at Bahrein, and in Jurassic limestones at Damman and Qatar, the cover-rocks being thin shales or anhydrite beds. Oils of widely differing character are found at different levels but one factor seems to be common throughout the whole region—an exceptional original oil richness.

Types of Crude

In general terms two very different types of crude oil occur in the region—the Kirkuk-Masjid-i-Sulaiman—Kuwait—Bahrein—Damman type with a specific gravity of about 0.82 to 0.86 and a sulphur content of 1 to 2 per cent., and the Qaiyarah-Euphrates type of 0.95 to 0.98 S.G. and with 6 to 8 per cent. of sulphur. No satisfactory explanation has yet been forthcoming to explain the distribution of these two strongly contrasted types ; probably there has been original oil generation from different sources of different types and the subsequent history of migration and accumulation has brought about a mixture of crudes in varying proportions. Qaiyarah is only 27 miles across the strike from the north-western end of the great Kirkuk field and yet in this short distance there is this extreme change in oil quality. The cover-rocks at Qaiyarah are much less effective and there has been extensive leakage to the surface. It might be thought that the Qaiyarah crude is a weathered or inspissated residue but the analysis of the crude does not bear out this suggestion. In spite of the heavy gravity, high sulphur and very high asphalt content, the Qaiyarah crude contains a surprisingly high content of top ends, about 20 per cent. of benzene and kerosine fractions, indicating, perhaps, that it is a mixed crude from different sources, a mixture of a light type of crude with a highly asphaltic and sulphurous crude. It is not an oil which has lost its light ends—it is rather a crude which has an abnormally high proportion of asphalt.

In Iran there is a gradation of oil quality from the Lali field in the north-west to Gach Saran in the south-east with an increase in gravity, in asphalt content and in total sulphur in this direction. Still further south-east, at Kuh-i-Mund, a large coastal anticline 50 miles south-east of Bushire, a test-well found heavy asphaltic sulphurous crude in reservoir limestones of Eocene and Middle Cretaceous age.

Structure

The fold belt which contains the great oilfields of Iraq and Iran is characterized by unusual structural simplicity and regularity. Behind it the high mountain zone of the Zagros system is compounded of highly compressed folds and thrust slices and still further to the north-east great overthrust zones or nappes. In front of this highly compressed zone, however, there is a belt of more widely spaced regular folding with individual anticlines of giant size. The anticline on which Kirkuk is situated is a good example illustrative of the uniformity of compressional forces through long distances in this foothill belt. The oilfield occupies a length of 60 miles at the north-western end of this great anticline. To the south-east the oilfield is terminated by a saddle at Tarjil, and further south-east the anticline rises to another crest maximum at Khor Mor, falls again to another saddle, then rises slowly past Qasr-i-Shirin to a crest maximum

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at Imam Hasan where Senonian marls are exposed, then another saddle and then another crest maximum in the mountains of Pusht-i-Kuh, exposing the Middle Cretaceous limestone. This great anticline maintains an almost straight course for about 250 miles.

The strongly folded zone comprising the mountain anticlines and the foothills, between the front of the major thrusts and the flat or lightly folded Arabian foreland, is about 200 miles in breadth and is substantially broader than the average along the Alpine mountain system as a whole. It would seem as if the thick skin of sedimentary rocks became easily detached from its rigid basement and folded into these long simple wrinkles. Perhaps the Cambrian salt series has supplied the lubrication permitting this freedom of movement just as the Jura Mountains are thought to have folded above a surface lubricated by Triassic salt. The existence of Cambrian salt in the Persian Gulf region is demonstrated by over a hundred intrusive salt plugs, but further north-westward there is no certain knowledge of the extent of salt development, though the character of many of the mountain anticlines, some with steepness on either flank of 60 deg. or more, is indication of an " abscherungs " surface at no great depth and may therefore imply the continuation of Cambrian salt in that direction.

The broad flat folds of the Arabian foreland show that the intensity of the compressional forces which formed the great Zagros Mountains was dying out as the stable Arabian shield was approached. But even these foreland anticlines are of large dimensions, some having closures of 1,000 to 1,500 ft., and closed areas of many square miles. Perhaps movement of Cambrian salt may have been a factor, producing " non-piercement " structures and thereby accentuating the normal gentle anticlines. The anomalous hill of Jebel Sanam on the Kuwait border south of Basrah is thought to be an intrusive mass of Cambrian rocks though no salt is visible at the surface.

Cover Rocks

The accumulation and retention of oil in the limestone reservoirs of the Iraq and Iranian fold belt has only been possible because of an outstandingly efficient cover-rock series—the Lower Fars. The Limestone anticlines are steeply folded and, in the case of Lali, even overturned. The limestones are so freely fractured in consequence that a small exposure of limestone is sufficient to drain a major anticline of its oil content. The Lower Fars contains thick beds of salt, salty marls and anhydrite, and the plasticity and impermeability of this formation as a whole is such that it either prevents leakage completely or else reduces it to relatively small surface seepages of oil or gas.

The Lower Fars is thus an important factor in the preservation of these great oil accumulations, but it has, incidentally, caused difficult problems of geological structural interpretation, in some cases incapable of solution without geophysical assistance. The salt of the Lower Fars has provided a lubricating medium which has allowed the higher groups of strata to slide over the more rigid Asmari anticlines to such a degree that exact definition of the Asmari structure is difficult or impossible from surface geology alone. The Lower Fars salt has also moved independently and formed salt anticlines on the flanks of Asmari anticlines or in synclines, and in some cases, such as Lali and Gach Saran, surface synclines overlie Asmari Limestone anticlines. Fortunately the basal member of the Lower Fars, a thick anhydrite known as the Cap-Rock (or G Group at Naft Khaneh), consistently clings to the surface of the Asmari Limestone and gives due warning of its proximity. The cross-sections illustrating Dr. Barber's description of these fields show these conditions clearly. The thickness of Lower Fars Stage I, that is the lowest stage containing most of the salt beds, varies from nothing over the crestal area of some anticlines to as much as 11,000 ft. drilled thickness at Zeloi and perhaps to as much as 15,000 ft. on the flank of an anticline such as Lali.

Reservoir Rocks

The reservoir rocks of the Iraq and Iranian fields are limestones ranging in age from Lower Miocene to Middle Eocene, and as a generalisation it may be said that the first limestone underlying the Lower Fars cover-rock series is the reservoir limestone regardless of its exact age. The Kirkuk oilfield is an interesting example. At Baba Gurgur the limestone is of Lower Miocene and Oligocene age and the underlying Eocene is developed as globigerinal marls, whereas at the north-western end of the field the reservoir limestone is mostly of Middle Eocene age. Thus, though there is a limestone about 1,000 ft. thick which functions as one continuous physical reservoir, there is a considerable transgression in age and the one common factor throughout is the continuity of the impervious Lower Fars cover.

The Naft Khaneh—Naft-i-Shah field has a reservoir limestone of Lower Miocene age but only 250 ft. in thickness, and it is underlain by about 400 ft. of anhydrite, salt, and thin limestones, below which lie the Oligocene/Eocene marls and marly limestones. The anhydrite and salt indicate a locally intense lagunar phase, represented at Masjid-i-Sulaiman by thin beds of anhydrite in the middle part of the Asmari limestone.

The reservoir limestone of the main Iranian fields from Lali to Gach Saran is the Asmari limestone, named from the type locality at Asmari Mountain where it is approximately 1,000 ft. in thickness. The formation consists mainly of thick bedded greyish foraminiferal limestones. From Lali to Haft Kel the middle part has many intercalations of anhydrite, and marl-bands come in increasingly towards the base, where there is a strong 25 ft. bed of anyhydrite ; the south-eastern fields show a more consistently limy development. There are variations in detail and in thickness between the different fields but in the main the constancy of development is more remarkable than the differences.

The porosity conditions in the Iraq and Iranian reservoir rocks vary considerably. In Kirkuk there is a zone of highly porous sugary reef limestone about 200 ft. thick, while the remainder of the limestone is only of medium porosity ; the Masjid-i-Sulaiman and Lali reservoir limestones are of low average porosity, whilst Haft Kel, Agha Jari and Gach Saran show a progressive improvement southeastwards. All these limestone reservoirs have one thing in common, notwithstanding these considerable variations in porosity, namely a well-developed fissure system which allows free interconnection between wells many miles distant from one another and which is responsible for the high productivity of most of the wells. In the Masjid-i Sulaiman field there are certain local areas, and in particular the north-western pitching end, where fissuring is insufficiently developed to give productive conditions, but this is an abnormal circumstance among the oilfields in general. At Kirkuk observation wells distributed throughout the length of the 60-mile oilfield have shown a uniform fall in pressure consequent on oil production obtained from a relatively small area in the central Baba Gurgur dome. Haft Kel production was drawn during the first few years of its development from the south-east pitching end and yet it was found that the pressure fall had been uniform throughout the 17-mile length of the field.

The reservoir rocks and reservoir conditions in the Arabian fields are notably different from those of the Iraq-Iranian fields and they are different in many respects from one another. The Saudi Arabian fields, Bahrein and Qatar, have limestone reservoirs of ages between Middle Cretaceous and Jurassic, but the reservoir rocks of Kuwait are sandstones of Cenomanian age. Such a sandstone development, known as the Nubian sandstone when definite evidence of age is lacking, occurrs in a peripheral zone around the old Arabian massif though it is absent in some sectors. It is lacking in the Hasa coastal zone, Bahrein and Qatar, but present at Kuwait and again in the Ga'ara depression, near Rutba in north-western Iraq.

It is naturally quite impossible in this short review of the salient features of the Middle Eastern oilfields to do more than indicate how the exceptional size and importance of these fields is the result of a favourable conjunction of so many geological factors. The unfavourable geographical factor is being conquered by the large diameter pipelines now under construction or in contemplation.

Political Problems and Policies

by Max Weston Thornburg

The author of this article is the well-known economic consultant who was war-time Petroleum Adviser to the U.S. State Department and a former vice-president of the California Texas Oil Co. An acknowledged authority on the Middle East, Mr. Thornburg last year completed an economic survey in Turkey under the auspices of the Twentieth Century Fund. He is at present engaged on a far-reaching economic survey of the oil areas of the Middle East in the course of which he has made extended visits to Baghdad and Teheran, where he has discussed political and economic problems with the leaders of all parties.

While PETROLEUM TIMES *does not endorse the whole of Mr. Thornburg's views on the complex problems with which he deals, we are pleased and privileged to present his informed analysis of current political influences and trends in this important area.*

The role of the Middle East in world affairs is changing rapidly. No longer is it the "cross-roads of the world," or a "life-line of the British Empire." Those were negative aspects, which saw the Middle East only as a passive geographical area, a stage upon which the action was supplied by others. To-day its significance lies in three new aspects: the renascence of the Middle East peoples, vast reservoirs of oil, and a field for the deployment of opposing forces between Russia and the West.

Of these only the last is negative, in the sense that it will be others who deploy those forces. They are not necessarily the sinister forces of war. In fact they are more likely to be social and economic than military, if the strategy which directs them is wise. Almost inevitably, however, in this area of vast potential and awakening opportunity two conflicting modes of national life, the Russian and Western, will strive for supremacy.

Both the other new aspects are positive, in the sense that they are qualities of the Middle East itself, with their sources in the people and their lands. One of them, the vast economic power which inheres in the world's greatest supply of oil in a world which runs on oil, involves alien as well as national interest—but the Middle East's own hand is on the valve. The other is the vast store of primary power which springs from the human will to rise from age old lethargy and become part of the modern world. This latter source of energy is the key one, with fifty million people on the verge of a chain reaction, the linking elements of which lie deeply embedded in the common traditions of religion, race and social history.

In what direction are these two positive and indigenous forces going to be released? Will they, or *must* they, be in conflict with the West? How can they be influenced, directed or controlled? And what should be the strategic pattern for the deployment of economic, social and cultural forces best to demonstrate the principles and practices upon which the western ideas of freedom have been built?

None of these questions can be answered fully here, but there is desperate need that those who are shaping the policies of the Western Powers should face the questions squarely. The answers found must neither dodge main issues nor subordinate them to trifling affairs of home politics or to the short-range aims of narrow business minds.

The need is equally great for a sound understanding on the part of the Western peoples as a whole as to who the Middle Eastern people are, what are their main problems and how are they trying to solve them. Particularly for Americans, to whom the Middle East is new, is this important; for Americans perhaps even more than the British can recall that freedom and prosperity are not heritages in the beginning but must be won through effort. Aladdin's lamp takes hard rubbing these days, whatever it took before. Both the old legends and the false ideas implanted by current propaganda must be replaced by a certain minimum of knowledge. This will include the facts that this quarter of the world is now moving in great strides, that whether its people move with us or against us is for *them* to say—not for us, and that if we want our way of life to be taken as their model we must show them that way and help them make it work.

It is for those who represent us in high places, both in government and in commercial institutions, to know the details; but it is for all the Western people to demand that our programme demonstrate the best we have learned to do, and that it be just.

A Cultural Entity

What is the Middle East geographically, and who are the people who live there?

For our present purposes we may say that it begins where Europe and Africa ends, and that it ends where the new India and Pakistan begin. Certain areas are marginally a part of it, such as Afghanistan and the Sinai Peninsula of Egypt, while others such as Egypt itself and Pakistan may be oriented towards the Middle East on certain basic issues and towards other neighbouring economies for the rest. The term only *suggests* a geographic area. What it *defines* is the integrated system of political, economic and social forces which are constrained by fundamental circumstances to act in unity. These fundamental circumstances include some natural features such as the bordering oceans and inland seas, and the towering mountains on the east. They include also the surrounding pressures of the outside world, with Russia hanging ominously for 2,700 miles across the north. Primarily however the circumstances which unite the Middle East are innate in the people and their history, in their social institutions and their common aspirations. These make the Middle East with which we have to deal.

Within this general framework however, all the interest do not by any means lie parallel. In fact it is their divergences and their conflicts which give the region one of its most significant characteristics. With the exceptions of Iran and Turkey, whose Indo-Aryan and Turcoman origins class them in separate racial groups, the mass of the people may be referred to loosely as "Semitic," although scientifically this grouping is more linguistic than ethnic. Even more loosley this latter group is conveniently divided into "Arab" and "non-Arab," to distinguish the majority from the various minorities which still cling tenuously to some cherished bond of union. These minorities, which here as elsewhere are sources of dissension, fall into rapidly shifting categories depending upon whether the point of view be racial, religious, political, economic, social or national. When, as in the present Palestine situation for example, all of these are involved simultaneously the close view presents a kaleidoscopic effect, while the more distant view oversimplifies these elements into "Arabs," "Jews," and "neutrals," which accounts for much of the blindness with which far reaching Western policies have been adopted. Failure to distinguish between the Jews of South Eastern Europe, of Western Europe, of the types indigenous to the Middle East, of ancient Judea and of the modern political school of Zionism, closes the door at once to understanding the Palestine problem or the far wider one stemming from it, of inter-group relations in the Middle East. Similar failure to distinguish between the various groups comprising the "Arab World" compounds the consequences of such ignorance or indifference. Such oversimplification unfortunately comes close to characterising the casual and superficial view of the Middle East taken in the Western Countries, and particularly in the United States.

In addition to the minorities which have some semblance of organisation, there are other divisions reflecting un-named social stratifications. Probably nowhere else in the world, except in India, are found the same residue of ancient social and economic classes, with all their degrees of privilege and privation so deeply rooted that generations of wise and just administrations will be required before the slave awakens to the freedom which is his now in theory, and the patrician to the responsibilities which he vaguely recognises but is powerless to implement. These social ills of the Middle East run so deep that the most deplorable conditions found in England or in the United States are trival in comparison.

Internal religious controversies add to these shifting groups. The banner of Islam draws the majority of the people to it, but no sooner are they there than contesting schisms divide them. Such divisions may loom large to the outside eye but they fuse together quickly when faced with a common cause.

Pan-Islamic Fervour Spent

What has just been sketched is a static aspect of the Middle East, not in the sense that the factors described are not themselves in motion, but in the sense that they do not move the Middle East. Their fury is spent internally. Given this intricate pattern of diverse, contrasting and conflicting conditions, what major forces are at work to move the Middle East along the path taken by modern nations? And what other forces to hold it back, or to move it another way?

First, unquestionably, is the region-wide and portentous awakening of the people themselves to a new life which they now see within their reach but have not yet entered upon. These are the people, we must remember, who in the seventh and eighth centuries were swept up from a pagan and primitive past by *Islam*, and in turn under its energising fervour swept over most of the then known world almost to central Europe. No resurgence of that same fervour is likely to move these peoples again. The *Jihad*, or Holy War, on the scale which once carried the Prophet's banner across the world or which to-day could pit itself against modern social concepts, belongs to the first exhilarating stimulus of a new idea, not to an accustomed ritual which 1,300 years of familiar practice has settled over the Moslems' daily lives more like a comforting mantle than a goad to new achievement.

But religious stimuli are not the only ones which can move masses of men into action. None of the great movements in modern times which have threatened the world with war or given it promise of peace have been essentially religious. Two centuries ago it was the concept of individual liberty that made a new nation in America and produced the Republic of France. Social tectonics in the present century has most often taken the form of a mass movement inspired and led by an individual, rather than a spontaneous expression of the people themselves as in the American and French revolutions. This, too, is likely to be the pattern of the movement now stirring in the Middle East. In Turkey it is well advanced. In Iran it was suspended by an accident of war. Saudi Arabia has produced such a leader. Where he will lead, and whom, remains to be written in full.

In all great modern movements two necessities have stood out: first, that of a stable political economy through which the new discipline can be imposed; and second, maximum economic development to provide the needs of modern society. The ostensible purposes of reform movements have varied according to the situation and the responsiveness of the people, but underneath them all lie these two basic requirements—*political stability* and *economic strength*. Until these two prevail no other material objective, whether social betterment or conquest or prestige in world affairs, can be achieved. All leaders of modern movements have known the truth of this.

The Growth of Economic Nationalism

In the Middle East, since its general reorganisation following World War I, the concept of the modern *nation* has been adopted as the basis of political unity. Within a fixed political boundary mutual interests and a common government have supplanted with slowly spreading universality the ancient groupings of race or tribe. Among them the immediate origin of nationhood varied according to circumstances. These origins included the maturing of mandates exercised by friendly powers, conquest and internal reformations. Among them too, the growth of national consciousness has proceeded at different rates, according to the social level at which they started, type of leadership, tradition and other circumstances. In all cases, however, saving for a few political entities which were not absorbed by others and which have not yet attained viable statures of their own,* the paramount division of the region became one of *nations*, recognised as such by their membership in the Assembly of the United Nations. Within them subordinate divisions based upon religion, race or tribe, became matters of internal administration resting upon principles first established in the older nations of the West.

Political economies striving for stability within these several nations might follow existing models or devise patterns of their own. Both courses have been taken. Political stability is at best a relative term. The chaos of two world wars with a world depression between them has given this level a wide range. The forms and the principles of these national political organisations nevertheless have survived and become stronger.

One ominous tendency, however, must be noted at this point; that of dictatorship. Its danger lies largely in the ease with which it can be defended day by day, disregarding its general trend. Political stability comes quickest when political power is concentrated in the hands of an individual or small group. The

* Bahrein, Kuwait, Qatar, Muscat and other Arab States under British protection.

urgency of its establishment as a prerequisite to economic organisation works against the acceptance of democratic evolution, which can proceed no faster than men's minds, and social responsibilities can be developed along new lines. Seizure of political power is therefore rationalised as a step for the people's good. When this arbitrary discipline has been established its first step is to control the sources of economic strength by controlling, through nationalisation, the basic means of production. This too can be rationalised on the ground that imperative social reforms demand economic developments on a scale and at a rate which unorganised private resources are incapable of achieving. Once the political leaders have exercised this economic power, and the greater that power becomes, the less easy to take it from them. The " dole " system of bestowing government favours, which is almost inevitable under such a regime, can easily be manipulated to avoid opposition from the underprivileged classes and to deter those with greater resources from becoming a vigorous factor in the economic development of the nation.

The " collectivist " process just sketched determined the courses of the totalitarian regimes, stripped of their camouflage, of Europe and Russia—and can be seen in progress to-day in many Latin-American countries. It can be seen, too, in the Middle East, where primitive social conditions and backward economies supply the setting most favourable to it. The " etatism " of Turkey is an example. Iran under the late Shah was another and the same tendency emerges again in the current "Seven Year Plan " now pending enactment in Teheran. It is beginning to show in other even less developed Middle East countries.

The reason that the arguments advanced in favour of State economic development are persuasive in these countries, is that they are correct—*if we assume that each of these backward countries is compelled to rely solely upon its own faculties for establishing a strong economic position in a minimum of time—and in the face of world competition.*

The very concept of private enterprise, the freedom of the individual to create new wealth through the exercise of his own resources, has not yet been grasped by the people of the Middle East. Nor are the necessary skills and organisational techniques available ; nor in most cases, the private capital. Private enterprise as an instrument for quickly establishing national economic strength cannot be created by proclamation. It is the product of evolutionary growth. With these points in mind we may now seek the reasons which induced, if they did not indeed compel, the newly organised political economies of the Middle East to adopt the collectivist economic formula. For this we must first look briefly at the parts played by certain foreign countries in the affairs of the Middle East.

Foreign Interests and Influence

The Germans were very active in both Iran and Turkey for many years before the first World War and continued to be until the second. Government in Iran under the old Shah was stable, if bad, and the Hitlerian philosophy of centralised economic control found fertile soil under his administration. In Turkey, political stability was quickly established by Ataturk, and German economic leadership, particularly in technical fields, tended strongly towards State control with emphasis on the production of raw materials to exchange for German manufactures. German influence in both cases was set against the very idea of private enterprise and individual liberty.

Soviet influence in Iran was confined largely to the Northern Provinces and except where Russian interests were directly concerned (e.g. oil concessions and the Caspian fisheries) was political rather than economic. In Turkey on the other hand the Soviets competed with the Germans for the upper hand in economic affairs, and through advisors who accompanied heavy loans to Ataturk, succeeded in establishing in Turkey almost a counterpart of the Soviet economic organisation.

French influence was confined mainly to Syria and Lebanon and has been important only in the cultural fields, except for a certain lasting influence in the technique of finance, due largely to French management of the vast Ottoman Bank.

Iraq and the countries to the south have been for many years the particular province of the British, who adopted from the beginning a closed door policy towards all other foreign powers mixing in the political affairs of the area. British policy and performance within this region is characterised by two outstanding features : first, the excellence of the political administration through which it moulded and guided new governing bodies ; second, the almost complete apathy it showed towards the development of sound local economies. The first requisite of a new nation, the technique of responsible government, was given close and careful attention and a relatively high degree of political stability has marked the history of each State under the British aegis. Of the second requisite, however, the same cannot be said. To state the matter plainly, except as it served British political or commercial purposes, the economic condition of the Arab countries has remained, with few exceptions, about where it stood twenty-five years ago.

This failure of the British to parallel *political* with *economic* development, is of vital consequence. Political organisation *must* be backed by economic strength in order to survive. If the government must provide this for itself the collectivist process is most likely to be chosen, for the reasons given earlier. Since the war there is an added reason, in the prospect of loans from the International Bank and from the American aid programme. Such assistance if granted, is for *Government* use, not private, and if the use of the loaned resources is not closely stipulated and supervised it is in effect a subsidy to maintain a growing collectivist system. If the British had introduced the principles and beginning techniques of private enterprise, of modern agriculture, of light manufactures and of a national programme for orderly and progressive economic development with the same earnestness and ability they displayed in establishing political disciplines, that economic pattern would by now have been fixed and the danger of a collectivist regime far less than it is to-day. This apparent disregard on the part of the British for the internal economic development of the country is not explainable as negligence. The British are not negligent. Their primary concern was regional security, achieved first by the British Fleet and next by the installation of stable political institutions. It was only later, possibly too late, when it became evident that a rising standard of living among the people of a country is the surest disinfectant against Communism, that the British began in earnest to attack the problems on this level. The heavy drain of the war, however, coupled with the confusion of political reform at home, puts present limits to what they can do. To point this out is not to indict past British policy. It is mentioned here only as a factor in the situation which faces us. The over rapid assumption of western ways has not proved an unmixed blessing to backward countries, as Britain has learned from much experience. The disinfecting value of modern western economic practices, however, warrants it acceleration to-day in regions which are particularly exposed to Communism.

American influence in the Middle East until a decade ago, when the influence of American oil companies began to make itself actively felt, was limited to that of the American schools and colleges which for nearly one hundred years have trained young men and women more or less the same as they are trained in the United States. The prestige established by these schools was extended rather than diminished by the American oil company activities, which avoided political controversies and did not share the British administrative responsibilities of the region. These circumstances, coupled with the emergence of the United States from the war as the first in power among the nations of the world, gave America an opportunity to use her vast influence to guide the groping policies of those governments and instill confidence in the capacities of their peoples. What America had to offer for this purpose was less on the diplomatic level than on the level of practical economics, and less a source of cash loans than a source of experienced guidance and demonstration of American methods. Such a contribution would have complemented in the economic field the British achievements in the political field.

But what did America do ?

In the United Nations conference in New York, with casual indifference to the broad consequences of its action, it prevailed upon that Assembly to declare racial and religious criteria the basis of political statehood. The Middle East had known *that* basis for a thousand years and more. In that one step, which was not taken carelessly but with studied political purpose and deplorably crude technique, the moral prestige of America was extinguished and Arab faith in her ideals destroyed.

This may have meant little to Americans. To the Middle East it meant much. It meant that the tribunal of the United Nations must henceforth be regarded with serious misgivings. To the newer nations in the Arab World it meant that the *national* basis copied from the West, upon which their hopes and modern disciplines had been founded, was ephemeral and less to be relied upon than the composite of traditional groupings which they had discarded in its favour. That they fell back upon the Arab League was natural as a tactical move. Of greater significance from our present point of view is the fact that it represents a retrogressive step in the social development of the Middle East. It is not the consolidation of interests among a group of Arab States that constitutes a reversion to tribal or racial unity or a backward step in the development of modern statehood. A recognition of their common interests in many fields and a corresponding integration among Middle Eastern States, on the contrary, would strengthen them vastly. This would be true, for example, in connection with their interdependence for food supply, or with their currencies and customs barriers, their communications and immigration regulations, their public health problems and many other things. Such compacts between nations, whether regional or world-wide, tend to bring about the understanding between the countries of the world which is one of the highest aims of nationhood. The retrogression comes with the substitution of tribal or racial interests for the national unity which regards all citizens as equal in their rights. It was this element that the United Nations introduced with its Palestine decision, and which has become the dynamic element in the Arab League. Driven by that decision the Arab League is spreading in a pattern of its own, regardless of national boundaries, and selectively absorbing its constituents on the basis of a single test, *Arab or Jew*? As the contest is prolonged the political disciplines which are essential to make the League's work successful will become stronger. Rivalries will intercede but they will be personal, not national, and the most powerful will prevail. This is the law of the Arabs. It is because the present trend is in this direction that it is retrogressive. Political stability in the Middle East cannot rest upon two conflicting principles. Where this bungling of a vital issue by American politicians will lead to in the future no one can tell to-day. That the national basis upon which political stability in the Middle East was developing has received a heavy setback can hardly be denied. Since *economic* organisation must rest upon *political*, it is equally affected.

Middle East Oil a World Interest

One other vast source of foreign influence remains to be fitted into the sketch just given. This is oil. The oil deposits themselves belong to the countries in which they are found, but *oil from those deposits* constitutes a new world interest. " Oil in the Earth " is the product of heat, pressure and organic material over ages of time, but oil available in pipelines as a weapon of war or as an instrument of peace-time industry, is the product of skill, money and risks, and those who contribute these feel a strong claim to the commodity they have created. This claim itself is not in conflict with any national interests, nor is it an issue in the Middle East to-day. The national revenue from oil in the countries where it has been developed has put those nations generations ahead in their economic progress. In several cases it has been oil revenue alone which has enabled their survival. No conflict inheres in this dual claim to the benefits of oil development. Inequalities in division may exist and have existed but mutual concern in their rectification will make adjustments possible.

The reason that oil is a tremendous force in Middle East affairs to-day is that its possession in the hands of those governments supplies them at once with the *economic* power that is needed to make their *political* position unassailable. No Middle East government which has a successful oil development under its control is likely to be overthrown by anything short of a foreign invasion or a general revolution. Nor is it any longer dependent upon either the democratic support of its people or their united economic efforts as a source of national strength. Oil revenues, throughout the Middle East as in Latin America, accrue to the government itself, not to private land owners as in the United States, consequently they can easily become subsidies to maintain totalitarian practices which would be short-lived under the necessities of competitive economic undertakings.

With this in mind the satisfaction with which the oil companies regard their own considerable contributions to direct social benefits within these countries, may not be well founded. Except as an emergency measure the gratuitous supply of economic needs (whether from a government or a private source) is less to be commended than provisions for self-help through productive effort. " Free men do not need free meals." Voluntary private disbursements for social improvements moreover, which merely relieve the national budget to the extent of the money involved, are worth little in permanent effect. What really is needed in almost every such case is a contribution not of cash but of expert counsel and assistance in the stimulation of productive effort.

The oil companies, generally speaking, have been as generous in their direct contributions to social needs as the British Government in its establishment and tutorship of strong political institutions. Both have in common the failure to implant the principles and assist the beginning growth of a free enterprise system on a level which can be assimilated by the local economy.

In 1944 the author wrote* :

> " Whether or not the use of government funds for the establishment (in the Middle East) of industries of types ordinarily left to private development marks the beginning of a socialist state economy, or simply represents a means of quickly building national industries with the only funds and administrative ability available, remains to be seen. Development by private capital with only necessary government assistance, while the most desirable as a means of bringing a reasonably uniform prosperity to the people as a whole and with it a socially and politically stable nation, is the method least likely to prevail without assistance. This is so because of the scarcity of private capital, the insecurity of private investments under present forms of government, and the lack of technical and managerial skill. If a government is favourable towards private development, industries which were started as state enterprises might gradually be turned over to private ownership, thus freeing the government funds for further initial developments. To make this possible, however, great effort will be required to develop private enterprise rapidly enough to assume the responsibility for such operations before state ownership has become a fixed principle, a fixed source of revenue and a fixed aim of ambitious politicians.
>
> From the standpoint of the oil companies which invest hundreds of millions of dollars in the development of oil resources, and depend upon the continuity of national policy as a basis for their risks, the cross-roads at which a national government takes its decision between nationalised capital and private capital is a point of more than casual significance. The oil companies concerned in the development of the Middle East still (in 1944) have it within their power to exert a determining influence on this decision. To realise the possibilities of this influence it is necessary that they look beyond the current stage of development in which the controlling necessity is to satisfy certain urgent needs of Government, and begin to encourage the development of local private enterprises within these countries. At first it may seem an aimless waste to promote and favour local building contractors, cement mills, printing offices, transportation concerns, mechanical shops, food producers, material importers, shipbuilders, stevedoring and port servicing concerns, etc., when the company itself or some experienced foreign organisation can perform these functions better and cheaper. This may be true for the moment. The difference in cost, however, will more than be paid one way or the other when the course of national policy has been set either in the direction of nationalised economic development or of private enterprise."

The foregoing review of foreign influence in the modern development of the Middle East makes it plain that *in no case* has an external force of importance operated to encourage and assist the growth of individual enterprise as a process of national economic evolution. This being so, and with nearly all other circumstances favouring the collectivist technique, it was almost inevitable that the Middle East would become a group of collectivist states, within each of which a small political unit holds a tight

* " Economic Survey of the Middle East."

grip on the sources and means of production and determines the economic level on which the majority of the people live.

The significance of this is twofold. On the political side it means that the growth is well advanced towards dictatorship instead of towards parliamentary democracy. On the economic side it means that a great gap exists between the economic life of the people themselves and the economic developments undertaken by the central governments as a means of enhancing their own power and prestige. While neither of these consequences *necessarily* follows a true collectivist intention, both are natural outcomes of liberal reforms which sweep ahead faster than the mass of the people can follow. The democratic form of government develops slowly among those who can neither read nor write, and State-owned factories, government farms and monumental public works have little effect on the standard of living of people who are still fed by an ox-drawn wooden plough.

Not Dollars but Ideas

Given a few decades of freedom from war or its threat, these highly centralised governments, with appropriate aid from outside, could close up the gap just mentioned by increasing the emphasis upon social and economic advancement at the level of the people. It is at this level that foreign aid should be directed, and not first with money but with experienced guidance and demonstrations of good practice. The growing restlessness of these peoples would respond to such aid as this. Their political organisation into nations has provided the faculties of modern administration which are necessary to direct the development of their own resources and to utilise those furnished through aid from other countries. Turkey and Iran, oldest as modern nations, lie closest to Russia and her intolerable conduct has compelled them to shape their policies first to meet her threats. In both cases strong central governments under Ataturk and Reza Shah Pahlevi established highly centralised economic organisations, both of which have now run their courses. The nationwide system of Sumer Bank and Eti Bank establishments in Turkey would be classed as bankrupt by western standards. In Iran the 140 state establishments under the Industrial Bank have been bankrupt almost since they started. Many of them have been idle for years, although their payrolls are still maintained. And these two countries easily lead the Middle East in their wealth of natural resources. Both are now desperately in need of assistance, not of money but of experienced economic guidance. Turkey now allocates more than half her national budget to building up her army, but the deplorably low standard of living of her people—despite her potential wealth—invites the infection of Communism through channels which no army can close. In Iran, where political stability was lost early in the war, Communistic infection is virulent. In both these countries, and they are key ones in the Middle East, unless British and American help is prompt and effective the Russian menace will be met at their southern borders and not their northern.

In both these cases recent internal political reforms have opened the door for such help. Turkish leaders have signified their readiness to allow private enterprise to share the burdens and the benefits of national economic development. They have also declared their intention to deal with the agricultural and transportation deficiencies which now bind their people to an ancient way of life. Moreover they have made good these declarations by actively starting these long delayed projects. In Iran as these words are being written the Council of Ministers is putting the last touches to a bill which, if approved by the new Majlis, will not only outline and authorise a far reaching programme of basic economic works but will allocate from the country's own resources every dollar, pound sterling and riyal which is necessary for its accomplishment. What neither Turkey nor Iran can furnish for itself, however, is the technical skill and experience without which even the soundest programme and the most ample financing are fruitless.

Further south Communism is also spreading, and more rapidly during the past few months than ever before. The Arab States are much younger politically and, except for those with oil, much less favoured with natural resources. The standard of living on the whole is correspondingly low. Even those with ample oil revenues have not been helped to help themselves. Whatever the condition of the budget 90 per cent. of the people have not yet been *shown* why they should reject the false promises of the Communist organisers. In one provincial town in northern Iraq recently a local official reported 10,000 indigents encamped awaiting a government ration of food. Lack of seed and shortage of rain had leapt the narrow margin which these farmers and grazers struggle to maintain between themselves and starvation. No international loan should be required to correct this situation before another winter passes, nor should "relief" wheat again need to be brought from Australia to feed Iraqi farmers.

On the political side the Arab peoples have breathed life into the Arab League and made it in effect an *Arab State* to match the United Nations creation of a *Jewish State* in Palestine. In this new Arab State all Arabs are citizens. Its mandate is clear and the combined resources of the Arabs will in all probability be placed at its disposal. In this grim contest the resources of the Arabs are not measured in money or weapons of war. Their strategic advantage lies in their power to turn the Middle East away from the West. As civil *nations* the Arab countries were "*responsible*" in the western sense, for that was the pattern they followed. Among tribal states, however, responsibility knows other laws, which are strange to the western world except as the Old Testament is recalled. "An eye for an eye and a tooth for a tooth." A contract will be faithfully observed but the criteria are those of the East, and a contract within the tribe comes ahead of any outside it. The oil contracts are outside it.

Among the Arab states, therefore, we are now facing at least the possibility of political deterioration at the same time that we must face the problems of improving the general economic level in these countries to avert the spread of Communism and of preserving relations which are essential to the continuing availability of Middle East oil. Sooner or later the people of the West will awaken to the significance of the United Nations action on Palestine and take steps to amend it. If this is to be done at all it must be done soon. The political disciplines which have been developing for twenty-five years within the Arab States, and which could serve now as a basis for their social and economic advancement, will disappear quickly. Engineers and agronomists have little chance in an Old Testament system, and modern private enterprise still less.

Today the Middle East is balanced upon a sword edge. On one side lies a system of modern nations in various stages of evolution but all dedicated to the social and economic advancement of their peoples on a basis of civil equality. On this side the seeds of western democracy have already been planted. With encouragement and assistance that harvest could be assured. Political stability is well on the way and economic stability will follow. On the other side is the return to tribal unity which the other nations of the world left far back in their own histories—but have now forced again into the Middle East. These awakened peoples have no wish to return to such a policy, nor will they for long. On that side there is only one ultimate course. The primitive herd instinct which bands tribal groups together in critical situations provides no basis for political stability in the modern sense, nor can it stand for long against Communistic tactics. Azerbaijan gives an example here.

In general the countries of the Middle East have resources in agriculture and mineral wealth, including oil, which should make them prosperous within a relatively short time. The help they need to do this is the kind that the United States and Britain—whatever their straits in other ways—have in overflowing abundance. This is technical skill and experience in guiding production. Nothing else is needed *first*. Without such help and guidance the great forces which are rising in the Middle East will tear it apart instead of building it up. With such help, directed in proper balance both towards the governments and towards the people who seek our type of individual achievement, the Middle East could take a place in world affairs today worthy of its place in the chronicles of world history.

THE MIDDLE EAST: A DEPRESSED AREA

A Challenge to the West

by Christopher Holme

The author of this article is well-known as a writer and broadcaster on Middle East Affairs. He served with the Palestine Government as Public Relations Officer between 1941 and 1946, and is intimately acquainted with the problems of the other Middle East States. To ensure the author freedom of expression we withhold the name of the international institute in London to which he is attached.

THE MAIN ECONOMIC FACT about the Middle East is its poverty. It is one of the depressed areas of the world. The main political facts about the area are, first, that it is dominated by the West, and secondly, that it lies on the frontiers of the Great Power conflict.

The Middle East as a whole is thinly populated, between 70 and 80 million people in a region more than twice the size of India. But less than 5 per cent. of the region is cultivable, and in the cultivated areas the population may be very dense indeed. Egypt is the worst; the Nile Delta has a rural density of over 1,700 inhabitants per square mile—perhaps the highest in the world. In other districts, as for instance in most of Arabia, scarcely any settled population can be supported at all, and the inhabitants are forced to move from one place to another in search of pasture for their herds.

The population and pressure on the land would be still greater, if it were not kept down by disease. In Iraq, which could support a much larger population than it now does, the infant mortality rate is estimated at 500 per thousand.

By far the greater part of the people get their living, such as it is, from the land. Hence the main preoccupation is with water, the Middle East's greatest shortage. Water is provided by rainfall, in those few favoured areas where there is enough, or by irrigation from the great rivers, the Nile, the Tigris, and the Euphrates. Apart from improvements of method, and the introduction of modern dry-farming techniques, all agricultural development plans for the Middle East depend on extensions of irrigation.

But the food potentialities of the region as a whole are poor, and where they are rich, as in the Nile Delta, they are intensively exploited, leaving little scope for further development. The region is equally poor in industrial raw materials and in power supplies, with the important exception of oil. There is the high quality cotton of Egypt, and its iron ore; iron, copper, chrome, and other metals in Turkey; potash and bromine in the Dead Sea; iron and other minerals in Iran; and some minerals in Cyprus. There is a shortage, amounting in wide areas to total deficiency, of timber. Apart from oil, the main power supplies of the Middle East are some coal in Turkey and Iran, and mainly undeveloped hydro-electric possibilities in other countries. But use of rivers to obtain electricity may conflict, as it does in the case of the Jordan, with their use for irrigation, and owing to the importance of agriculture and the abundance of oil, it may be found more economical to obtain electricity from oil-driven generators.

Social problems in the Middle East are as intractable as the economic. The region is backward because it is poor, but it is also poor because it is backward. Subsistence agriculture is the general rule, and at this level it is notoriously difficult to break through the wall of conservatism, illiteracy, and economic subjection which imprisons the peasant. Middle East governments consist to a large extent of landowners or their representatives, and they find it difficult to bring in effective reforms, which are apt to cut across their personal interests. No real agricultural development is possible without agrarian reform, the elimination of obsolete systems of land tenure, and a fairer division of the land.

From the Middle Ages to the 20th Century

The only answer to the problem of population pressure, as it is felt in Egypt, is industrialisation. Both industrialisation and agricultural development imply a revolution in the social structure of the Middle East. There are those who say that without such a revolution they cannot occur, and point to the example of Britain, the U.S.A., the U.S.S.R., in all of which the necessary social conditions were created, through revolutionary or evolutionary processes, before industrialisation occurred, instead of being the consequence of industrialisation. Whatever the force of this argument, it is one which, as we shall see below, the West simply cannot afford to accept. Unless Soviet methods are employed—and the West could not, even if it wanted, go against its own nature by employing them—revolutions cannot be imposed by an outside power. And the West has no time to wait for a Middle East revolution to occur. Assuming that it is interested in the emergence of the region from its present state of backwardness and poverty—and we shall see that it cannot be otherwise—it has only one method open to it. It must seek to reverse and to telescope the slow historical cycle—stagnation, decay, revolution, advancement. The Middle East has to jump in one stride from the Middle Ages to the twentieth century.

What the West must do is to promote economic development in the hope that social changes will follow. Even the gift of economic development is not an easy one to get accepted, and though the need for such a Middle East policy has been recognised, at least by the British Government, since the war, it is still a long way from having been applied or achieved results on the scale which is necessary.

There are two further aspects to the twin problems of agricultural development and industrialisation. Both are international in their requirements and both need capital. Schemes of irrigation, land settlement, and of major industry all cut across the national frontiers which were arbitrarily drawn across the Middle East by the Powers after the First World War but which today after 30 years confront the Middle East planner with serious problems of competitive national interests and lack of regional co-operation. Nothing could be more international than a pipeline, and the oil companies know what complicated negotiations with different governments are necessary before one can be laid.

Then there is capital. The poverty of the Middle East means a scarcity of capital. Under the nationalist impulses of the period between the two wars some industrial development was undertaken, particularly in Turkey. Turkey is indeed an exception to what has been said above about social conditions in the Middle East countries. Owing to the revolution carried out by Kemal Ataturk and to the healthier conditions of Turkish peasant life, a large measure of industrialisation and modernisation has been carried out since 1920. The result is that Turkey alone of all the Middle East countries presents a solid and united front against the threat from the East. It is a fortunate chance for the

West that social conditions there are not in the same chaotic and backward condition as in Greece or Iran. Industrial development in Turkey has been almost exclusively the work of the State. The only alternative to State industrialisation was industrialisation by foreign interests and it is inevitable that any country which today has a choice in the matter should choose the former. Some fanatics for "free enterprise" have deplored the promotion of industrialisation by the State, ignoring the fact that without such State action it would not have occurred at all.

Egypt is another country where there has been some measure of industrialisation. Here too the first steps had to be taken by the State. The process was begun in the nineteenth century by Muhammad Ali, but he ran into trouble because his military successes cut across the interests of the Great Powers, and he also ran into debt. None the less he and his successors, although their military adventures and over-enthusiastic public works bankrupted Egypt, did lay a foundation on which it rose to be the undisputed leader of the Arab world and the centre of Arab renaissance. In its later stages, under the British occupation, industrialisation in Egypt was the work not of the State but of a group of Egyptian business men, the Misr group, who now control or have a large interest in some of the biggest Egyptian industrial concerns. The ramifications of Misr in textiles, banking, transport, and other interests are extensive.

Regional Co-operation Vital

Thus, the tendency throughout the Middle East has been towards industrial monopoly, either under the State as in Turkey, under a private group as in Egypt, or under a foreign interest as in the oil industry. This is the result of the very large investment of capital required to develop industries in backward countries. The only organistaions able to provide this are large ones with big reserves to fall back on. This tendency is sometimes regretted by the doctrinaires of free enterprise, but such regrets are idle, since we cannot wish away the basic economic factors making for monopoly. Rather the problem to be faced is, assuming that very large industrial organisations are necessary to develop backward countries, who should exercise control over such organisations? Much of the industrial future of the Middle East countries will be concerned in providing an answer to this problem.

Reference has already been made to the international character of Middle East developments, and the need for regional co-operation. The rivers which it is desired to dam for electricity or to use for irrigation flow through more than one country. The exploitation of oilfields and the processing and distribution of oil have a way of jumping over national frontiers. Again, many of the countries are too small to support the apparatus of economic nationalism—protective tariffs, separate financial services, and so on. But the fact must be faced that the present tendency is by no means all in favour of regional co-operation in economic matters. The Middle East today is not a natural economic unit. Its economy, viewed as a whole, is not balanced. All the countries are exporters of food and raw materials and importers of manufactured goods and other raw materials. A relatively small percentage of the foreign trade of Turkey, Iran, and Egypt, in particular, is with other Middle East countries.

A Landmark in Middle East History

There was a welcome break in this tendency during the war when the establishment of the British Middle East Command and parallel civilian bodies provided an administrative framework within which regional planning could be attempted. Such planning moreover became a matter of life or death for the region since the imports from the rest of the world on which it normally depended and the markets which it normally supplied were cut off by the war. Shipping was scarce and imports of food and raw materials had to be reduced to a minimum and closely related to military needs. In 1941 there was set up in Cairo the Middle East Supply Centre, which in 1942 became a joint Anglo-American agency. The achievements of this body are a landmark in Middle East history. Its purpose was to save shipping space and to see that the civilian population of the region had the necessaries of life. The methods used were the encouragement of an increase in food production, the giving of help to industries, and the allocation of scarce materials. The Centre's control of scarce supplies was used to bring pressure on governments to co-operate. For example, control of the supply of fertilisers was used in Egypt to compel a decrease in the cotton acreage in favour of food crops. Another of the more striking successes of the Centre's period of activity was in locust control. A number of able and enthusiastic British and American scientists and technicians were attached to the Centre and it was under its auspices that Middle East agricultural development schemes on an international scale came under serious discussion. Important pioneering work in this field had already been done in the Sudan. The absurdity of supposing that development of this kind is possible unless promoted by Government, supported by a highly trained staff, will be apparent to anyone who studies these Sudan schemes in more detail.

War-time Economic Studies

There was thus a certain body of British experience already in existence on which the Centre could draw. But generally speaking there was a great deficiency of information and statistics throughout the area. One of the Centre's ventures was a statistical conference held in Cairo to discuss methods of improving Middle East statistics. In 1944 representatives of all Middle Eastern countries—except of course Turkey which by its non-belligerence was excluded from the range of MESC activities—attended an Agricultural Development Conference in Cairo to exchange views and information concerning their agricultural problems.

But perhaps the most enduring achievement was the undertaking of special studies on matters affecting the Middle East as a whole. Three of these have been published and are the only authoritative surveys of their kind.* After the war the Centre was unfortunately wound up, and the opportunity was lost of providing some form of continuity by handing over its functions to an organisation of Middle East governments. So far as the Arab Middle East countries were concerned, however, it was laid down in Article 2 of the Covenant of the Arab League, formed early in 1945, that one of its purposes was the "close co-operation of the member States, with due regard to the structure of each of these States and the conditions prevailing therein, in economic and financial matters, including trade, customs, currency, agriculture and industry, and communications and social welfare matters."

Post-war British Assistance

Since the war there has been established in Cairo a British Middle East Office equipped with a full staff of technical experts. These include agriculturalists, irrigation specialists, and a statistical adviser, any of whom may be lent on request to Middle East governments, and who have been doing a great deal of useful work. As each such request, however, has to be made by an individual government, the Cairo Office cannot undertake regional planning. The function of the office is thus purely advisory, and it cannot operate at all except in those cases where its services are requested by the government concerned. Despite these handicaps, the mere existence of a central pool of scientific and technical information on which anyone from the Middle East can draw should not be undervalued. But it is certain that proper use will not be made of these resources unless the peoples of the Middle East countries themselves can be educated to appreciate their importance. Under present conditions of nationalism there is strong suspicion of interference, particularly by interested Powers. Yet in order that the Middle East peoples themselves and those British and Americans who are in contact with them should begin thinking on the right lines, somebody has to show the way.

A start was made in providing adequate documentation with

* 1. *Agricultural Development of the Middle East*, by B. A. Keen : H.M.S.O., 1946.
2. *Middle East Science*, by Dr. E. B. Worthington : H.M.S.O., 1946.
3. *Rural Education and Welfare in the Middle East*, by M. B. Allen : H.M.S.O., 1946.

the three MESC publications mentioned above. Since the war the work has been taken up in London, on an unofficial level, by the Royal Institute of International Affairs (Chatham House), which has just published the first of a new series of brochures under the general heading of Middle East Economic and Social Studies. This little book, *Land and Poverty in the Middle East*, by Doreen Warriner, is of the first importance. The author, a specialist in the agrarian problems of backward countries, who herself worked in MESC during the war, has given a most concise and readable survey of what is the Middle East's basic problem. No one with an interest in the area can afford to ignore the facts and the interpretation presented in such lively fashion in this book. It is to be followed by studies made by other experts on Middle East industry, transport, education, banking, demography, and so on.

To sum up, the Middle East is a depressed area whose poverty is due both to an overall poverty in natural resources, and to social and political backwardness. This backwardness is itself also the result of poverty. For anyone interested in raising the living standard of the area, the only method available is through State schemes of agricultural and industrial development which should if possible be organised on a regional scale.

Western Interests and Influences

It is common knowledge that the Middle East is a region of vital importance for the West. On strategic grounds alone it is clear that neither Britain nor the U.S.A. would easily acquiesce in the Middle East falling under the domination of a third Power. When to the strategical argument is added the fact that the Middle East is a vital source of oil supply for the West and contains perhaps the biggest reserves of oil still remaining unexploited in the world, it becomes evident that British and American interests will continue. But the oil industry, just as much as the British and American Governments, requires that the Middle East should be an area of order and security. The Middle East cannot in the long run be secure unless it is also prosperous. If just over the frontier in the Soviet Union economic development in Soviet Muslim dependencies goes ahead, while the Middle East countries under British and American protection continue to stagnate, the mere force of example, without any special effort by the Middle East Communist parties—and of course they will make such an effort—will be enough to keep the region in a state of permanent unrest.

Neither the oil industry nor the Western Powers which it serves can afford to leave the Middle East populations to their own devices. They cannot afford to leave them to the hazards of private business, to the few adventurous pioneers who are willing to risk capital on an area which is fundamentally a poor risk. Even if developments occur under such conditions, there is no guarantee that they will be of the kind which are needed to foster a healthy economic life in the countries concerned. Indeed, past experience suggests that they may do just the opposite. To take only one recent instance, during the war there were cases in Iraq and Palestine where an enterprising local sheikh acquired a tractor or an irrigation pump which he hired out by the hour to his tenants. But he charged such a high rate that the peasants were worse off than before and got still deeper into his debt. In Palestine, a benevolent British administration took legislative action to protect the peasant against this form of " agricultural development " by private enterprise. No such action was taken by the Arab Government of Iraq.

It has been mentioned above that Middle East governments are apt to be by their nature reactionary, and are too often composed of landlords with a direct interest in preventing reform. But Middle East governments, like governments everywhere, are subject to pressures from below. There is a new spirit abroad in the region. There is a pressure from the younger Arabs, educated in Western institutions, for better things. It is feeble compared to the magnitude of what has to be done, but it is there. Every Middle East government since the war has taken up some sort of programme of economic development. It is true that in most cases action has been slow to follow, and that excellent plans on paper have been left to moulder in official pigeon-holes. But at least the idea was there, and even that was missing before. These governments need constant prodding to remind them of the facts of life and prevent them frittering away their resources on luxuries for the rich and " jobs for the boys." Valuable surveys have been carried out by a British firm under government contract in Syria and the Lebanon. In Iran there is talk of a seven-year plan based on the survey work of American and British firms. But in none of these cases has very much been done. Iraq is more encouraging, and work there is already well advanced on a composite programme of development which includes large extensions of the area under irrigation, expected to add from 70 to 100 per cent. to the cultivated area of Iraq, new railway lines, and a new oil refinery.

The Oil Industry's Role

Generally the tendency of Middle East governments is to promise a good deal more than they perform. The attitude of the West should be, conversely, to respond quickly to any appeal for advice or assistance, and above all to do so in such a way as to catch popular imagination and make it difficult for action once started to be dropped. In this new approach the oil industry has a special part to play. It has to be admitted that hitherto the sensational developments that have occurred and are occurring in the expansion of Middle East oil production have taken little account of the needs of the Middle East itself. In the matter of social services the oil companies have shown themselves aware of their responsibilities so far as their own employees are concerned, but it is being increasingly borne in upon them that their responsibility does not end there, and that the well-being of the whole population of a Middle East country in which they are operating is somehow their concern. This means in effect that they have a direct interest in the well-being of the region as a whole. It is not enough to develop the oilfields and to pay out great annual sums to Middle East governments. Under existing social conditions there is no guarantee that this money will be used in the best interests of the Middle East people at large.

Oil the Sole Important Asset

Moreover, the oilfields are unevenly distributed. The biggest and richest of them are in sparsely populated Bedouin areas. Egypt, which presents the most serious and explosive economic problem in the whole area, has not even enough oil for its own needs. Taking the Middle East as a whole—and there are good historical and strategic reasons for doing so—oil is the region's sole important asset. It is the only thing which requires us to qualify our statement about the poverty of the Middle East. But it is a wasting asset. From a Middle East point of view the region's most important raw material is being drained away to Europe and America and the money received in payment is being frittered away in luxury imports for the rich. This is an exaggerated picture, but there is enough truth in it to call for the serious attention of the oil industry. The exploitation of Middle East oil is not a simple business deal which can be isolated from the economic and social conditions of the area.

This has been recognised by the more enlightened leaders of the oil industry itself. There are encouraging developments in Saudi Arabia where the American oil companies are helping King Ibn Saud with programmes of education and modernisation. He has also received big subsidies from both Britain and America. Here again it is inconceivable, in this patriarchal State, that economic modernisation could be carried out by any other agency than the King himself. The King is everything and without him the country would fall to pieces. The picture of Saudi Arabia is encouraging. But even here a word of warning has been given by an American authority. Referring to the forthcoming expansion in oil production and corresponding increase in oil royalties he writes :*

" It has been estimated that by 1952 crude petroleum production will reach 500,000 barrels per day. This level of production

* *Monetary Problems of Saudi Arabia*, Raymond F. Mikesell : Middle East Journal, Washington, April, 1947.

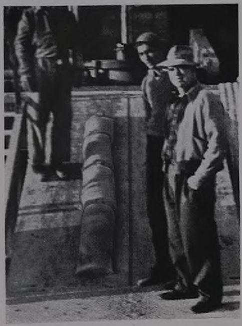
would provide annual royalties of about 40 million dollars plus perhaps an additional 10 million dollars in foreign exchange income from local expenditures by the oil company. A proper utilisation of this income can be the means of greatly increasing the standard of living of the Saudi Arabs. On the other hand, in the absence of government planning and adequate financial machinery for directing the utilisation of foreign exchange income, the foreign exchange from oil royalties is likely to be used largely for the importation of private motor cars and other luxuries by a few wealthy merchants, government officials, and landowners. The dissipation of Saudi Arabia's newly discovered wealth in this manner would do little to improve the economic well-being of the vast bulk of its people."

In Iran the patient educational work of the Anglo-Iranian Oil Co. has more than doubled the literacy rate of its employees during the last decade, and standards of hygiene have made even more rapid strides.

More significant than these local schemes was the British recommendation, in connection with the proposed agreement covering the relations of the oil companies with each other and with the Middle East governments, that a bank for general economic development should be set up covering all the territories concerned. To it the oil companies would assign a proportion of their profits for investment in long-term development projects. But this 1945 Anglo-American oil agreement was not ratified and so nothing came of the proposal. Referring to this failure, Miss Warriner (*l.s.c.*) remarks :

" The success of such policies (of using oil revenues to promote investment and the economic development of the Middle East) will depend entirely on whether they can be linked to the general impetus among the people concerned towards better living standards and all that that implies, and whether they can strengthen this impetus against the forces which oppose such development. For money alone will not bring social progress ; as we have seen, direct foreign investment does not automatically bring better living standards. Indeed, the difficulty is that foreign lending, if linked with any intervention in social institutions, may cause a strengthening of nationalist policies against such intervention, and a hardening of the opposition to resist such changes. Thus foreign investment in such projects as a Euphrates Valley Authority might result simply in contributing towards the incomes and power of the landlords, and so might not initiate any of the economic changes on which progress depends. On the contrary it might easily mobilise against itself such progressive groups as already exist among the younger generation. Could such a policy be based on genuine United Nations co-operation ? If it were, it might be easier to divest it of the appearance of foreign intervention and to link it with the progressive forces inside the country without raising reaction against itself."

Fortunately, since this was written, the Middle East States themselves have been pressing the United Nations to set up a regional economic commission for the Middle East similar to those for Latin America and Asia and the Far East. The Middle East delegates showed a sober appreciation of the problems that have to be solved, and one can only wish that such clear thinking were general among their own governments. An *ad hoc* committee of the Economic and Social Council of the United Nations has been set up to " study the factors bearing upon the establishment of an economic commission for the Middle East." It seems unlikely that the committee will find any good reason why such a commission should not be set up. It is true that the U.S.S.R. would expect, as an interested Power, to be represented on it. But if the opportunity be vigorously seized by Britain and America to use the commission for setting in motion a thoroughgoing plan of economic development for the Middle East, it could hardly be opposed by a Soviet delegate.



This photograph of R. H. Connor and his " cement torpedo " should have accompanied the article on the IPC's exploratory drilling in Palestine. To the readers who looked in vain on page 64 for this photograph we tender our apologies

PART of TARTARI
ASTRACAN on this part is the Bounde of the Kingdome of Moscovia from the years 1494 taken of the Tartars
CAITACHI
Astracan
Georgu : ria
Pitgorski
MENGRELIA
THE SEA DE BACHU sometymes the CASPIAN & HIRCIAH SEA, it is also called by other names towitt, of the countreys and next places, it is called the greatest Lake of the whole world being solt it aboundeth with great plentie of fishes.
SEA, which is the grecians the Blacke Sea ... whose water flo: propontis the aboud with fishes
Giorgia
TURCOMANIA
ARMENIA
MEDIA
Taurus ol Ecbatana the throne of the Kinges of Persia
PART of THE PERSIAN KINGDOME
Emperour hereof is to this day cal Sophy, who doth daily valiantly recou the Empire which was Lang agoe taken of the Saracens & Turkes, there are con ally fierre warres among them
POPUL CURDI
ALIDULI
DIARBECH
SORIA
SEA
ARABIA
THE DESERT of ARABIA
The Desert of Beriara
ORMUS
THE SEA ELCATIF, sometimes the ARABIAN GULFE
DESERT ZUES
ÆGIPT
Nilus fluuius
AYAMAN olim Desertum Theama
Sandie desert places
Elcatif-deserti
The gate of ferro
Medina Talnabi where the graue of Mahomet is sene
The Sea of Mecca & Bohar
Corsam & the Arabian & the redd Sea sometimes Gulfe
MASCALAT
HAPPIE
ARABIA
MAFFA
BESCHAR
ALIBINALI
GUBEL
HAMAN
Deserta vasta
IRMIN
ZIBIT
FARTACH
Bello
DAFILA
BRAGASSO
TIGREMAHOR The Turke of late subdued it which before obeyed Prester Iohn or the christian Emperour of the Abyssines.
ADEN REGN
Delacca here is fishing of pearles
GUE GEVE
OF THE REDD SEA

Aerial Surveying for Oil in the Middle East

by

T. D. Weatherhead O.B.E., M.A.*

There is a wide application of air photography to the development of the oil resources of the Middle East. From the original exploration of an area to its final detailed exploitation and construction of refineries the air photograph can play an important part. The main advantages of air survey can be outlined as follows :—

(*a*) An air photograph can be a mathematical document on which it is possible to measure distances and heights and from which accurate plans and maps with contours can be produced.

(*b*) It is a very rapid method of obtaining information—in a few hours hundreds of square miles can be photographed.

(*c*) The air photograph provides an overall view of the earth's surface and records it in detailed form. By this means the inter-relation of various features can be detected which often cannot be appreciated on the ground.

(*d*) The air photograph provides a great amount of detail of value to the specialist.

(*e*) The information obtained from air photographs is objective. Once the photographs have been taken the information can be rechecked without undue trouble.

Air photography should therefore be considered as an additional tool to assist the work of the geologist, the surveyor, the engineer, the planner, etc. It does not entirely supplant work formerly carried out by ground methods but it reduces the amount of ground work very greatly and often provides information which cannot be obtained on the ground.

Air survey has been used for a variety of purposes in the development of the oilfields of the Middle East. A list is given below of some of the surveys carried out before and since the war and the main purpose for which they have been undertaken. In each example the photographs are used for stereoscopic examination by the specialists engaged on the different types of work.

Area in sq. miles	Scale	Purpose
Photographic Mosaics		
7,000	1/50,000	Development
8,836	1/40,000	Geological interpretation
26,000	1/21,120	Geological interpretation
1,768	1/21,120	Development
48	1/5,000	Development
Contoured Maps		
316	1/21,120 with 50 ft. contours	Oilfield development
384	1/10,560 with 20 ft. contours	Oilfield development
44	1/2,500 with 5 ft. contours	Oilfield development
Detail Plans		
4,500	1/50,000	Oilfield development
500	1/20,000	Oilfield development
1,200	1/10,000	Tidal area
80	1/2,400	Town planning and development of refinery areas
8	1/1,500	Town planning and development of refinery areas

It is most important that careful thought be given to the planning of an air survey and that the closest co-operation exists between the client and the operators. The specifications for each job will vary according to the type of country and the purpose of the photography. The type of aircraft, camera, lens, filter, scale of photography, time of year and many other factors have to be related to the final answer that is required. It is usually more economical to take photographs which will satisfy the precision requirements of air survey mapping than those which will only be suitable for examination.

Although no aircraft yet exists which has been specifically designed to meet air survey requirements, modifications to existing types can be made to produce a suitable aircraft. There are two main requirements : for areas where exploration is necessary the machine must fly as high as possible—at least 20,000 ft.—in order to obtain small-scale photographs. The aeroplane must therefore be fitted with oxygen and have an endurance of approximately six hours with a maximum speed of at least 200 m.p.h. The other requirement is for large-scale photography which is called for when large-scale mapping is needed in the development stage. For this a slow flying aircraft at a low altitude is required. The lack of detailed maps or easily identified features in desert or mountainous areas makes it imperative for the air photographer to have a really good view of the landscape below, to either side and ahead of the aeroplane, so that once the starting point of a photographic run has been located it is not lost to view as the aircraft is brought round on to course.

The aircraft is fitted with an earth inductor compass which is neither subject to the vagaries produced in the magnetic compass by tilt or acceleration, nor to the precessional errors of the gyroscopic direction indicator. The pilot is therefore able to keep the aircraft on a true and constant heading for as long as is required. Auto-pilots are also used to eliminate the gradual deterioration in the standard of flying which is inevitable in long photographic sorties flown by a human pilot.

Experiments have been carried out with Decca Navigator equipment as an aid to survey flying, with considerable success, and the R.A.F. has proved the value of Gee.H. The value of a radio or radar aid lies in two main points. Firstly its ability to ensure a standard lateral overlap between parallel lines of flight and to guarantee complete coverage. Secondly to determine the position of the aircraft in space and thus to provide co-ordinate values to points located on the photographs, thereby dispensing with a considerable amount of ground control. Application of these aids, however, is complicated by the fact that the necessary accuracy is only possible over a limited range and it is unlikely that networks will be found covering the areas to be surveyed. The movement and installation of stations in the outlandish parts of the world where these surveys are usually carried out is a laborious and costly business and would only be economically worth while for very large areas.

The modern air survey camera is constructed to satisfy the high precision requirements for mapping from air photographs. The British camera is the Williamson O.S.C. which uses a negative size 9 in. by 9 in., and a magazine holding 500 exposures. It is fitted with a between-the-lens shutter and the whole camera is enclosed in a perspex spherical dome into which hot air is passed to retain the camera at a normal temperature when operating at altitude. It is important to retain the camera in conditions of normal temperature and humidity as otherwise electrical discharges on the film may occur. Although the film camera is satisfactory for most types of work, it is better for the production of very large-scale plans to use glass negatives as all dangers of distortion, which are inherent in the use of film, are then reduced to the minimum.

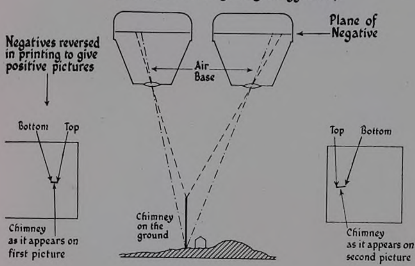
* *Technical Manager, Hunting Aerosurveys Ltd.*

There are three main types of lenses used, the choice of the lens depending again on the purpose of the photography. The 6 in. lens is normally used for exploration surveys and topographical mapping, as by using this lens the altitude at which the aircraft is to fly is reduced to the minimum and the wide angle view produces the greatest sense of relief in the stereoscopic model. The wide angle lens is naturally most liable to produce distortion but this can be reduced to very small values by calibration and correction.

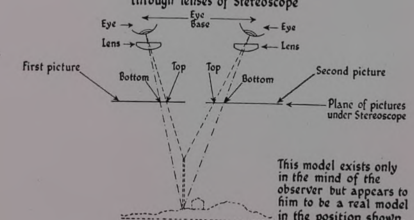
Vertical air photographs are always taken with a forward overlap of approximately 60 per cent.—the same point on the ground is therefore photographed from two different positions in the air. When the pair of photographs are studied through a simple binocular stereoscope, each eye sees a slightly different view of the same object. These two different images are fused in the brain to form a three-dimensional picture. The stereoscopic impression is due to the slightly different positions occupied by features relative to one another in the two views. In this way the illusion of relief is created, which is the basis of all interpretation and mapping from air photographs.

There are two main types of air photographs—those taken with the camera in a vertical position and those taken pointing obliquely at the object. The oblique photograph provides the more familiar view and therefore is valuable in illustrating areas to those who may be unfamiliar with the vertical view. For most geological work the vertical photographs, which can be studied stereoscopically, are of more value than obliques. Since they present the plan view, the whole layout of structures can be seen, while on oblique photographs the view is a perspective one and a certain amount of the topography is hidden. The oblique photograph, however, can by the angle of its view sometimes show the details of structures which are not visible or cannot be definitely identified on vertical photographs.

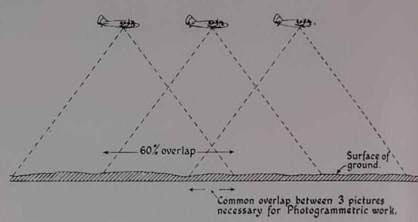
First and Second positions of Cameras in the Air (Size of Cameras greatly exaggerated)

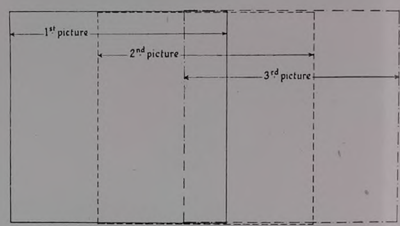


Eyes of Observer looking through lenses of Stereoscope



Position of Aeroplane for 3 successive exposures





Plan of area covered by three successive pictures

The scale of the photographs will be determined by the use to which they are to be put. For reconnaissance surveys where the chief purpose is to study the main geological formations of an area a scale of 1/40,000 to 1/62,000 is satisfactory. For detailed study of an area a scale of about 1/20,000 is necessary. Vertical photographs should be taken as nearly vertical as possible. Apart from producing eye strain on the observer, a tilted photograph will produce distortions in the stereoscopic image which may lead to false interpretation.

In order to navigate the aircraft over areas that are unmapped or inadequately mapped, it is necessary to divide the country into blocks and photograph strips. These are then used as photographic maps on which to navigate. Although radar and radio aids are undoubtedly the methods of the future they are at present uneconomical for the normal sized area to be photographed in the Middle East. Photography is carried out in parallel lines of flight, the photographs being taken at intervals so that there is a 60 per cent. overlap in the forward line of flight and approximately 30 per cent. overlap between the parallel lines of photography. This is essential for the mapping processes that are used and to enable any part of the area to be studied stereoscopically.

It is important to choose the correct filter to produce the best photographic quality over the particular type of country to be surveyed. Many desert areas in the Middle East have little relief and show a very small range of tone values. It is therefore essential to use a filter in order to accentuate the differences in tone. In areas where there is plenty of topographical relief and a wide range of tone values a minus blue filter to reduce the effect of haze will normally give a satisfactory result.

The film is developed and printed at the main flying base so that the photographic coverage, correct overlap and quality can be checked as quickly as possible.

If the photographs are to be used for constructing a photographic mosaic it is important to arrange that photography of adjacent areas is taken at approximately the same period of the day so that the shadows are similar. Mountainous areas should be photographed around mid-day to reduce the shadows to a minimum, and flat desert areas during the early or latter periods of the day so as to let the shadows accentuate what relief exists. The time of the year for photography will be determined by the weather conditions, but the growth of desert vegetation may be a fact to be borne in mind as it will increase the contrast on the photographs.

In most parts of the Middle East the photographic season is limited by sandstorms and haze. While the weather in the winter is often cloudy and the mountains covered with snow, when the weather does improve the air is very clear. The spring is the most suitable time, until the approach of the summer sandstorms. In areas not affected by these photography can continue. The above generalisation is based largely on experience in Iraq and Southern Iran.

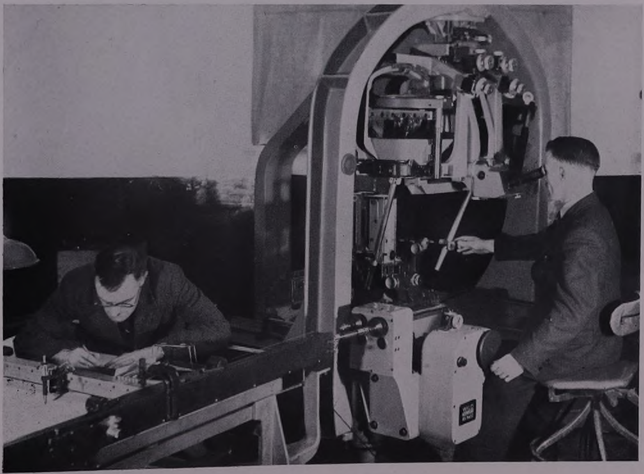
Photographs to be used for accurate mapping must be related to survey triangulation points, the co-ordinates and height values of which are known. In areas where there is ample topographical detail the most satisfactory method is to complete the photography first, select the points for which co-ordinate and height values are required and then carry out the ground control. In countries where there is little or no topographical detail, such as barren desert, it is necessary to make artificial marks on the surface of the desert large enough to show on the photographs. This is no mean task, since the mark has to be permanent for several weeks and must not be removable by wandering Bedouins. In order to make a cross large enough (for example to be visible on a photograph at a scale of 1/25,000), the arms of the cross must be 60 ft. long and approximately 10 ft. wide.

In order to prepare a medium- or small-scale plan map of a reasonably flat area a technique known as the slotted template method is employed. This is a mechanical version of the old radial line system. A grid is drawn out on to which are plotted the positions of the triangulation stations. Points of detail are chosen on each photograph and a template cut so that slots are made in the direction of each chosen point of detail or minor control, each slot being radial from the centre of the photographs. Since all the photographs in the forward line of flight overlap each other by 60 per cent. the centre points of three photographs will show on each one and the minor control point is intersected by three slots or rays. By this means the exact position of that point is fixed, just as on the plane table the position of a point is fixed by the intersection of three rays, the general result being a great number of subsidiary control points in complete sympathy with the triangulation control. With the minimum of triangulation points provided by normal ground survey methods, data for an accurate plan map of a large area can be rapidly compiled. For many parts in the Middle East this is the most rapid and economical method of producing medium and small scale maps without contours.

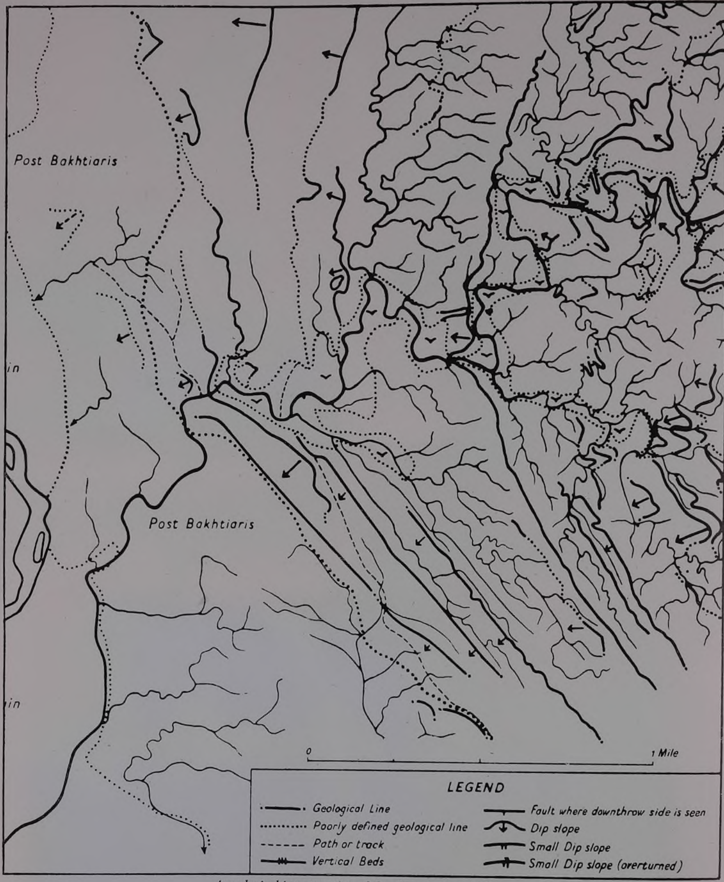
To appreciate fully the advantages of air survey it is important to understand the practical difficulties of carrying out this work by ground methods alone in many areas in the Middle East. In some parts transport is difficult if not impossible and the season during which the climate is suitable for ground survey is limited.

Perhaps the greatest advance in air survey technique has been the ability to produce accurate contoured plans and maps from air photographs. This is certainly one of the most important services that air survey can offer to the development of the oil-fields in the Middle East. Such a development will entail the choice of the best routes for roads, sites for camps and other buildings. By studying the air photographs stereoscopically it is possible to decide which are the best sites and from the photographs the contoured map can be drawn, which is the basis for all subsequent work. Many are the examples where roads and railways have been built along uneconomical routes because the area had not been adequately surveyed in advance. The air photograph, by providing an overall view of the area in three dimensions, presents at the outset all the possibilities for a projected route.

Accurate contoured plans and maps can be produced from air photographs with the aid of modern stereo plotting instruments. This is not the place to describe in great detail the method by which this is carried out but a brief description of one of these instruments will be of interest to those who have not had the opportunity of seeing them.



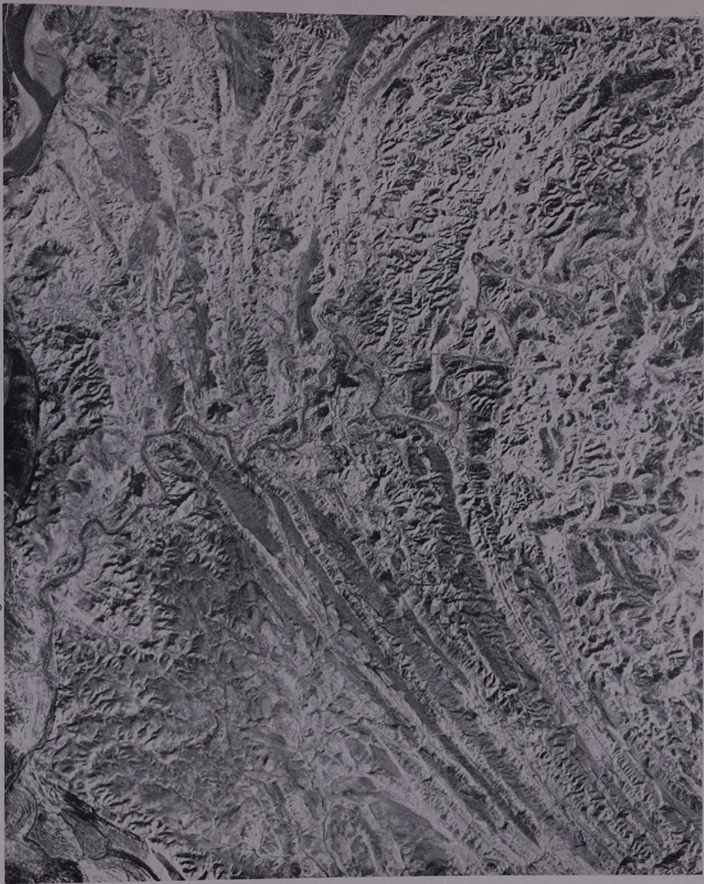
The Wild A.5 plotting instrument



A geological interpretation of the photograph opposite

The Wild A.5 plotting instrument is designed to establish the conditions at the instant of exposure. On either side of the instrument are skeleton cameras which correspond to the positions of the camera in the aircraft when the exposures were made. Into these are placed the two photographs, which are then studied stereoscopically through the binoculars. By adjusting the position of the two cameras the two photographs are mutually orientated so that a perfect fusion is obtained over the whole area of the stereoscopic model under examination. The next stage is to relate the two photographs to the ground control points, the plan and height values of which are known. A mark visible in the optical system can be moved in one plane through the model and by moving the foot pedal can be moved in a vertical plane. By means of an accurately geared mechanism the movement of the mark in the optical system is synchronised with the movement of a pencil on the drawing table. It is thereby possible to set the mark at a point on the photograph for which the true plan and height values are known and by moving the mark around the photograph and keeping it just touching the surface of the ground, to draw a contour on the map.

Assuming that the necessary standards of accuracy have been maintained in the flying, photography and processing of the film, it is possible with these instruments to draw contours at 5-ft intervals. Plans up to scales of 1/1,000 can be produced by the



A vertical photograph of the pitching end of the Agha Jari structure

same means—so high is the precision of this instrument. One of the great advantages of the Wild A.5 is its ability to extend the triangulation on small-scale photography from the first pair of photographs for which ground control data is available, over a series, thus minimising the number of triangulation points that have to be surveyed on the ground.

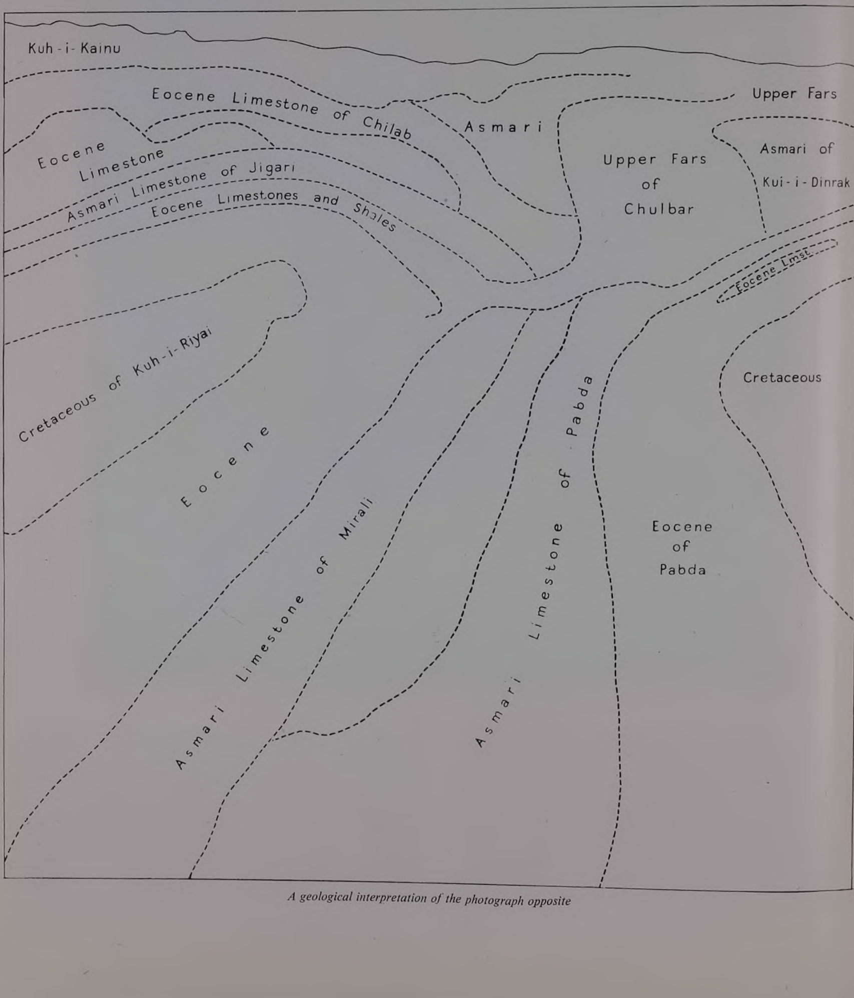
A great deal of the cost and difficulty in preparing maps by ground survey methods in the Middle East is taken up by the establishment of the control. Air survey reduces the amount of work that has to be done on the ground to a minimum. It is therefore possible to arrange to carry out the ground control during the most suitable season, and the plotting is carried out in the office under the best working conditions.

The Wild A.5 therefore fulfils two main functions. On the one hand it is able to produce very large-scale plans with contours suitable for engineering and detailed development schemes and secondly to extend triangulation control. After this has been completed the photographs are passed to a basically similar but simpler instrument, the A.6, with which it is possible to plot the detail and the contours on each pair of photographs.

Another type of mapping instrument that is used for the preparation of maps with contours from the scale of 1/10,000 to smaller scales is the Multiplex, or as the English version is known, the Williamson Ross S.P.3. This instrument is based on the anaglyph principle of projecting one photograph through a red filter and the other through a blue filter and studying the image through compensating spectacles fitted with similar coloured lenses and thus seeing the image stereoscopically. A small table equipped with a pin-point of light in the centre can be moved through the three-dimensional model and adjustments made to its height above the plotting table.

A pencil is fitted exactly underneath the pin-point of light which draws on the plotting table every movement made with the table. Thus, as in the A.5, the mark in the optical system is moved to points on the photograph for which the plan and height values are known, so in the S.P.3 the pin-point of light is moved to similar positions on the photographs and the details and contours drawn out. It is also possible with this instrument to bridge a number of photographs from one group of control to another, but it is not designed to produce large-scale plans nor very close contour intervals.

Another method of presenting information which can be of great value to the geologist and development engineer is in the form of photographic mosacis. As the word implies, a photographic mosaic consists of a number of separate photographs joined together to make one complete photograph of a large



A geological interpretation of the photograph opposite area. A mosaic can be constructed to be almost as accurate as a map (provided that the ground relief is limited to 10 per cent. of the flying height), by rectifying the individual photographs to the detail on a map or other control that may be available and then laying these rectified photographs down on to the control. For areas where there are no adequate maps or control the photographs can be fitted together as accurately as possible to make an uncontrolled photographic map of the area.

The uses and advantages of photographic mosaics are twofold. Firstly a photographic mosaic or photo map shows considerably more data than a map. It will, for example, show the details of land use and surface features which are not shown on maps. The areas under cultivation, villages, parts that are being eroded by wind or water, etc., will be visible. In the Middle East, where as a rule there is little surface vegetation, the geomorphology of an area is clearly shown on a photographic mosaic. The different rocks will be indicated by different tones and texture on the photographs.

The second use and advantage of a photographic mosaic lies in the fact that it is possible by this means to view an area of perhaps several hundred square miles in extent at once and on one photograph. This makes it possible to study the

An oblique photograph of the Kuh-i-Pabda area, SW Iran inter-relationship of geological structures and to see a pattern in a complex area which would be quite impossible to appreciate on the ground.

In the oil-bearing districts of Southern Iran, for example, the mountains are barren of vegetation and their contorted structure is most vividly shown on a mosaic. To travel over much of this country on the ground is extremely difficult and, even if it were done, the detail and understanding that comes from seeing the overall view on a mosaic would still be unobtainable. In other parts where the surface details are less pronounced, as in desert areas, the photographic mosaic is again able to provide information which it is sometimes impossible to observe on the ground. Those who have travelled over some of the desert areas in the Middle East will appreciate the limitation of view one has of the flat desert and the difficulty of recognising unidentified features. On an air photograph slight changes in tone will indicate the presence of outcropping rock as opposed to sand or scrub. Areas where the water content near the surface is higher than the surrounding country will be shown as darker patches on the photographs. Salt deposits if not covered by sand will show as distinctive patches.

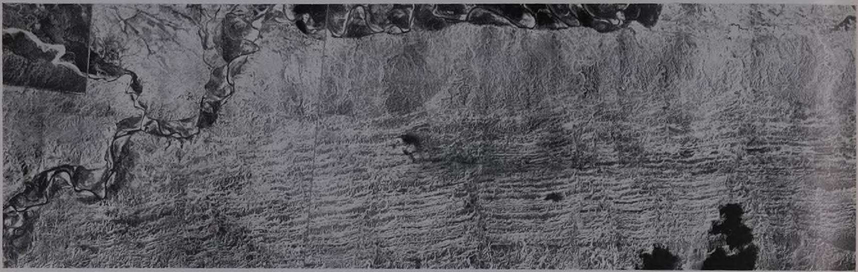
Looking at vertical stereoscopic air photographs the photogeologist is able to see an area as if with the eyes of a giant standing many thousands of feet high and with clearer sight, giving a greater sense of relief than human eyes can obtain from the same altitude.

The scale of the photographs will determine the detail of the information that can be interpreted. For many areas in the Middle East the air photographs are used to carry out geological reconnaissance of a hitherto unexplored area. If such a reconnaissance survey were to be carried out by ground methods a map at the scale of 1 in. to the mile, or even a smaller scale, would normally be produced. It is therefore logical to require photography at approximately the same scale, or as near to it as possible, on the grounds of economy and secondly because of the great area that can be viewed on one photograph.

With stereoscopic pairs of photographs the morphology of the terrain can be studied, which often provides clues to the geological history and structure. The morphology is determined by the lie of the strata, and naturally where strata that are resistant to the forces of erosion exist they will persist while less resistant strata are eroded away. The vertical air photograph will show escarpments and dip slopes and by viewing the area stereoscopically the direction and magnitude of the dip can be seen. Similarly the drainage pattern can be traced, which is often a useful clue to the geological structure.

The main uses of the air photograph to the geologist can be put into three headings, firstly for preliminary office examination, secondly their use in the field, and thirdly for office check and compilation. The routine followed by geologists varies according to the type of area in which they are working and often to their own experience in the past. Some prefer to undertake as complete as possible a geological interpretation of the photographs before proceeding into the field and to prepare a geological map of the area which will be a guide to the field parties. Others consider it best to take the photographs into the field direct and to annotate the photographs with the various geological findings when in the field.

The methods of preparing accurate topographical maps suitable for geological work have been described above ; for many areas, however, an unrectified photo-geological map is satisfactory. This is usually carried out by studying a pair of photographs stereoscopically and superimposing some non-distorting transparent material, such as Kodatrace, over one photograph and annotating on to this material the drainage pattern, alluvial beds, the main geological features and, by symbols, dips and other data. A strip of photographs is interpreted in this way, information being annotated on to the Kodatrace and then the strips of traces are compiled together and fitted into whatever basic control is available. Although this will not provide an accurate map it forms the basis of planning further geological work in the field.

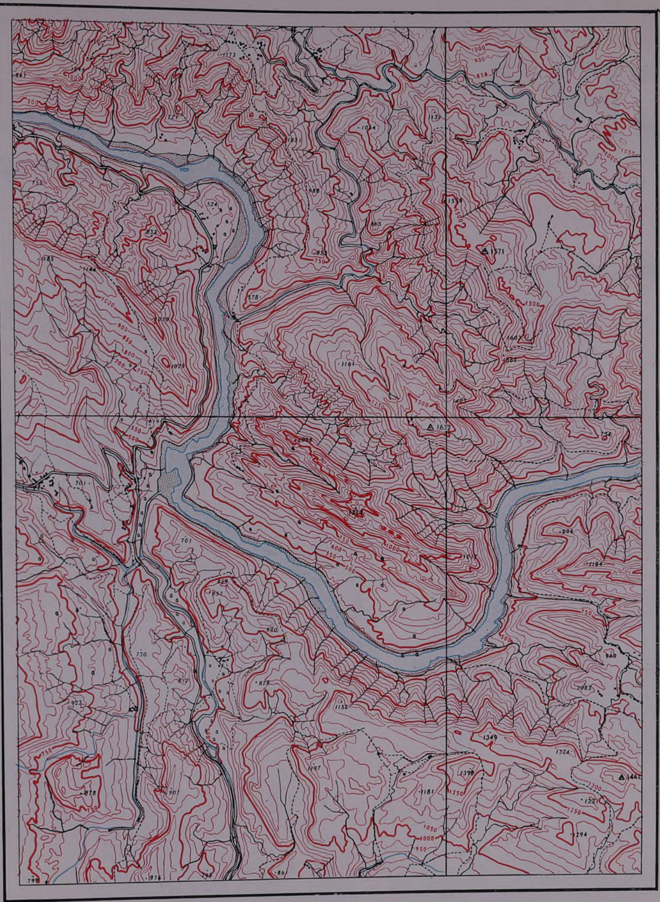


A mosaic of the Agha Jari structure

It must be stressed that the interpretation that takes place in the office must always be checked by visits to the area and must preferably be carried out by a geologist who is familiar with the area in which he is working, otherwise serious mistakes can be made.

The technique and developments that have been made in air survey can be of considerable assistance to aerial magnetometer surveys. Although there are few results to hand of oil surveys undertaken with the aerial magnetometer there is little doubt that it will be of great value in the future for making reconnaissance surveys over very large areas, particularly in difficult and inaccessible country. The advantages of carrying out a magnetic survey by air methods are firstly that the recordings are not confused by the returns from local magnetic bodies of no depth or significance. Secondly the survey can be carried out at great speed, in a fraction of the time and very much cheaper than would be possible by ground methods. Thirdly the aerial magnetometer will provide a continuous recording of the intensity of the magnetic field, whereas by ground methods recordings are only taken at intervals.

Air survey can assist aerial magnetometer surveys by providing the control to which the magnetic surveys are plotted. The area to be surveyed can be photographed from a high altitude first and maps or photo maps made from these photographs, from which the navigation of the magnetometer survey can be planned. During the magnetometer survey flight a 35 mm. camera would take vertical photographs of the area and another camera would



Part of a topographical map at a scale of 1/21,120 *with* 50 *ft. contours, plotted from air photographs by Hunting Aerosurveys Ltd.*

photograph simultaneously with the vertical air photographs the instruments recording the height of the aircraft, the temperature, the time and the number of the ground photograph. In this way the magnetometer record is tied in with the vertical photographs of the ground and thus the magnetometer record is related to definite geographical co-ordinates. A radar or radio aid can be used for fixing the position of the aircraft in areas where ground control is very poor or non-existent.

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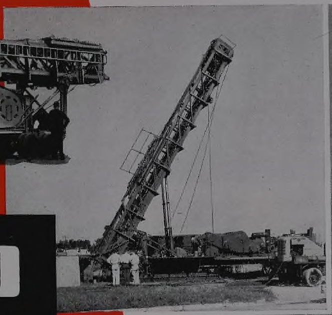

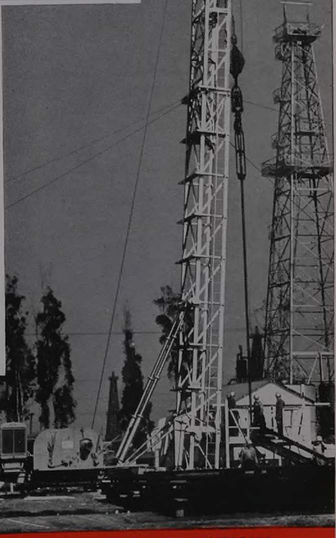

. . . vehicle —mounted under

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"TWIN" CYCLING PLANTS SAVE MILLIONS OF BARRELS

California Company Employs CLARK Compressors in Two New Conservation Projects . . .

Two new cycling plants operated by the California Company, one at Lake St. John, La., and the other at Cranfield, Miss., are "identical twins", although entirely independent in operation.

In each plant, 9 Clark 800 B.H.P. Right Angle Compressors pump dry gas back into the sands at 4,000 pounds pressure per square inch. It is estimated that these two conservation projects will effect a combined saving of 45,000,000 barrels of crude oil and condensate which these fields would otherwise have lost.

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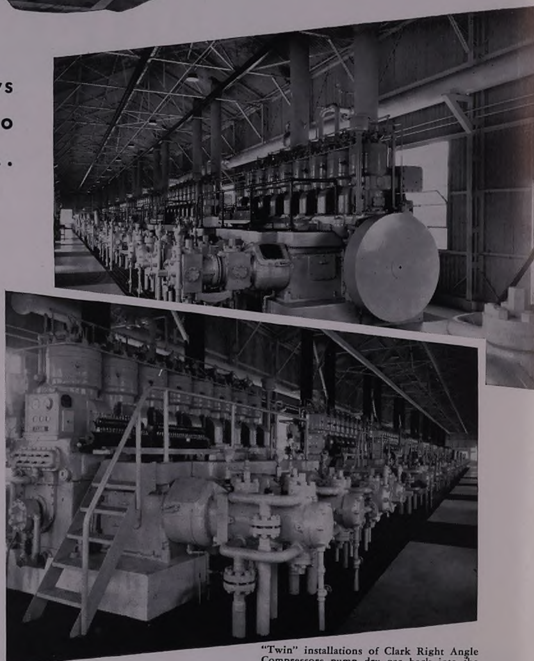
Write for further information on this modern method of increasing yield which has been described as 'just like discovering a new oilfield'.



"Twin" installations of Clark Right Angle Compressors pump dry gas back into the sands at two new cycling plants operated by the California Company. One is at Lake St. John, La., and the other at Cranfield, Miss.

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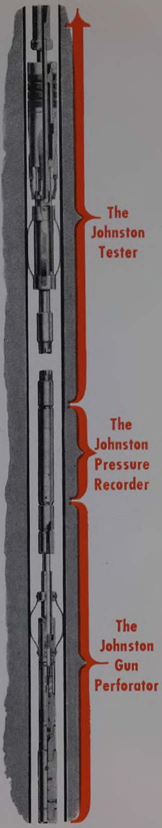

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