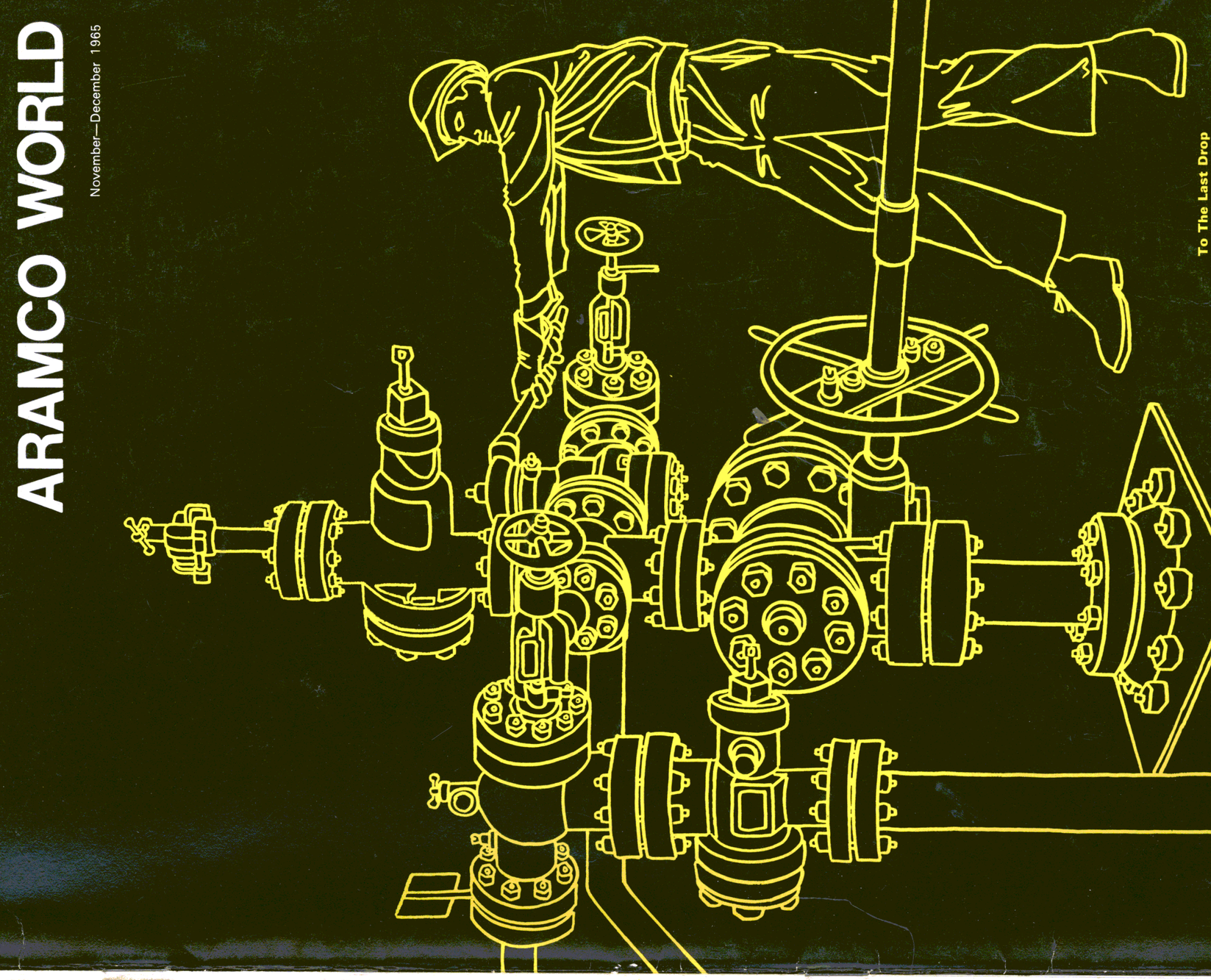
ARAMCO WORLD
November—December 1965



To The Last Drop

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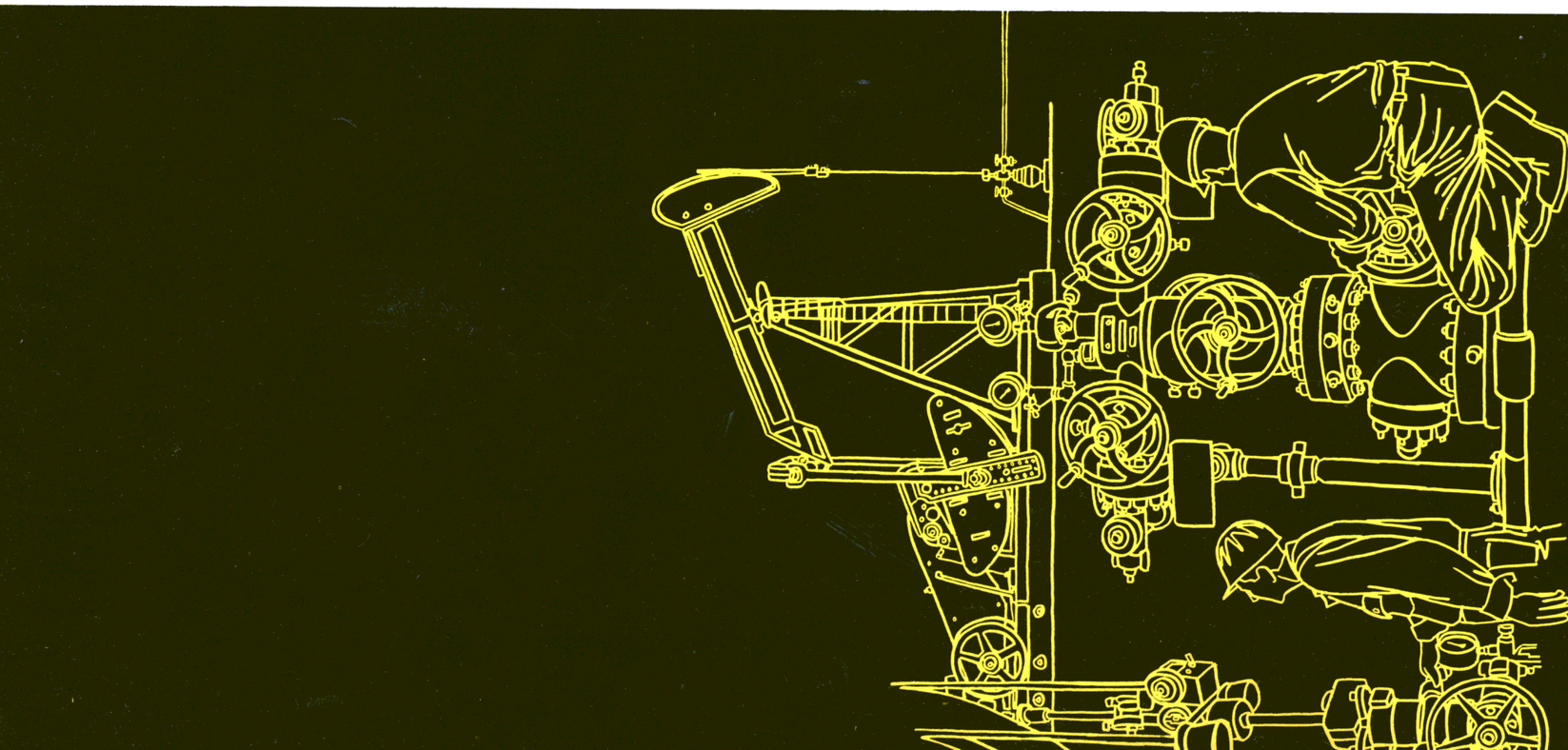
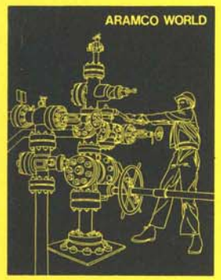


ARAMCO WORLD

VOL.16 No.6 PUBLISHED BI-MONTHLY NOVEMBER-DECEMBER 1965

Published by the Arabian American Oil Company, a Corporation, 505 Park Avenue, New York, New York, 10022; T. C. Barger, President; J.J. Johnston, Secretary; E. G. Voss, Treasurer. Paul F. Hoye, Editor. Designed and printed in Beirut, Lebanon, by the Middle East Export Press, Inc. In the United States, all correspondence concerning Aramco World should be addressed to T. O. Phillips, Manager, Public Relations, Arabian American Oil Company, 505 Park Avenue, New York, New York, 10022.



Cover: A 'Christmas Tree,' shown in this drawing by designer Don Thompson, is a familiar sight in Saudi Arabia's oil fields. A low steel fixture of piping, valves and bolted fittings, a 'tree' controls the production from a flowing oil well. Such an installation is possible only when certain conditions exist, as Brainerd S. Bates makes clear in his article on oil reservoir problems, "To The Last Drop," starting on Page 17.

IN SONGS AND NAMES AND ON THE LAND ITSELF - THE MARK OF THE MOORS IS PLAIN...

BY ERIC DE MARÉ

MAJORCA'S MOORISH MEMORIES

When the sun rises over Majorca's highest mountain, the Puig Major, to warm the Sóller Valley far below, you may still sometimes hear a sweet and plaintive folksong from the orange groves which is as oriental as a Persian miniature. For in the music of the people of the Balearic Islands, as in their architecture and customs, and even in the inflections of their local dialect, is the indelible imprint of three centuries of Moorish rule which gives a new dimension to the oft-repeated assertion that "Africa begins at the Pyrenees."

That any influence whatsoever remains from those days long past is remarkable. It bears silent witness to the strength and durability of the Muslim occupiers' spirit. Next to the Spaniards themselves, who after all have been calling Majorca their own for the past 700 years, it was the Moors who left the most lasting physical and cultural landmarks on this beautiful Mediterranean "Isla de la Calma."

Hanging on the terraced mountain slopes above the Sóller Valley, for example, are settlements whose names give instant testimony to their Arab origin: Binibasi, a charming little cluster of dwellings interspersed with a variety of palm tree the Moors brought from their native Africa; the small, stone town of Fornalutx which looks down upon Binibasi toward the valley's head; and far across the valley, beyond the sparkling *torrente* splashing out from a hidden spring, the village of Bibiaraitx. The mountainous northwest, reminiscent of the Atlas mountain region so familiar to the Moorish invaders, abounds in Arab place-names: Biniatzar, Teix, Alcudia, Alaró, Andraitx, Felanitx and Benisalem, to mention a few. And the town of Valldemosa where Frédéric Chopin and George Sand spent their brief and tempestuous exile from France, traces its name to the wealthy Moor, one Sayyid Mousa, who dwelt there.

If their heritage is less apparent, nevertheless many other warrior peoples were tempted by the balmy climate and strategic location of Majorca—midway between France and Africa, Spain and Sardinia—to wage war over a verdant island scarcely larger than present-day Rhode Island. The victor's reward was command of the sea commerce of the Western Mediterranean.

The earliest recorded conqueror of Majorca was that redoubtable city-state of merchant seamen, Carthage,

Hidden away in the gardens of this ancient estate called Alfabia is this placid bathing pool once used by the women of the Moorish governor's harem.

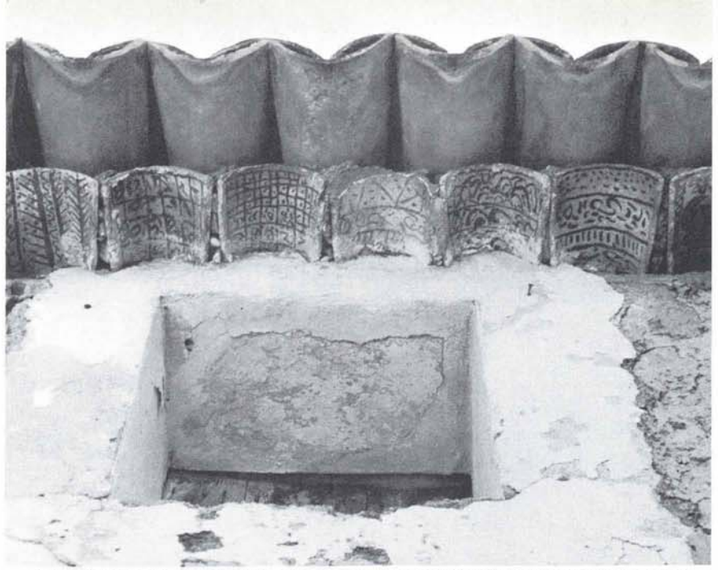
Photography by Eric de Maré

which planted a pioneer colony in the Balearics in 654 B.C., squeezing out first the Phoenicians and then Greek traders with the same colonial ideas. The Carthaginians in turn were rudely shouldered off the islands by the Romans who, like Hannibal's commanders, drafted Majorcan youth into their legions to make use of their famed skill with the slingshot. As the Roman Empire in its turn declined as a warlike power, the Vandals succeeded them in Majorca, only to yield in time to the troops of Count Belisarius, fighting in vain to restore the glory of Rome under the eastern Emperor Justinian.

And then came the Moors, sweeping up the length of Spain from Africa under the Omayyad viceroy Tariq, in whose honor the Pillars of Hercules were renamed Jabal Tariq, the "Mountain of Tariq," now fused and molded to its present denomination—Gibraltar. From 903 until they were expelled by a resurgent nationalistic shock-wave spearheaded by King James I of Aragon in 1229, the Moors settled down as if they were going to stay forever. In a sense, they have.

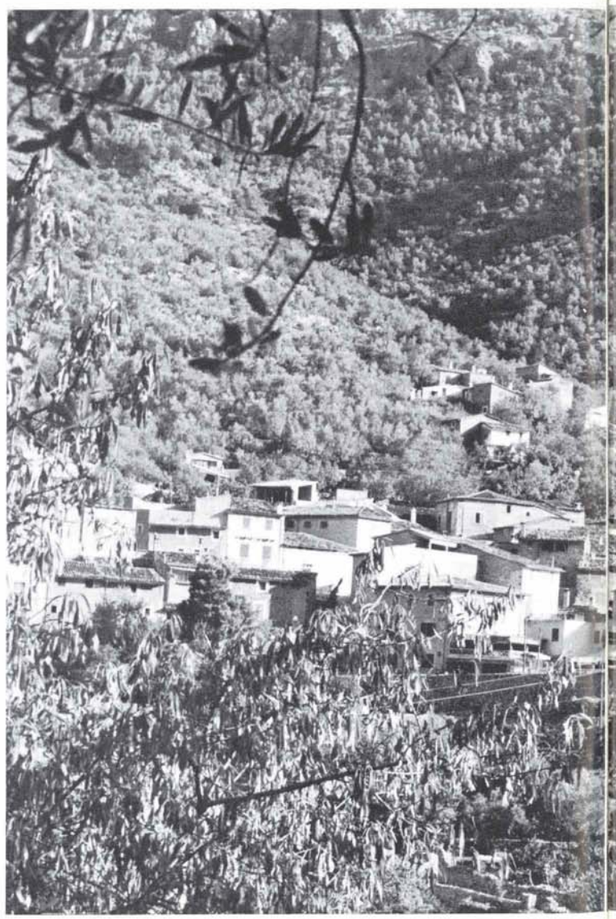
Surprisingly, the architectural remains that most dramatically point to past greatness are relatively rare for the Moorish period. The only complete Muslim structure which survives is the thermal bath at 13 Calle Serra in the Old Town of Palma. Its square basin is now filled in, and covered by a dome supported by horseshoe arches resting on 12 columns. Not far away, spanning the street called *Almudaina* (and could any name be more Arabic?), is a lofty stone arch which once formed an entrance through the ramparts to the Moorish city. Other visual evidence of Muslim occupation is scant: an occasional inscription in Arabic script carved on a stone lintel, a cool vault below some rural manor.

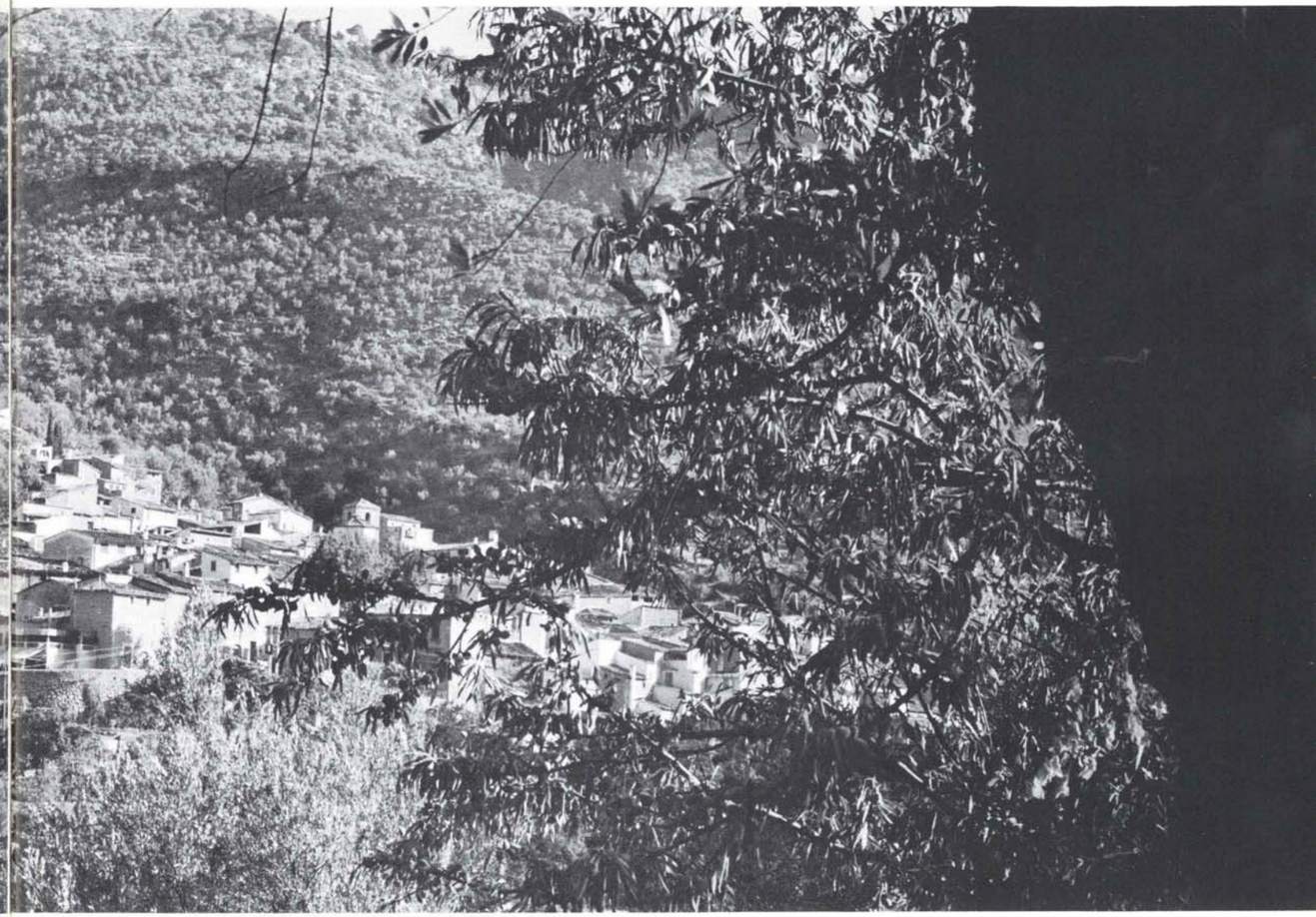
Yet across the whole island echo intimations of Islamic culture, and nowhere more bountifully than across the countryside itself, for the Moors were splendid cultivators. They did much throughout Iberia to render sterile land productive. They terraced the slopes and built irrigation

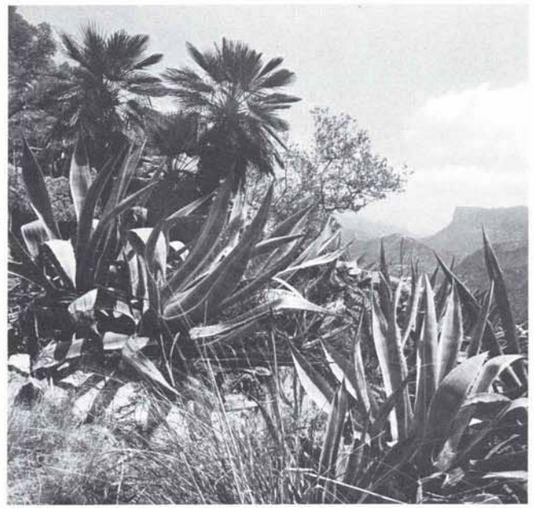


Designs found on tiles tucked under the caves of mountain farmhouses suggest their Arabic origins.

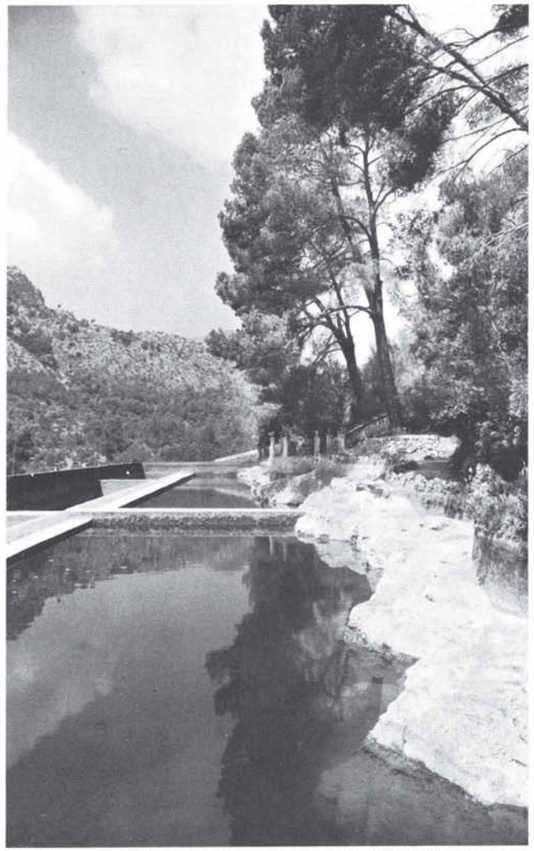
Fornalutx in the Majorcan hills is one of many villages whose names hint of the Moorish occupation.







Proud Muslims once enjoyed this view of Majorca from their gardens at Raxa.



Blending utility with beauty, Raxa's great hanging lake is also an island reservoir.

systems with great reservoirs and cisterns, often underground, where the winter rains could be collected and later carefully distributed during the dry summer season to cultivated land over a network of channels. Since a water supply was, and still is, one of the major problems of Majorca, the Muslims' Spanish successors diligently preserved and improved Moorish methods of terracing and irrigation, so that the original works survive to this day. Water wheels are still finding practical application in the fields and wonderfully picturesque windmills, seen in numbers on the road from Palma to Pollensa, supply the power to lift water for irrigation. Both mechanisms were introduced to the island by the Moors.

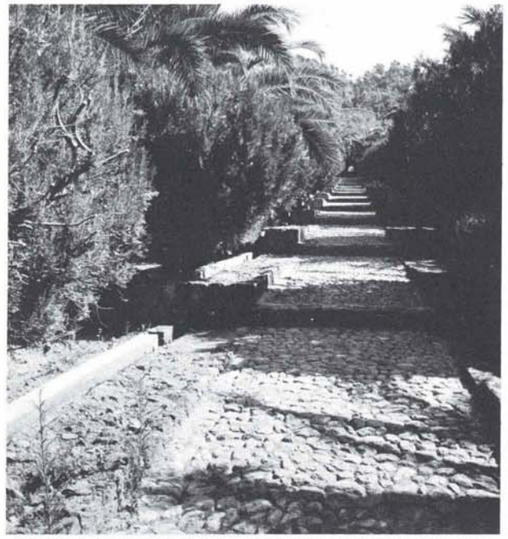
Thus great areas of Majorca are today very much as they must have been in the eyes of their Moorish lords seven centuries ago. Many of Majorca's olive trees, stunted giants with swirling grey trunks and dusty green leaves, were in fact planted by Arab cultivators, and it is at least possible that some which still bear yielded their first fruit to Phoenician settlers before the Christian era.

To the Arabs, accustomed to long journeys across burning desert sands, green fertility was symbolic of life itself, and from their skill in agriculture applied to the problem of survival in arid lands, developed the art of horticulture. Garden craft became one of the foremost arts of Muslim civilization, and so highly regarded that particularly elegant specimens were considered a foretaste of paradise. Under the Omayyads, Cordova, in southern Spain, was said to measure 20 miles across and contain no less than 50,000 gardens, while Granada in the Sierra Nevada mountains nearby was described as "a goblet full of emeralds" because of its floral sumptuousness.

The roots of Muslim preoccupation with horticulture lie far back in time, and spread by way of Damascus and Baghdad as far east as Persia and India. Pliny noted that

Olive trees planted by the Moors more than 1,000 years ago still flourish.

◀During the intense midday heat, the ancient cobblestone streets of Fornalutx, like most Mediterranean villages, are usually quiet and almost entirely deserted.



Entrance to the gardens of Alfabia is this verdant stone-surfaced incline.

An irrigation canal built by the Moors 700 years ago is still in use in the Sóller Valley.

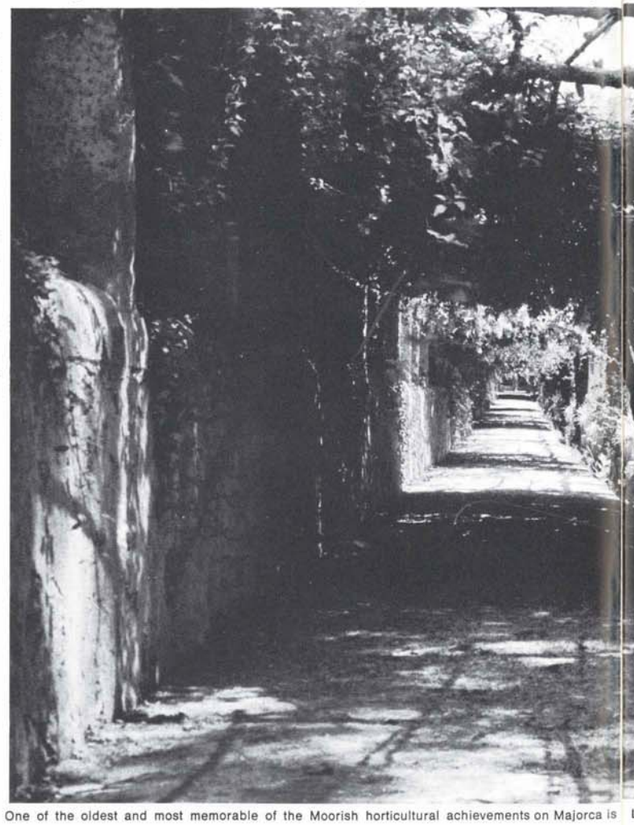
A former staircase decorated with columns and statues is a feature of Raxa gardens.

"the Syrians are great gardeners, taking exceeding pains." The pains of their Spanish kin reached an apogee of artistry in the courts of Alhambra, where in the city of Granada a late-flowering Muslim culture outlived its Damascene parent by centuries, succumbing only in 1492. In Alhambra can be seen the classic elements of the Muslim garden: the close relationship between buildings and plants, intricacy combined with formality, a shady-green intimacy, and above all, the use of running water in open stone channels. Flowing through rooms, courtyards, cloisters and gardens to bind the elements into a single harmonious whole, like threaded jasmine petals which make the fragrant necklace still worn in southern Spain, the channels had the practical purpose as well of cooling by evaporation the areas through which they passed—an efficient form of air-conditioning used in Spain even today.

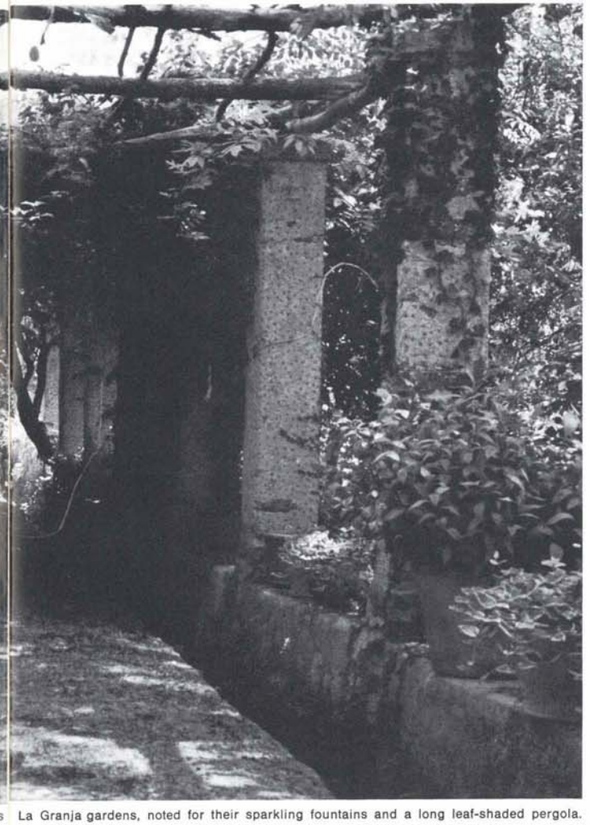
Symbols were everywhere: four channels for the Four Rivers of Paradise, the solemn cypress signifying eternity, the jasmine, rose, lily, azul iris, each with its special meaning. But water, glinting in the hot sunlight, running darkly in the cool shadows or springing up suddenly in joyful abandon to moisten the dry mountain air, was the dominant symbol to the Moors who, deprived of it in their home country, prized it the more.

The prototypes of these great gardens have vanished from Majorca along with the Moors themselves, but the forms have survived in the symbolism and the use of water as a decorative medium. In the neighborhood of Alfabia, Raxa and La Granja, all of which still show visible signs of earlier Moorish occupation, gardens can be found which carry on the old traditions.

Alfabia lies a few miles from the Majorcan capital of Palma on the Sóller road, where the mountain range



One of the oldest and most memorable of the Moorish horticultural achievements on Majorca is



La Granja gardens, noted for their sparkling fountains and a long leaf-shaded pergola.

A bearded Muslim mask over a fountain contrasts sharply with the otherwise baroque style of the Raxa.

provides protection from cold north winds. It is the finest of the water-gardens and more "Arab" than the others. It was originally the country seat of Benahabet, the island's Moorish governor who, by betraying his countrymen to James I, was allowed to retain his property after the *reconquista*. The manor house, approached by a grand avenue of plane trees, has a baroque facade with a great central archway. Behind the entrance lies a broad vestibule, flanked by long stone seats and leading into a wide courtyard from which, looking back, one can see over the vestibule a perfectly preserved "honeycomb" ceiling, such as those for which Alhambra and the Persian city of Isfahan are celebrated. Incorporated in the design is the Arabic inscription: "The law is God. Mercy is from God. God is great. Wealth is from God."

To the left of the facade a long, dramatic stairway of pebble-mosaic bordered by water channels, rises gently toward a baroque wall fountain. Above it in earlier times were the harem—the women's quarters—and its gardens, placed at the highest point of the estate for seclusion and to afford the ladies the finest view of the green countryside; and alongside, a pleasantly modern touch, is a stone-vaulted reservoir which used to be the women's bathing pool.

The main feature of the gardens, however, is the 200-foot-long pergola of stone columns and arching foliage and flowers, which runs downhill from the harem area toward a distant fountain. Here and there openings among the leaves frame panoramic views of the surrounding mountains. On hot days the pebbled pavement is cooled by jets of water sprouting from stone jars. Another pool, shrouded with exotic trees, ferns, tall palms and giant bamboos, provides an atmosphere of oriental luxuriance to the area below the manor house.

Linking the harem garden with the long pergola is a circular clearing surrounded by stone columns on which rests an iron, dome-shaped trellis, intertwined with climbing flowers. It may not be more than 200 years old, but it carries on the ancient tradition of the Moorish *glorieta*, the arbor gracing many a Spanish garden which is sometimes a circle of tall cypress or bay trees, at others quite an elaborate piece of pavilion architecture. The *glorieta* is a shady and secluded outdoor room, a refuge from the sun by day, a dining area for the family on hot summer evenings, a trysting place for lovers at night.

A few miles back along the Palma road, a track turns off through the olive groves toward the Raxa gardens. After the reconquest of Spain the estate was presented to the Count d'Aspurias, Sacristan of Gerona, as a reward for his support of Don Jaime's crusade. The big house is typical of the period. An imposing entrance, a tree-filled courtyard, an olive press complement gardens designed by Cardinal Antonio Despuig, Archbishop of Valencia, who imparted a Renaissance flavor to his property with treasures brought back from Rome in the 1790's.

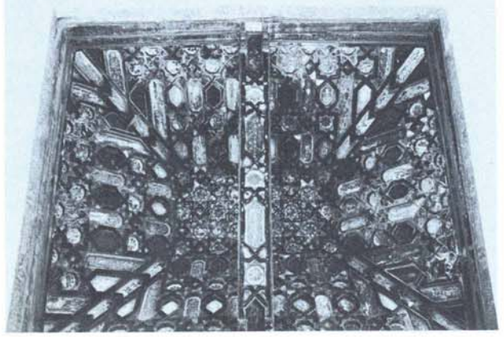
Yet the Cardinal did not entirely muffle the ancient note of Islam. He built a formal staircase up the lower terraces toward the former harem enclosure, and embellished it with urns, columns, statues, lions couchant and bearded Muslim masks. Tier after tier of terraces rising above a formal fountain provide a climax for Raxa's grand stairway. In springtime they overflow with the colors of myriad flowers, and even in the summer's heat they are verdant with succulents, prickly pears, pines and palm trees. At the very top of Raxa's slope a small, classical gazebo surveys magnificent mountain prospects in every direction. Inside this little temple are several plaques of Arabic designs and inscriptions set in plaster, presumably found on the site and preserved by a later builder with a taste for the past.

The garden of La Granja, between Palma and Valldemosa, is unusual in its abundant supply of water and an open first-floor loggia to catch the cool breeze. Overtones from Moorish days are detected in the secluded *harem* garden, the formal public garden with its long pergola and jet-cooled *glorieta*. Between the two gardens, an informal pool is shaded by thick foliage, kept perpetually green by a fountain plume rising to an impressive height. Feeding the pool is a cascade plunging down a mossy, tree-lined gorge, adding to the soothing sound of running water heard in every corner of this fertile garden.

The unhurried tempo of Majorcan life has always been its chief delight, a refuge of quiet from the cities of peninsular Spain. This quality is still its great appeal, combined with a sylvan, rural loveliness created in large measure by Muslim masters of long ago to whom the island was a pearl in its Mediterranean diadem.

Eric de Maré, a British architect who turned to writing and photography, has written a number of books and has contributed articles and photography to The Architectural Review, The Guardian *and* The New York Times.

This perfect Moorish ceiling survives in the manor house at Alfabia.



The only complete Moorish structure in Majorca is the Moorish Bath in Palma, a domed structure, supported by Moorish arches and columns, over a Roman urn. ▶

THE FACE OF MEDINA

BY FUAD RAYESS

Medina is a changing city.

The second holy city of Islam, Medina, isolated in a quiet corner of western Saudi Arabia, has for years, even centuries, proudly held aloof from the forces and influences that, inexorably, have begun to change the traditions of the past everywhere.

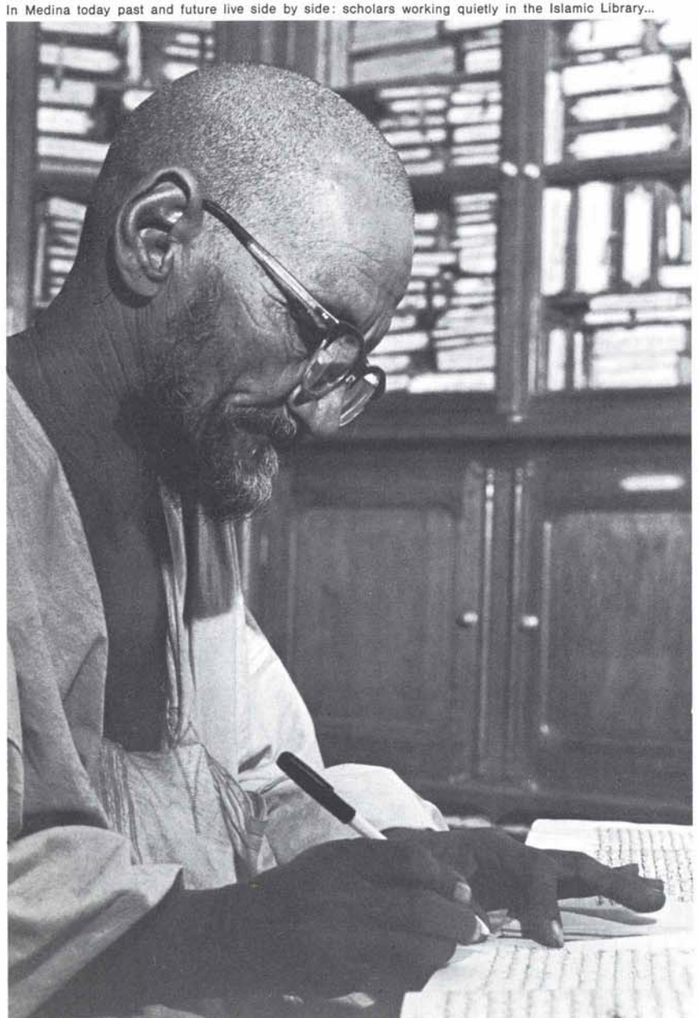
But now the winds of change are blowing across the desert to Medina too, rippling the quiet of its isolation. Just outside the city, planners and engineers have begun to rebuild the once-famous Hijaz Railway and strengthen Medina's links with the world; new buildings have begun to go up in anticipation of the day when the railroad will bring additional thousands of pilgrims to the site of Muhammad's tomb; beside the famous Prophet's Mosque a modern market place has been established that will, in time, enlarge and widen the whole range of goods and services now available to those who dwell within the city's limits.

But that is in the future...

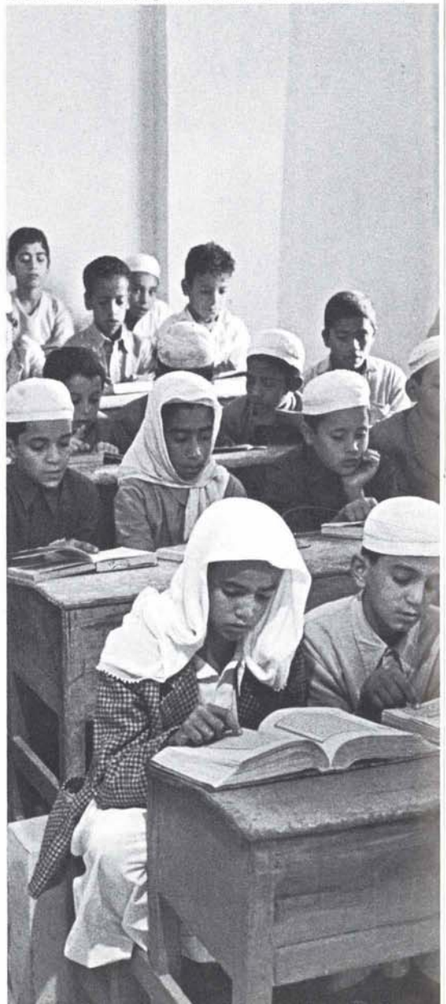
Today, despite the evidence of things to come, the face of Medina is still an ancient face—one seamed with

Photography by Abdul Latif Yusif

In Medina today past and future live side by side: scholars working quietly in the Islamic Library...

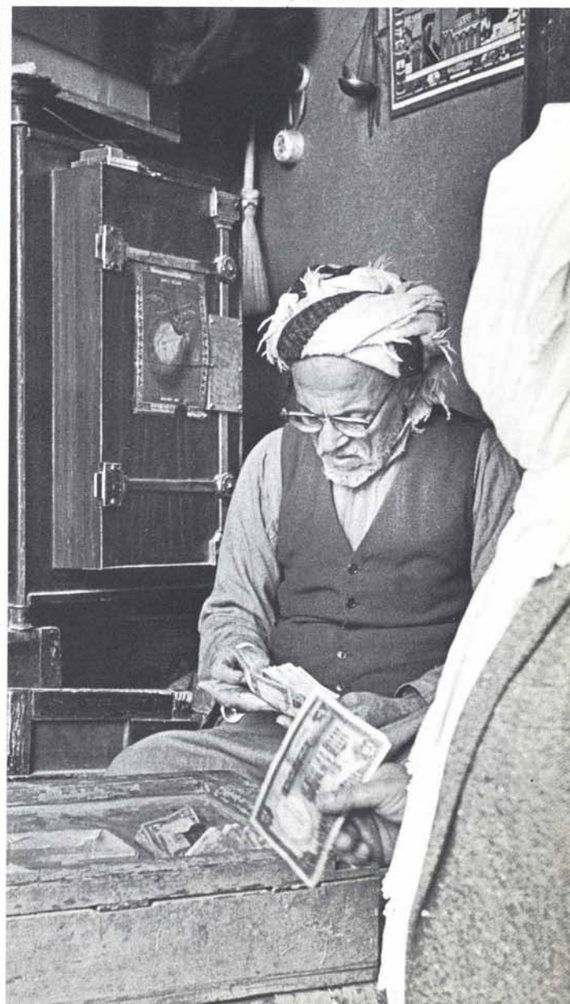


...and children studying the Koran in an elementary school...



In the streets of the city the scenes are varied too: smiling children at play after school has let out...

...and the money changers crisply counting out bank notes.

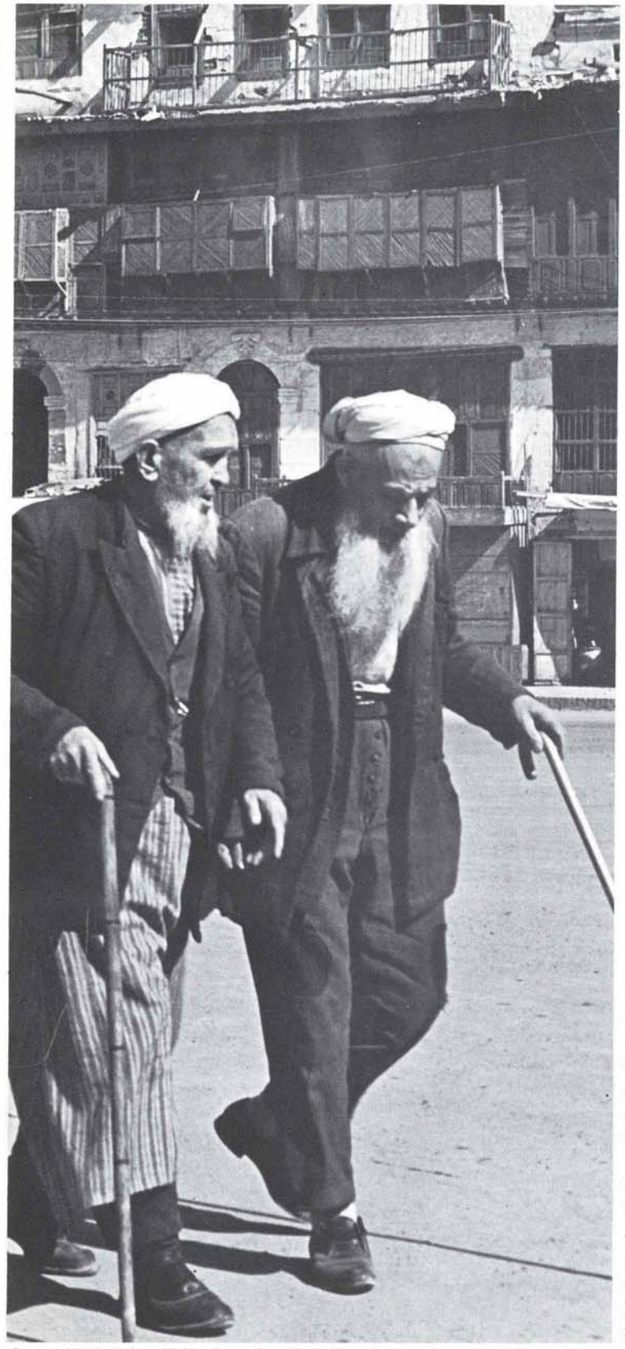


he market place customers and merchants inspect fruit and produce which are grown in gardens outside the city.

Food is plentiful in Medina and easily available in small food shops scattered throughout the city's market area.

As in any city toy trucks and trains prove irresistible to youngsters.

Over tea, elders of the city discuss problems and exchange gossip.



On a quiet street two old friends continue their discussions as they make their way home.

the wisdom and contentment of the old, tested habits of an unhurried people that leaves its fate in the hands of God. Today life goes on as it always has, moving along familiar paths and in known patterns.

Medina's day begins as do the days of all Muslim cities, with the call of the *muezzin* — waking the city, as a famous 11th-century poet wrote, "before morning in the bowl of night has flung the stone which puts the stars to flight."

"God is Greatest," he chants. "God is Greatest. I affirm that there is no god but God and that Muhammad is the Prophet of God. Come to prayers. Come to fulfillment. Come..."

From the top of a slim minaret by the famous mosque, his voice cries out in grayness that is not night, nor yet day. Moments pass and suddenly a new day's sun throws its light across the plain and the city stirs and rises.

In Medina the time has not yet come when every home can store its food, so every morning the people must go forth at once to buy their provisions for the day. That they must is not a matter of regret, for the market place is the place where they not only buy what they need and sell what they can, but where they learn what is to be known, and meet who are there.

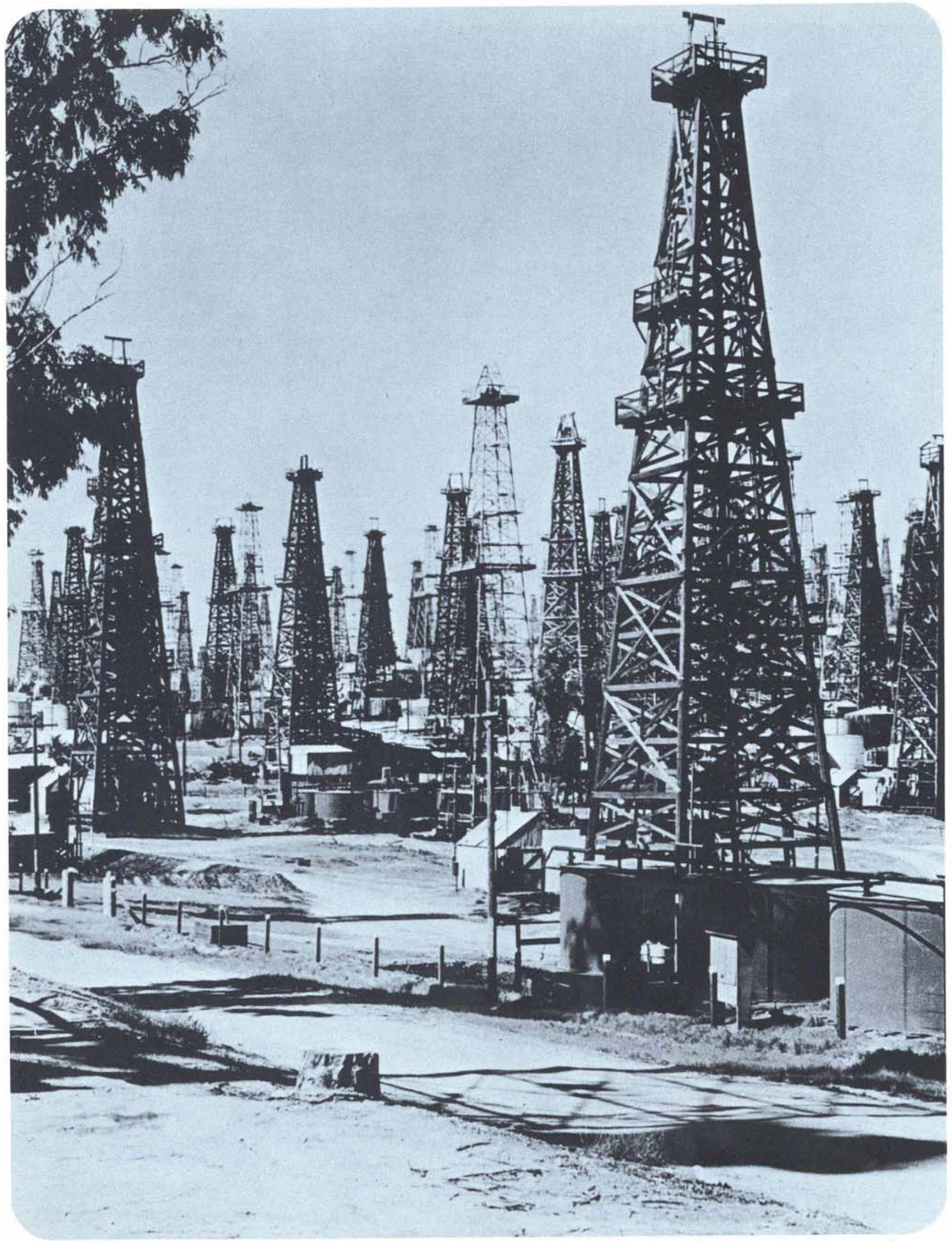
The market is a noisy place. Tradesmen, after all, must sell their wares and customers must dispute their prices and how can this be done in a whisper? There is bread to be bought, and dates, or pans, perhaps, to cook in and pots to carry water. There are bracelets for a lady's arm and watches from around the world, and toys to enchant the eyes of a child. And in Medina, proverbs to the contrary, it is silence that is silver and speech that is gold.

The sounds of Medina, of course, are not limited to the market place. From schools comes the drone of pupils chanting their lessons or cheering loudly in recess. There is the creak of pulleys as workmen haul buckets of cement to the tops of new buildings, the hum of car engines and the constant rise and fall of voices in the coffeehouses where old men with moments to spare—and who in Medina cannot find some?—sip thin bitter coffee or sweetened tea.

Here and there are pockets of silence. In certain stalls, on low wooden desks, scribes quietly prepare letters or petitions for those who cannot write. In other stalls money changers exchange coins and bills with only the faint clink of gold and the crackle of bank notes. In libraries, men of learning rustle paper and parchment as they sit in study. In mosques, where they go to nourish their spirit, there is only the sound of whispered prayers.

All these are the things of Medina. But the new wind blows and the signs are everywhere. Slowly, inevitably, the ancient face of the city has begun to change...

Fuad Rayess, is a former writer for Oil Caravan, *a monthly magazine published in Arabic by Aramco, and is now General Supervisor, Arabic Press and Publications Division of the Aramco Public Relations Department.*



In the early days of oil, close, inefficient spacing of wells, like these at Signal Hill, California, often left great quantities of petroleum untapped.

From all the wells, all the oil...

TO THE LAST DROP

BY BRAINERD S. BATES

An artificial lake surrounded by a grass embankment, with high chain-link fencing around all four sides to keep small boys from swimming in it on hot summer days. This, to the average person, is a reservoir—a place where water is stored in vast quantities for future use. The image is doubtless at least partly responsible for the erroneous impression that oil in its natural state is stored in large underground pools, abysmal, cavelike, their walls dripping with black, oily slime.

While municipal and industrial water reservoirs are clearly visible entities, nobody has ever seen an underground oil reservoir. It is possible, however, to look at and hold in the hand a *piece* of an oil reservoir. Go out to Saudi Arabia's Ghawar field, far in the desert, or to offshore Safaniya, in the Arabian Gulf, where the Arabian American Oil Company (Aramco) is now drilling. Occasionally the derricks working at these sites bring up long cylindrical samples of the rock the drilling bit encounters a mile or more below the surface. Examine these cores carefully. They tell a lot about what an oil reservoir really is.

First of all, the cylinders look as solid as the stone front of an office building. Viewed through a magnifying glass, they turn out in most cases to be made of millions of sand-like grains. Often their surface, in the language of the trade, "bleeds." If the wetness exuding from inside feels slippery there is a good reason, for these slender columns of rock, only inches in diameter, contain minute quantities of petroleum.

From its nine producing fields, spread over great distances across eastern Saudi Arabia and out into the Gulf, Aramco's crude oil production has been averaging around two million barrels a day. That oil moves from microscopic spaces in porous sandstone and limestone, where it had been resting inert for millennia, to the bottoms of wells and then up thousands of feet to the top. What is more, the oil moves the whole distance from its original habitat to the wellhead without having to be pumped. Taken together, the oil reservoirs in the company's nine producing fields, measured around their outer periphery, cover an area of about 1,300 square miles. Spotted strategically in these fields are about 300 producing wells, each with a well bore no more than seven inches across.

The control of fluid movement in these reservoirs is a formidable challenge to reservoir engineers. They must control the amount of petroleum taken out of vast areas underground, i.e., oil reservoirs, in order to maintain a balance between withdrawal rates and energy pushing the oil to the surface. They have to devise in producing zones means of maintaining pressure, the force which moves all Saudi Arabian oil through and out of a reservoir. They must employ techniques most likely to produce maximum quantities of crude oil with the greatest possible efficiency and economy. In the oil business, as in any other industry founded on technology, a resounding scientific success may turn out to be a thumping failure economically if costs and designs do not receive equal attention.

Reservoir engineering, then, deals with the occurrence and movement of fluids in reservoirs and the development and operation of these reservoirs for maximum economic recovery of oil, gas, or both. Like everybody dealing with an applied science, its practitioners are part physicist and part chemist, able to find their way through the loftier branches of mathematics and feel at home in many fields of engineering related to their specialty. In addition, reservoir engineers must have a firm grounding in geology. Their basic working vocabulary includes such words and phrases as *porosity*, *permeability*, *viscosity*, *conformance*, *capillary forces*, *interfacial tension*, *connate water*, and the kind of *line drives* never seen on a baseball field.

The petroleum industry is little more than a century old, its recognized beginnings dating from August, 1859, when "Colonel" Edwin Drake's famed wildcat in Titusville, Pennsylvania, struck oil at 69½ feet. During the first half of the industry's span it was the drillers who held the day, and petroleum production was to a large degree a hit or miss proposition. But the more imaginative oil pioneers sought reasons for noticeable drops in yields, tried unsuccessful gas vacuum pumps to "pull" the oil out of the ground, then experimented with injections of gas and air through adjoining wells into production pay zones to "push" oil to the surface.

Around 1914, drillers on the rigs were joined by petroleum geologists, assigned to analyze samples of subterranean strata as they were brought up by core barrels, and the era of systematic petroleum technology slowly emerged. Drilling bits continued to go deeper, drilling operations became increasingly expensive and the demand for petroleum soared. In the beginning oilmen assumed that when oil stopped coming the sources simply had dried up. They had no idea how much oil was being left behind in the reservoir. To recover these untapped reserves the industry

Photography by Burnett H. Moody, V. K. Antony, Brainerd S. Bates, Thomas F. Walters, E. E. Seal, Socony Mobil Oil Co., Inc., the American Petroleum Institute Historical Photo Library (Shell Oil Co.) and the National Supply Co. Drawings by David Pratt.

had to know much more about what went on deep in the ground in the vicinity of producing wells. Out of this need grew the science of reservoir engineering, which took shape during the 1930's, came to maturity after World War II, has now gone into partnership with the computer, and may be destined to figure in plans for peaceful uses of nuclear energy.

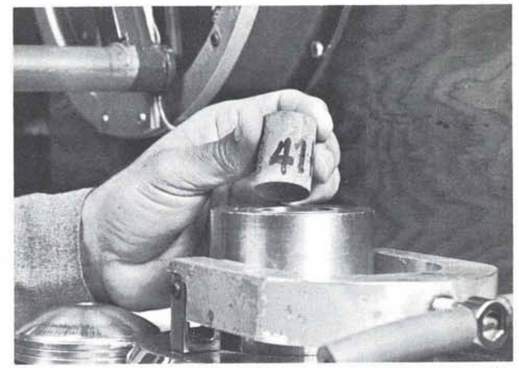
The aim of reservoir engineers was to place oil production on a scientific basis, and as the initial step they drew on geologists' theories of how petroleum was formed in the first place and their knowledge of formations holding it in the earth today.

Although nobody knows for certain, it is believed that crude oil has as its origin microscopic marine plants and animals which settled and mixed with sand and mud at the bottom of ancient seas. Rivers flowing into the seas carried more organic remains, which covered earlier layers of plankton and marine life until the enormous weight of the accumulated sediments compressed them into porous rock strata. Heat, pressure and bacterial action transformed the organic remains, sealed from decay by successive layers settling on top of them, into hydrocarbon compounds; in other words, petroleum. The newly-formed oil and gas started to bubble its way out of mud and silt and float upward through tiny pore channels. Most of these compounds kept on moving until they were eventually lost in the atmosphere. But some oil, as we shall see, did stay behind.

Meanwhile events of momentous import were happening on top of and beneath the earth's surface. The seas gradually receded, over the space of millions of years, and continents assumed their now-familiar shapes. Internal earth forces caused the outer crust to rise and fall, creating visible mountains and valleys on top, and contours and cracks in the nether regions. The oil being sought and produced by companies such as Aramco accumulated in geological "traps"—layers of porous rock covered by layers of impervious rock—made by buckling and folding of the earth.

Like the hydrocarbons which got away, oil and gas, together with salt water, migrated slowly in the direction of the surface through intricately-connected pore channels. But these compounds had been stopped by clay, shales, chalk and various kinds of dense rock layers overhead, which acted as sealing blankets. The hydrocarbons, being lighter than water, rose farthest. The lighter gas in turn separated out from the heavier oil. Each, contained in porous rock, ultimately came to rest at its own level: the gas on top, oil in the middle and water underneath.

Oil and gas at rest deep in the ground, however, are not what interest petroleum men. It is only when these hydrocarbons are in motion, destined ultimately to rise inside a well bore, that they become commercially attractive. Quite reasonably then, reservoir engineers devote much study to those conditions underground which make movement of oil and gas in storage there possible.



Samples are placed in porosimeter where nitrogen charges measure porosity.

The physical characteristics of reservoir rock which make it a natural storage place for oil and gas are linked to those qualities which permit hydrocarbons to move through the same rock: *porosity* and *permeability*. Both can be traced to the fact that sand grains, of which sandstone reservoir rocks are built, and fragments of carbonate material, making up limestone beds, are irregular—they never quite fit together properly. There are tiny voids between the grains and the fragments, occupying up to one-third of the volume of the rock, and it is these voids that contain the underground oil, and give the rock itself the quality of *porosity*. When the voids in reservoir rock are interconnected and continuous, hydrocarbons under pressure can travel through them, and the rock is said to have *permeability*. The ease with which fluids flow through successions of pore spaces depends, of course, on the arrangement of the spaces themselves. As in a pipeline, the larger and straighter they are the more efficient channels they make for fluids such as oil.

Nowhere are the lengths to which engineers go in analyzing oil reservoirs better illustrated than in their detailed study of reservoir rocks for indications of porosity and permeability in oil reservoirs. These two all-important characteristics depend on size and shape of the grains, the *manner* in which nature has stacked them—evenly, as in a brick wall, or haphazardly as in a rock pile—and the quantities of clay and other materials which cement the sand grains together. All these factors determine the volume and direction of pore space *between* the grains, and it is these spaces, of course, which are of vital concern to the oilman.

Just as water or oil will not flow through pipe without some kind of force behind them, so fluids require force (pressure) to move through permeable rock. A property of fluids which influences their ability to flow is *viscosity:* the cohesive forces between the molecules in lube oil, for example, are greater than they are in gasoline. For this reason, lube oil is more difficult to pour. Through mid-19th-century experiments with water filters a Frenchman named Henri Darcy derived a formula to predict how much water would flow through these filters. Oilmen have

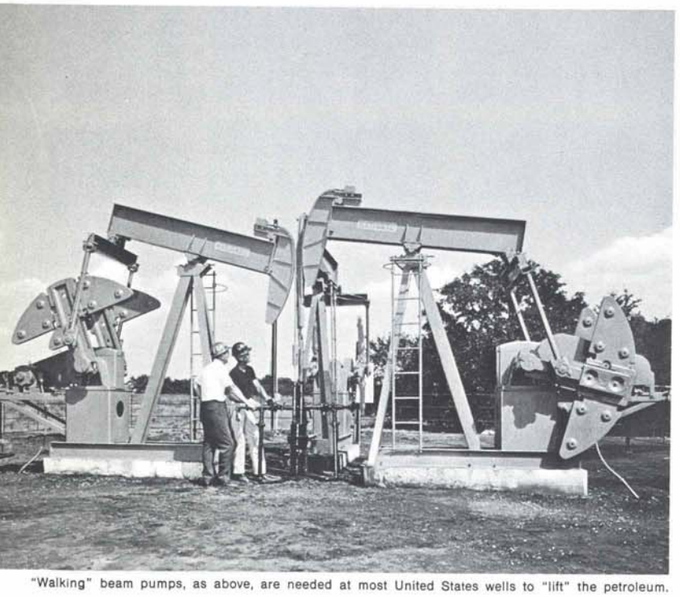
◀ Rock samples, brought up during drilling, are stored in labeled trays in Aramco laboratories until porosity, permeability and other characteristics can be tested.

adapted this formula to measure the ease of fluid movement through rock. Now a reservoir engineer who knows (1) the thickness of a producing interval in reservoir rock, (2) the degree of effective permeability of that rock (stated in darcy units or, more commonly, in millidarcies), (3) the fluid properties within the reservoir, and (4) the difference between pressure in pounds per square inch inside a well and out in the reservoir, has a good indication of how many barrels of oil that well is capable of producing in a day.

In order to predict fluid movements in its reservoirs Aramco has ways of testing reservoir rock for porosity and permeability under laboratory conditions. The samples of rock brought to the surface by core barrels at drilling sites are placed in carefully-labeled trays. They are then carried to the company's Oil Operations Laboratory in Dhahran, where plugs one inch in diameter and about 1½ inches long are cut out. Next the plugs are washed in a flask containing a cleaning solvent to remove all oil and foreign matter in them and then are thoroughly dried in a vacuum oven heated to 230° Fahrenheit.

An apparatus called a porosimeter finds the ratio of the combined volume of all pores in a sample core to its total bulk by holding the clean plug in a small airtight vault and having a charge of nitrogen pushed into it under pressure. Porosity is determined by measuring the amount of the gas entering the pore volume of the core.

Nitrogen under pressure is also used to help discover in the lab the permeability of a core plug. A sample of reservoir rock is placed in the metal sleeve of a permeameter into which hoses have been attached at either end. Valves regulate the flow of nitrogen coursing through the length of the plug. Gauge readings reveal the pressure differential across the plug, and the rate of the flow of gas is given on a calibrated flowmeter.



"Walking" beam pumps, as above, are needed at most United States wells to "lift" the petroleum.

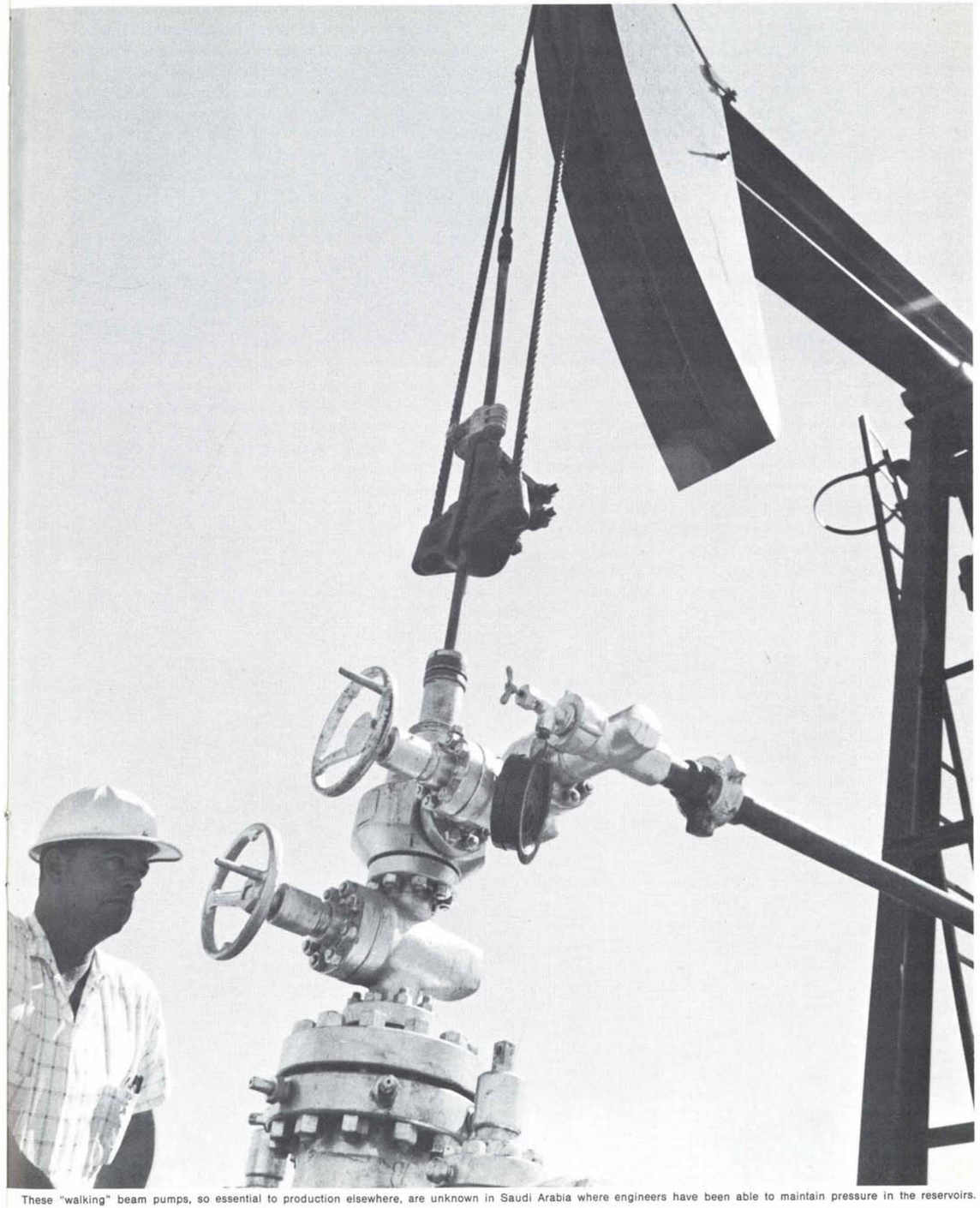
Too many people base their knowledge of oil production on old movies in which an oil well spouts to the sky, while handsome operators leap with joy as they wipe jet-black petroleum from grinning faces. In the past few decades the oil industry has learned a great deal about forces deep inside a reservoir, and the rare blowouts that do develop nowadays are strictly accidental. Their occurrence, far from being good news, means only tragic waste.

Yet the picture of a "runaway well" does illustrate a most important fact about oil reservoirs: that petroleum in the ground is under enormous pressure and that, when the ground is punctured deep enough and at the right place, that pressure is released, carrying oil up with it. The analogy of the freshly-opened bottle of soda pop is often used to demonstrate basic principles of reservoir forces. Remove a bottle cap and some of the drink pours out uncontrolled. Most of the soda, however, remains in the bottle. As everybody knows, it is the gas still bubbling up through the drink that gives the liquid its big initial spurt.

Likewise, it is stored energy in reservoir rock, including that of the gas associated with crude oil, that drives the oil through a reservoir and up a well. And, as in the case of soda pop, that force tends to dissipate rapidly after the "lid" has been taken off. Oilmen have been continually investigating sources of reservoir energy in order to find the most efficient and economical ways of maintaining the force, or at least controlling its decline.

Approximately nine out of ten oil wells in the United States have huge, ungainly "walking" beam pumps which tilt back and forth seesaw fashion to "lift" petroleum out of the ground mechanically. In contrast, many wells throughout the world, including all those in Saudi Arabia, have nothing more on top of them than a motionless series of valves and fittings about 10 feet high, called a control head, or "Christmas tree." So far no pumps are necessary over Aramco's wells because ever since its first oil well went into production in Dhahran 27 years ago company engineers have maintained a balance between natural withdrawals and available reservoir energy. Pumping must be resorted to at so many oil fields elsewhere because, among other reasons, they were developed before oilmen knew about conservation made possible by sound reservoir engineering practice, and oil field energy was irrevocably lost.

The energy which drives oil to and up a well bore has been stored in compression in all reservoir fluids and in the reservoir rock itself. Production specialists learned the hard way that if pressure in a reservoir is to be kept up, oil taken out of pore spaces must be replaced by water or gas. Further, for maximum recovery, the displacing fluids ought to move through the greatest number of these oil-filled voids. If sufficient replacement does not occur naturally, then water, gas or some other pressure-maintenance agency has to be injected into the reservoir through wells often drilled for this sole purpose.



These "walking" beam pumps, so essential to production elsewhere, are unknown in Saudi Arabia where engineers have been able to maintain pressure in the reservoirs.

Because of its relative weight, gas exists in reservoirs above an oil deposit and the water below it. What is more, gas and water generally move through permeable pore spaces more easily than oil does, and without proper management can arrive at the well bore first. Proper balance between well rate and the number of wells producing can encourage oil to move evenly through a producing interval, the desirable goal. As gas permeates downward from above and water upward from below, oil well producing rates are reduced in order to avoid serious trouble. Suction set up by too large a flow can cause water in the lower extremities to form a cone right under the well, with the danger that the water cone could eventually penetrate the well bore and severely restrict oil production.

Assuming that a newly-drilled well has struck a productive formation, oilmen have several ways of making reasonably certain that the hole will produce petroleum instead of water or gas. The most logical method after the well has been drilled is, of course, to control the rate of oil flow at the wellhead by proper adjustment of valves on the "Christmas tree." During the final drilling operation oilmen acquire a good idea how far down an oil-producing formation is likely to be encountered. They always try to complete the well between two impermeable structures to insure production from a single reservoir and at times avoid water or gas entry. Such an ideal situation is not always met, however, but in any case drillers must know what *type* of oil drive they can expect to meet as their bits grind downward.

There are three, rated according to the relative efficiency with which each kind of drive pushes oil. The least efficient, usually, is a *dissolved-gas* drive. Pressure in this case comes only from gas dissolved in the oil present in reservoir rock, which seeks to expand as oil is produced.

When there is more gas than can dissolve in oil at temperature and pressure conditions existing in a reservoir, and this gas bubbles to the top of a deposit, it creates conditions for a *gas cap drive*. The layer of gas up inside the impermeable trap pushes down on the oil to aid in its recovery.

A third type of recovery mechanism, often more efficient than the first two, is known as a *water drive*. Salt water, originally from ancient seas, migrated into porous channels of rock below and outside the relatively small limits of a structural feature containing oil. As the reservoir is produced the water moves into the oil-bearing rock and flushes petroleum ahead of it.

It happens that most oil-producing reservoirs do not fall into any one of these neat categories but have some combination of the three mechanisms as their driving force. Petroleum in Aramco reservoirs, for example, is moved both by water influx and dissolved-gas drives as primary sources of energy.

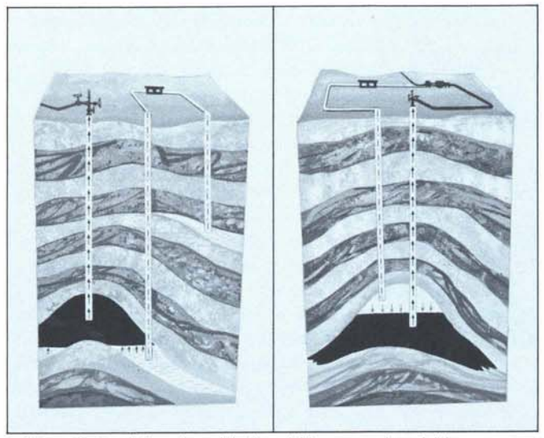
Natural phenomena of the kind that are learned in every high school physics class can be made to work on the side of the oil producer who takes advantage of them. As one instance, forces of gravity acting on gas, oil and water, which causes them to separate out from each other because of their differences in density, supplement pressure drives to help increase oil recovery when production rates are properly controlled. As another, capillary action, the reason behind a blotter's ability to absorb ink, aids in the removal of petroleum from smaller, low-permeability pore channels in reservoirs where a water drive is present by drawing oil-displacing water through these tiny channels, just as spaces between granules of a sugar lump soak up coffee.

It has been a long time, however, since oilmen relied entirely on the energy existing in nature to drive petroleum out of the ground. They discovered techniques which could get results similar to those obtained from natural reservoir drives if their introduction made economic sense. They began injecting gas into some reservoirs and flooding others with water. At first they used these *secondary-recovery* methods to restore reservoirs to life after they had become depleted and indigenous energies were too weak to produce oil by themselves. Later, just as a farmer uses chemical fertilizer to enrich soil, petroleum engineers started injection of water or gas early in a reservoir's life to supplement primary drives before these natural forces had dissipated into uselessness.

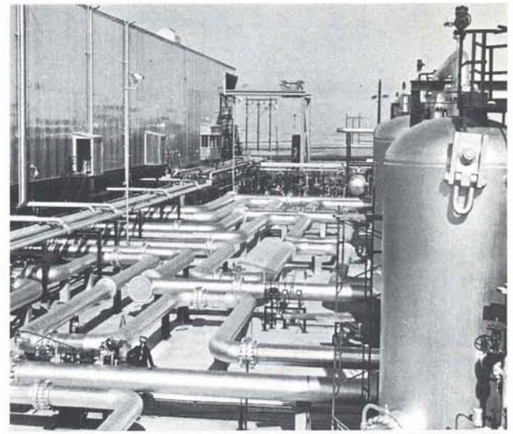
For some time Aramco has been maintaining pressure in the reservoirs of its Abqaiq field and at 'Ain Dar, the northern extension of the big Ghawar field, by use of water and gas. Aquifers (underground water-bearing formations) supply the liquid for water flooding, which is either injected at the surface or permeates down into the structure by gravity. The gas injected has been separated out from the oil produced by Aramco in installations called gas-oil separator plants. At 'Ain Dar the gas so recovered is collected and compressed in several stages up to 2,100 pounds per square inch in a plant designed to compress and put back into the ground 160 million cubic feet of gas per day. The entire injection complex installed to achieve this end cost $30 million.

Nearly everybody remembers yesterday's "big game" movies set in some distant place such as India in which lines of native beaters advanced noisily through covering bush to drive a tiger into a trap. The beaters were stationed in close formation so the animal could not escape through the human net. In a similar way, a secondary-recovery "sweep" of water or gas should pass through every rock pore in an oil-bearing structure, leaving no part of the reservoir untouched.

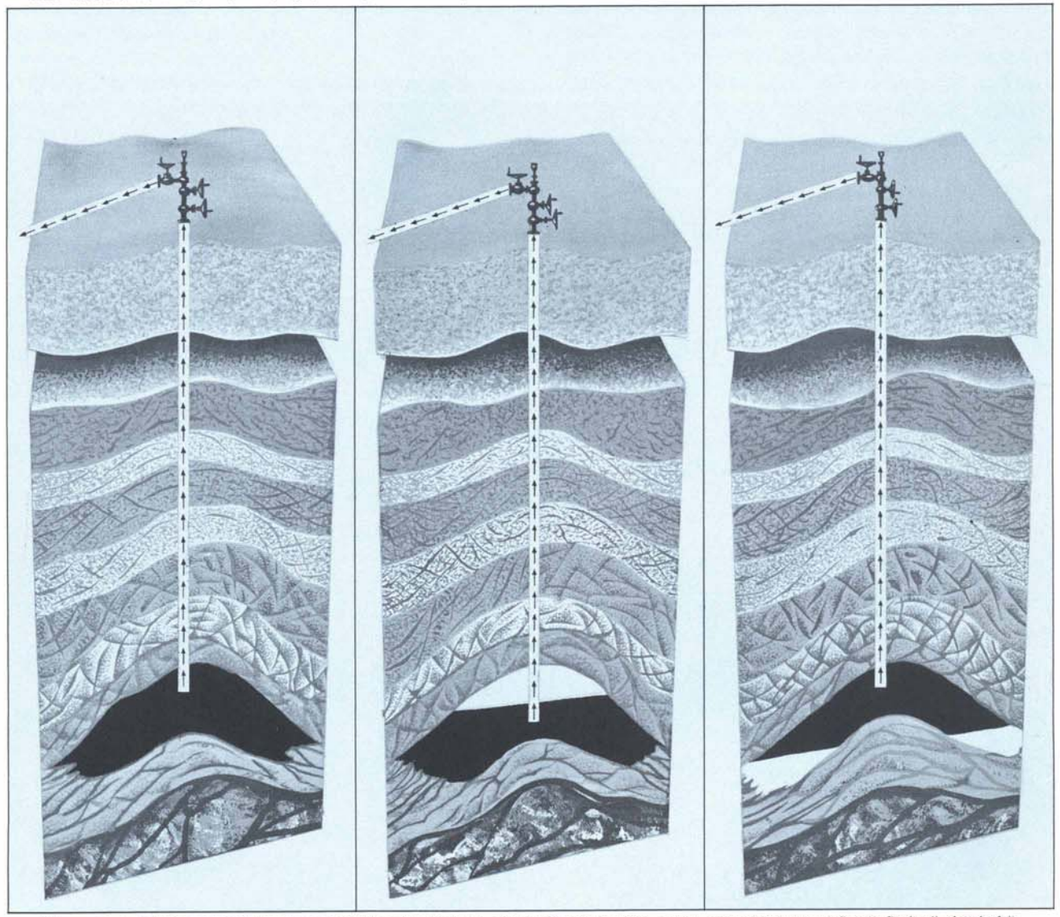
Trying for this optimum objective requires careful planning and study to locate water injection wells in precisely the right sort of pattern. Some such wells are placed in rectangular *five-spot*, *seven-spot* or *nine-spot* patterns, with the injection well in the middle. A *line-drive* operation is one in which injection wells are placed in rows. Sometimes results of reservoir research recommend locating water injection wells around the edges, and gas injection wells at the crest of a known producing formation.



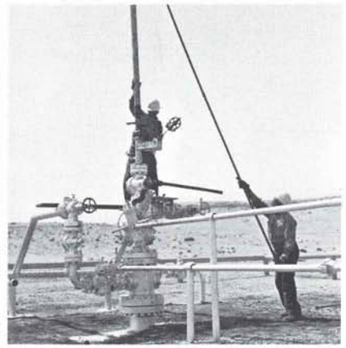
Water injection, left, and gas injection, right, are ways to maintain pressure.



Aramco's 'Ain Dar plant injects 160 million cubic feet of gas into wells daily.

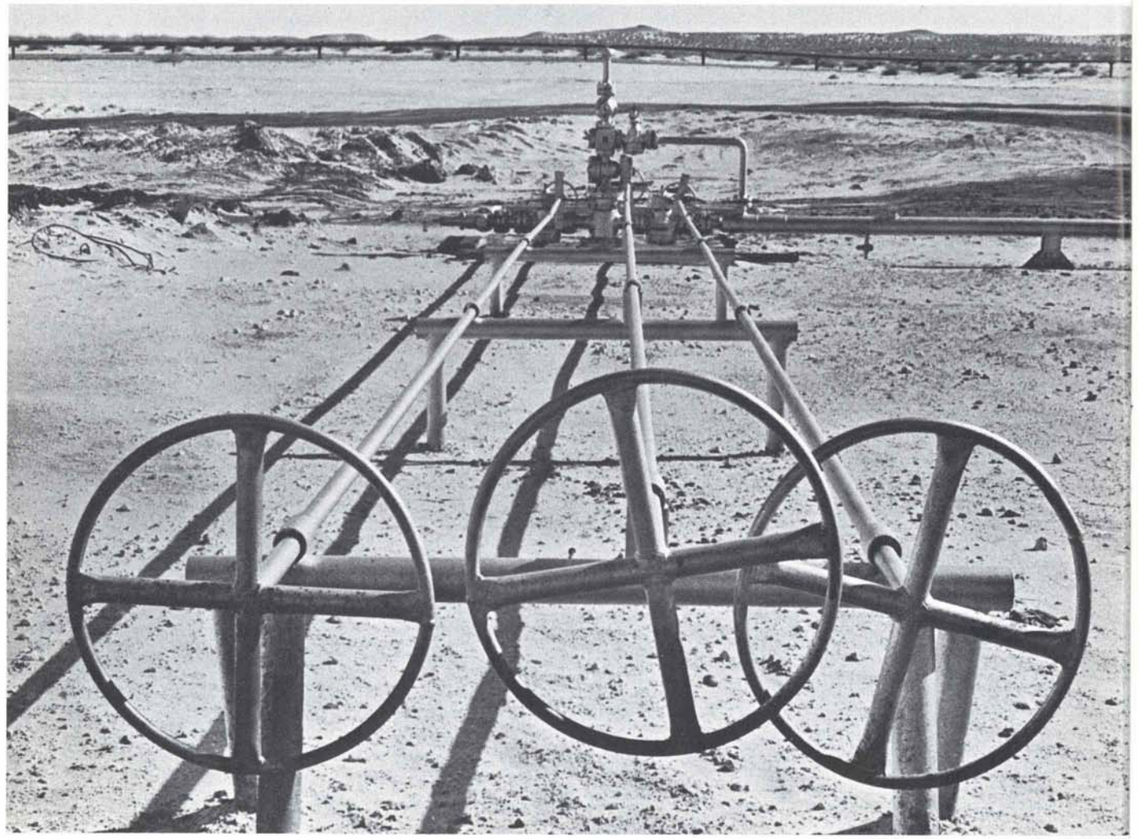


Primary drive methods employed by engineers include dissolved gas, left, a gas cap, in white, center, and natural water influx to flush oil ahead of it.



Experts ready a pressure testing "bomb", left, which is dropped via a "lubricator", right, into the well.

A typical gas injection well in 'Ain Dar area at the northern part of Ghawar field returns compressed gas through pipe at right into well head and down to oil reservoir.



Aramco's pressure-maintenance wells have all been drilled in this so-called *contour* pattern.

Even with the most scientific placement of injection wells, however, oilmen are still falling short of the maximum desired recovery goal with water flooding and gas repressuring. The industry is constantly experimenting with new and often rather startling techniques for driving oil in rock pores up to the surface.

In reservoirs known to contain heavy oils, thermal recovery methods are beginning to gain considerable acceptance. Essentially, this technique calls for heating a reservoir to something like 600° Fahrenheit to make the oil less viscous and able to flow more easily. Early experiments used hot water or steam as the heating element. In one currently-accepted application of the thermal principle, oil in a producing formation is burned, the fire sustained by blowing compressed air into the structure. The heat not only lowers the viscosity of the oil but forms condensed water vapors and vaporized oils, which together make up a composite water and gas drive.

The oil industry is now even thinking about stimulating production in stubborn petroleum reservoirs by nuclear-explosive fracturing of deep underground structures. The first published report about this possibility appeared in an oil trade magazine in December, 1963. The nuclear explosion as envisioned by petroleum scientists would produce a huge subterranean cavity whose roof would most likely collapse, creating in the fractured rock overhead what would amount to a large-diameter well bore into which reservoir fluids would drain.

All through the life of an oil reservoir, from the moment the decision is made to drill through the entire period it is being produced, the subterranean source of oil is tested, examined and analyzed like some giant, slumbering patient. Geologists studying its structures and environment can derive some idea of its extent, but nobody can be really certain that a reservoir contains oil before that particular reservoir is drilled. Still, the true potentialities of the structures remain unknown until it has been on production for some time and carefully-recorded observations are made of its performance. A history of its yield of oil, gas and water and of its pressure and temperature measurements over an extended period can reveal much about how long a reservoir will produce and give its production potential in total barrels.

By close observations of all its reservoirs Aramco knows at any given time how much oil remains within its fields capable of being produced in the future. Through such means, plus new discoveries, the company is able to say that total proven reserves of its liquid hydrocarbons are climbing steadily upward. Three years ago Aramco stated that it had 45 billion barrels of proven reserves. It is now estimated that it has 59.2 billion barrels.

At least once a year, sometimes quarterly and sometimes semi-annually, everyone of Aramco's producing wells can expect a visit from trained teams of Saudi Arabs assigned out of Abqaiq's Bottom Hole Test Unit. The men send down precision instruments housed in stainless steel cylinders which resemble skinny versions of naval torpedoes. These explosionless "bombs" measure the pressure and temperature at certain specified intervals in reservoirs pierced by the wells. The company also has a number of observation wells where such tests can be conducted without having to shut down production. Charted and graphed, information gathered by the measurement teams gives clear preliminary indications of reservoir performance.

But much more than a rough profile is needed before Aramco is ready to commit capital expenditures of the magnitude required to develop and expand oil fields. It costs an average of $300,000 to drill a well on land in Saudi Arabia. Including the platform that is required offshore, a new well in the Arabian Gulf can cost the company up to $500,000. Pipelines and necessary supporting facilities are tens and hundreds of times as expensive. With so much real money riding on the decisions of production engineers, truly detailed data are required to determine whether a reservoir's potential justifies, for example, drilling new wells—and where. Then there is the question of how many wells are required to control reservoir pressure distribution. There are so many permutations involved in such decisions these days that oilmen have to develop new formulas and turn to electronic aids to help them arrive at what, hopefully, are the right answers. Data provided by pressure and temperature "bombs," core and fluid samples, porosimeters and permeameters are converted into mathematical representations. The coded numbers are then punched into cards which can be "read" by computers.

The programed information collected in the field and in the laboratory is run through such complex computer programs or electronic equipment as the *simulator*, which handles mathematical representations of pressure performances and fluid movements; the *network analyzer*, consisting of a series of resistors and condensers able to duplicate electrically variations of pressure performance and fluid movement; and the *linear programing model*, into which are plugged mathematical codes standing for facilities performances, pressure performances and cost factors for each variable under study.

The names Spindletop, El Dorado and Signal Hill call to mind the romance and lustiness of petroleum's earlier days, when the stakes were climbing and chance played a major role. The cool, scientific approach to production challenges which characterizes the oil industry today has perhaps diminished some of the old excitement. But the more the odds favor the producer the greater the benefits accruing to users of petroleum, and that, in this day and age, includes nearly everybody.

Brainerd S. Bates, a graduate of Brown University, is a former editor of Aramco World *and a writer for Aramco's Public Relations Department.*

THE LONG STRIDES

BY MIKHAIL NAIMY

Change! Grow! Battle cries of Arab writers today...

Properly evaluated, modern Arab literature could be taken as a measure of the recuperative powers, the resourcefulness and the vitality of the entire Arab world. Arab writers, it would seem, are trying to do in a few years what it took the Western world a century to do.

The key phrase here, however, is 'properly evaluated.' To appreciate the long strides forward that Arab writers have taken, it is essential, first, to look into the background of literature in the Middle East and to examine the problems faced by those early writers who saw the need for change and tried to bring it about.

Just at the practical level, for example, the problems faced by many early writers seemed insurmountable. Arab writers able to produce works of value were unable to find publishers and had to pay for the printing themselves —which was primitive and inevitably required an accompanying list of errata—and then peddle the books in person from bookstore to bookstore, lucky if the shopkeeper would take five copies on consignment and even luckier if the shopkeeper ever settled the account. Readers, furthermore, were rare and what few there were preferred Western writers to Arab writers. There were no public libraries and few private ones.

But the real problem for Arab writers was the almost exclusive commitment of Arabic literature to poetry. Until comparatively recent times, in fact, the history of Arabic literature is a history of poetry. Prose, even the most artistically executed prose, always occupied a secondary place; the drama, the novel, the short story and the critical essay, in the modern sense, were virtually unknown, and the only specimens of good prose occur in the edicts and other pronouncements of the early califs and in the writings of a few masters such as al-Jahiz and Ibn al-Muqaffa'.

Arabic is a rich, accurate and pliant language, a language capable of expressing infinite shades of thought and emotion, a language, in short, that possibly more than any other, lends itself to poetry. Early in history, however, there developed—possibly because of the very pliancy of the language—a strict, difficult prosody that prescribed that any single poem, no matter how long, must have one rhyme from beginning to end without repeating the same word twice. By its very nature, of course, this prosody precluded the possibility of creating epics and narratives and so almost from the start such poems were restricted to certain manageable forms—elegies, eulogies, self-praise, praise of one's tribe—with content and imagery drawn, naturally, from the experiences and observations of the poet: the battles and feuds of his tribe, the camels and horses tribesmen owned, the swords and spears they used to win their victories, and the oases to which they led their flocks. Curiously, and unfortunately, Arab poets never really went beyond such subjects and poetry lapsed into stagnation and sterility. It wasn't until the 19th century, with Napoleon's foray into Egypt, the coming of Western missionaries and the appearance of more printing presses, particularly in Lebanon, that the Arab world finally began to stir from its intellectual lethargy. Later, as the controls of the decaying Ottoman relaxed, schools and newspapers made timid appearances. Some Lebanese intellectuals, who, chafing under the Ottoman rule, had fled to Egypt, founded newspapers and magazines.

By the beginning of the present century, it was obvious that something tangible was happening in the Arabic-speaking world. It was felt in all fields, social, political, literary and artistic—a realization that the Arab world was falling behind. In 1913, for instance, I wrote a critical essay bemoaning the somnolence and apishness of Arab literature in a world so wide-awake and so intensely active. It was the first expression of the work of a society in New York called *Arrabita* that would later produce writers like Kahlil Gibran and Ameen Rihani. In the same period, gifted scholars from Arab countries, who studied at institutions of higher learning in the West, soon became aware of the poverty and lethargy of their own literature and of its pressing need for enrichment and invigoration—a sort of blood transfusion from the richer and more vigorous literature of the West.

New voices were to be heard in Egypt too. Like our group in New York, they were the voices of iconoclasts —men like Taha Hussain, al-'Akkad and al-Mazini—who challenged ancient traditions and authorities, ridiculed many idols, and called for new forms and ideas. Literature, they said, so long divorced from life, must be rewedded to life. It must be stimulated and reoriented. The harsh rules of prosody must be relaxed and forms alien to ancient Arabic literature—the short story, the novel, the drama, the epic and the criticism essay—must be introduced.

No such battle is ever really over, of course, but since then there have been changes of a surprising magnitude. The short story, for example, today leads the present literary field. Many worthwhile stories have been written in Egypt, Lebanon, Syria and Iraq, which, properly translated, could be read with profit in any tongue, and Arab writers, especially the younger generation, no longer confine themselves to such models as Chekhov and de Maupassant, but experiment with Freudian motifs, existentialist ideas, and even vulgarity. What is true of the short story is also true of the novel, except that here progress has been much slower. Only a few novels so far have appeared that can stand a comparison with similar products in the West. Western masters of the novel, however,—English, American, Russian, German, Scandinavian and French—are very widely read throughout the Arab world, either in their native tongue or in translation, and there's little doubt that the novel is solidly entrenched as a literary form, and but awaits an Arab champion.

As for drama, progress has also been slow, but there have been changes. The ancient Arabs never had anything even remotely resembling a theater and with the advent of Islam, and its ban on women appearing in the company of men, there was no chance for a dramatic tradition to develop. Furthermore, the drama faces some difficulties peculiar to the Arab world. One is the almost unbridgeable gulf between spoken and written Arabic. Literary Arabic is actually the only language common to all Arab writers and the only language which can be read and understood by the educated in any Arab country. Yet to write for the theater in pure literary Arabic is to distort reality, for no one speaks it. On the other hand, spoken Arabic varies so much from country to country that it may not be understood. Furthermore, the use of colloquial Arabic undermines the prestige and usefulness of the literary language, which is the only medium of expression uniting all the Arab lands.

One of the major battle fronts is in the field of poetry itself, where an amazing variety of forces is at work. The old Arab classics still have their numerous and stubborn followers. French Parnassians and English Victorians are still around. America's Walt Whitman, the rambling giant of *Leaves of Grass*, also has his admirers and emulators, as do the Symbolists and Surrealists. In the last few years the imaginations of a number of young bards have been stirred by men such as T.S. Eliot and, to a lesser degree, Ezra Pound, and Rainer Maria Rilke. Those poets found a quick response in Iraq and their enthusiastic admirers in Lebanon helped to found a very presentable quarterly called *Shi'r* (poetry) and began to gather once a week to air their views on their own works and on what is, or is not, good poetry. The magazine reproduced not only the original contributions of the group but also published translations from various European and American poets of the same trend. Among this group were poets who liquidated not only the rules of classical prosody but did away with meter and rhyme and preached what they called the "Prose Poem." A similar movement with a similar magazine was started later in Cairo. To the great regret of the devotees of the "new" poetry and their friends, *Shi'r* discontinued publication after five years.

Just how far literature has come can be seen in Beirut where, today, there are no less than 40 publishing concerns, some of which are modern and efficient and able to turn out books the equal of anything in the West. In schools Arab writers have taken their place in the study of literature and students seeking higher scholastic degrees are choosing modern Arab authors for their dissertations. Private libraries are growing and the concept of public libraries has been introduced both in schools and municipalities. Whereas it was once rare that editions of any book exceeded 1,000 copies, editions of 3,000 copies are now no longer uncommon. And five years ago in Beirut a society called the "Book Friends' Society" began, each year, to set aside a week which it calls "Book Week." During that week, press, radio and TV are asked to do their share in extolling the virtues of books and in whetting the readers' appetites for them. The week terminates in a grand dinner at which $10,000 in prizes are distributed to the authors of the best books published during the year. The first prize—$1,500—is donated by the Lebanese Ministry of Education and presented by the Prime Minister himself.

Outside the Arab world, of course, the impact of modern Arab literature has been limited, and yet, considering the output, the number of works translated is not negligible. Translations have appeared in more than one European country of certain works of some Egyptian authors like Taha Hussain, Tawfic al-Hakim, Mahmud Taymur and Naguib Mahfuz. All of Gibran's Arabic works have appeared in English translation. Anthologies of modern Arab verse and short stories were published in Russian, French and English. In my own case a collection of my Arabic poems was translated into Spanish and published in Madrid several years ago and some of my stories have been brought out in Russian and Ukrainian. My *Book of Mirdad*, written in English and published first in Beirut, then in Bombay, India, and later in London, has been translated into Dutch and published in the Netherlands. A Portuguese translation of it is about to appear in Sao Paulo, Brazil.

The yardstick by which progress is measured, however, can never be merely quantity. It must be quality carefully weighed against the circumstances that produced it. By this test advances in Arab literature are not only remarkable but provide a sound basis for the hopes of its practitioners and advocates that in the near future it will become a valuable contributor to the treasury of world culture.

Mikhail Naimy, a Lebanese writer known for his biographical study of his intimate friend Kahlil Gibran, studied and lived in Russia, the United States and France and has been an important figure in Arab literature for many years.

Photography by Sa'id Al-Ghamidi

THROUGH THE REEFS

For the harbor pilots of Jiddah every ship is a new challenge to their skills and knowledge...

BY WILLIAM TRACY

From the bow of the tiny boat bobbing up and down in the shadow of a large, white passenger liner out of Karachi, Muhammad Ibrahim Salamah, chief harbor pilot of Jiddah, pointed to the largest of three ships anchored outside the reefs that bar the way into Saudi Arabia's largest port. "She's a British ship," he said. "She's here to pick up Malayan pilgrims. She goes 12,000 tons and she's a half mile offshore in 15 fathoms. I met her six miles out this morning and now we're going to take her through the reefs."

As he spoke he waved vaguely at the placid green waters of the harbor. It was a casual gesture and yet implicit in it was a graphic description of some of the most dangerous reefs on the Arabian coast—three overlapping ridges of jagged coral big enough to open a steel hull the way razors cut silk. The ships that inch their way through those reefs—nearly 1,000 every year—have to execute a 180-degree turn to get through the first barrier, cautiously pick their way through a middle channel while a strong current and uncertain winds vie with the helmsman for control, swing in a tight S-turn through a gap in the reef where the edges are no more than 30 feet from the hull and, finally, pivot sharply backward to the pier, a ship's length from still another sharp coral spine. For the pilots it is a constant challenge to their experience, a repeated test of their ability and a constant strain on their courage.

On this fall day, however, the day on which visitors had come to observe him in action, Muhammad couldn't have been more at ease. He plumped himself down on the deck of the small boat with the confidence of a man who not only knows his job but knows that others know he knows it—like the United States Navy admiral who skeptically watched him guide a 680-foot cruiser to the pier and later wrote him a note praising his "vast knowledge of the narrow channels in the coral reefs," and calling him "a credit to himself and the profession he represents." Or the other American naval officer who said: "I have yet to meet, in a long and world-wide experience with pilots, one in whom I have more confidence than in Muhammad Salamah, Chief Pilot of Jiddah."

Muhammad is a short, energetic man with a close-cropped gray beard, a huge, white-toothed smile and thick eyebrows. When he talks his face is in constant motion. He wrinkles up his eyes, strokes his beard, throws back his head to laugh, mops his brow and adjusts and readjusts his white creased Javanese cap at jaunty angles on the back of his head. On the deck of his small boat, in the midst of the cries from boys leaping into the water after coins, the shouts of vendors selling fruit and biscuits, the occasional deep whistle of the ships out beyond the reefs, and the murmuring of pilgrims filing up the gangplank of the ship from Karachi, he seemed completely and happily at home.

"Here! Sit right down here," he told his guests and slapped the deck with his palm and pulled a straw mat closer. "My grandfather built this boat," he said as he waited for his son to bring tea from the Primus burner

sputtering on the stern. "That was six months after Hussain bin Ali revolted against the Turks. When was that? 1918? The whole boat came from one piece of teakwood from Singapore. It was a gift from the steamship line that Grandfather went to work for. Worth 150 English sovereigns, then."

When the tea came Muhammad sipped it judiciously, smacked his lips approvingly and resumed a story he had begun to tell the night before in his home high in a building overlooking the harbor—the story how he, like his father and his father's father, had become the chief pilot of Jiddah.

Four generations ago, Muhammad had begun, his great grandfather was one of the last of the Red Sea captains who sailed their great dhows from Arabia to the shores of India and Africa, riding the winds of *shamal* and *monsoon* in search of cargoes to trade for gold. As was the custom, Muhammad's grandfather sailed with his father and, in the natural course of events, would have become a dhow captain too. About that time, however, Ferdinand de Lesseps finished the Suez Canal and the Red Sea suddenly became a waterway of the world, crowded with fast steamships flying flags from countries everywhere. No match for these huge competitors, the sailing dhows began to fade in importance and it seemed that Grandfather's career as a seaman was at an end. Along a dangerous coast, however, a reef can puncture steel as quickly as wood and the Arabian coast is as dangerous as they come. To lessen such hazards, the steamship lines began to search for pilots with experience and knowledge of the winds, reefs and tides in the Red Sea and soon former dhow skippers began to pop up on the bridges of Western steamships all the way from Aden to Suez. One was Muhammad's grandfather. A few years later his reputation was such that three steamship lines that transported pilgrims from the East Indies, Malaya, Siam and the Philippines—the Blue Funnel, the Netherlands Line and the Rotterdam Lloyd—engaged him as their man in Jiddah, the man who would be responsible for guiding the big steamers through the treacherous triple barrier that guards the harbor.

"And his son, my father, succeeded him," Muhammad had said, "and I succeeded my father and As'ad there" —he pointed to his son—"will succeed me." As'ad, he added, is an apprentice pilot who has already spent three years in Liverpool with a steamship company. Two other sons—Muhammad has 11 children in all—will also study in England and become seamen when they are of age.

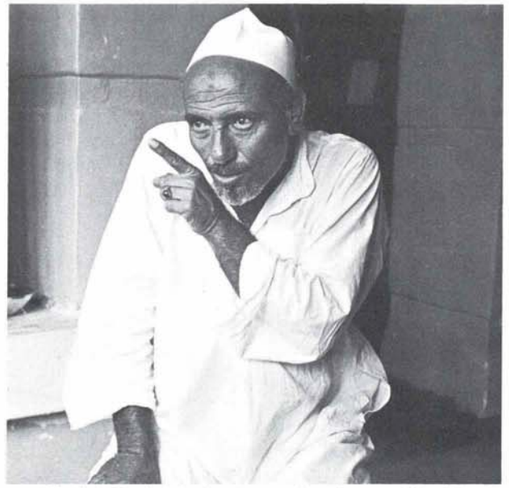
The succession does not occur automatically, Muhammad explained, but only after many years of study and training. And, squatting cross-legged on a rich red rug beneath a fan hanging from the high-timbered ceiling of his home, his charts of Jiddah's harbor spread out before him, Muhammad had gone on to describe how that training is managed.

"The first thing is to teach a boy to swim. From the start he must learn to love the sea, not fear it, and so swimming is essential. Then, he must learn how to handle a small boat with a paddle. Someone goes with him for a few days but after six weeks he should feel at ease alone in a choppy sea. We have a canoe about 12 feet long called a *ghoury*. My father learned all this at 10, but I was 16. He wanted me to finish secondary school first. I went to the first one in all Saudi Arabia, the Falah School."

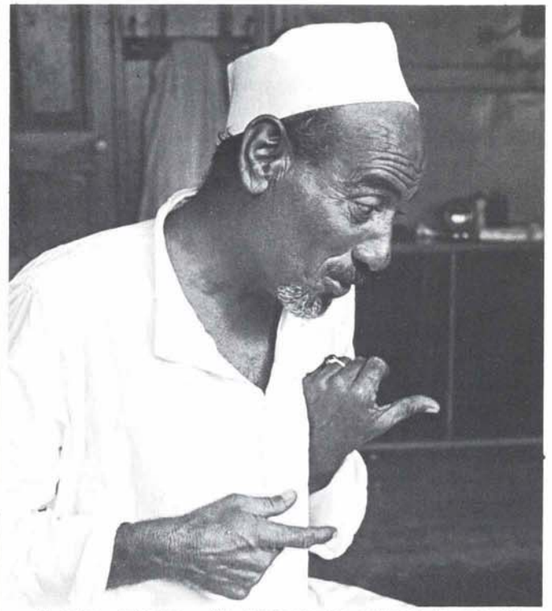
The third step in the making of a pilot is sailing. When a boy feels confident he goes out in a wooden dinghy without ballast and tips it over. The pilot boat crew circles around and watches how he manages to right it. Next, although he continues sailing, come a few years of lessons and hard work, making rope, tying knots, mending sails, repairing fish nets and so on.

Muhammad chats with the captain on the bridge awaiting permission to take the Kuala Lumpur to its berth.

At ease, but alert, Muhammad issues first commands.

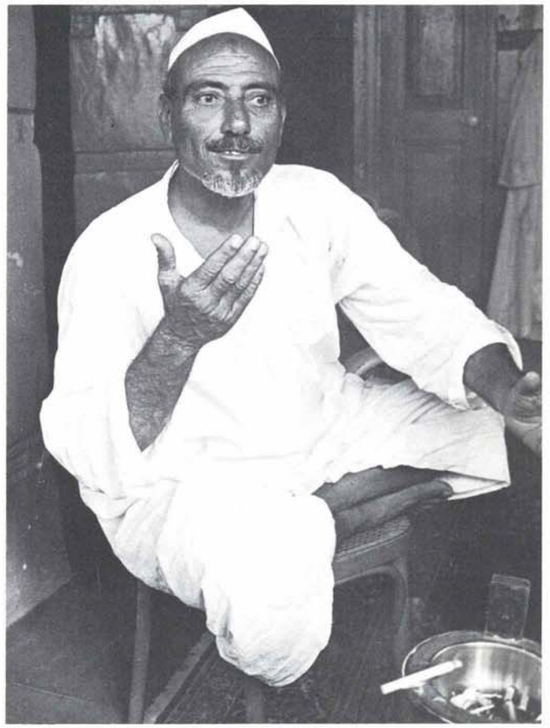


"The first thing is to teach a boy ... to love the sea, not fear it."



"My father used to say ... 'Boy, I teach you this, and here's the reason.' "

"It takes four years. He learns ... he stamps the bottom on his memory."



"...He must learn how to handle a small boat...and feel at ease in a choppy sea."

As he talked, Muhammad had seemed to relive the pleasures and drudgeries of his own apprenticeship. In the cool, carpeted room, surrounded by a cluster of his children, puffing on a cigarette, his face glowing with pride and years of exposure to wind, sun and sea, he alternately trod the water, pulled an oar and forced thick needles through salty canvas.

"After a time," he continued, "I begin to teach him the reefs. *Not* from a chart; that comes later. I say, 'lying this way, that way, so many rocks, depth this side and that; where is the shallow water?' It takes four years. He learns it so, so; easy, you know? He stamps the bottom of the harbor on his memory."

Meantime, the boy is allowed to steer the pilot boat in and out of the harbor, especially at night, but he's never allowed a compass. He has to learn to trust the sky and

the stars. When he finally gets to use a chart and a compass they are simple to him and only extra tools for what he can already do well. There's no danger if the compass goes wrong or a chart is lost or is inaccurate.

The young man goes with the pilot on the bridge every day for at least one year, and is encouraged to ask about anything he doesn't understand—the anchor, the engine, the rudder—and Muhammad always makes sure that his son comprehends every order because some day he will have to give them. "A young man looks to you. What you do, the next time he will do the same. But you must let him know. My father did the same thing with me. He used to say, 'Boy, I teach you this, and here's the reason.' "

If he shows promise at this point, the learner might be allowed from time to time to bring in small ships under the watchful eye of a licensed pilot.

"You watch him closely six or seven times," Muhammad continued. "You tell him, 'Now this is a secret between you and me,' but of course the captain knows he's learning and he'll say, 'I'm very pleased, but next time you'll do better.' Then you ask the captain later, 'What do you think? Can he handle 200 feet?' and the captain might answer, 'Yes, but not with a strong wind.' "

The apprentice is kept on a small ship for two years and watched closely during the first, when the captain always reports to the chief pilot whether the new man seems to have caught the "feel of the bridge." Gradually, in fine weather at first, he works up to ships of 300-500 feet length.

"This," said Muhammad, "is the real school."

Muhammad himself was 28 years old when he finally became a pilot. And when, four years ago, he became chief pilot, he had spent 35 years under his father's tutelage. It takes almost that long, he added, to feel completely at ease bringing the biggest ships into the Saudi Arabian harbor in uncertain weather.

"Sometimes in the winter we see the clouds coming from the south shift unsteadily, and others coming from the north. We have about one hour's warning before the two winds attack each other. We always take care. As you will see tomorrow."

All that had been the night before. Now, sitting on the deck of the pilot boat, Muhammad finished his story, adding a detail here, an anecdote there, his voice rising above the raucous noises from the docks. "We are not the only piloting family in Jiddah," he concluded. "There are two, mine and Sa'id Ragabon's. We have been brothers since my grandfather's day. Not just brothers—good brothers." Both hands came together in a firm clasp. "If one is sick the other helps him out."

At that point one of the ships sent a blast of its whistle across the harbor and Muhammad rose. "It's time to go out," he said.

He moved to the bow of the boat and washed his hands. The helmsman started the motor, eased the boat out of its berth and pointed the bow toward the jagged black volcanic mountains on the horizon which marked the site, 40 miles inland, of Mecca, the holy city. Muhammad bent to his prayers, his silhouette a reverent shape against the sky and the three ships in the haze beyond the reefs. When he had finished, his second son As'ad took the helm and the little boat headed for the largest of three ships in a cluster. As the boat gathered speed Muhammad began to describe the terrain that lies hidden beneath the quiet water. "That shade of green there is maybe three to twelve feet deep ... There are two reefs over there under that ripple; see the crease in the water? ... That wreck over there we put on the reef so as not to lose an anchorage if it sank in the harbor; it caught fire in 1929."

As he talked he gestured at the large white ship which the pilot boat was approaching. Black smoke poured from its green and yellow stack and its festive pennants and its flags stood out stiffly in the breeze. On the starboard side, in Arabic and English was written "*Kuala Lumpur*" and on the stern was added "London."

As Muhammad, his son and the visitors came aboard and began to climb the ladder to the bridge, the commanding officer, Captain A. Watson, stepped forward to greet them. He was a short, good-looking man with a full reddish face set under hair the color of surf. He wore wide white shorts, knee socks, an impeccable cap, and a faint air of impatience.

"Take us in now, please, Mr. Salamah. Much too risky if it gets dark. We'll load tonight and sail at dawn. We're a day late from the weather now and we've had a hundred men waiting five hours for that other ship."

With that he gestured to the first officer and spoke into the voice tube connecting the bridge to the engine room. "Okay, engine room. Righto. We'll take the wheel from here now."

In the bow, two bells clanged and the rattle of the anchor chain vibrated through the ship.

"How is the chain leaning?"

A sailor with a portable electronic megaphone called back: "Up and down."

A buzzer sounded. "Hello? Pardon? Right you are." The engine room was ready and Salamah's voice called out quickly, confidently. "Half astern starboard."

The Malayan helmsman cranked the engine room telegraph and Captain Watson gave what was to be his last command until the ship docked: "Have the port anchor ready. We'll need two on the windlass." He moved to the side and the ship was Muhammad's.

Imperceptibly at first, as the horizon revolved slowly past the mast, the ship began to turn, smoke from the stack billowing off to the side. In the harbor the ship from Karachi, loaded now and its lines cast off, began to move seaward.

"Start the starboard engine."

The telegraph clanged and Muhammad spoke again. "Full ahead two."

On the wing, Captain Watson and As'ad watched quietly, the captain because, for the moment, he had given up the control of the ship for which he is responsible; the son because one day he would be called upon to assume the responsibility that would be his father's in the next tense moments.

"Slow ahead two."

Salamah moved from one side of the bridge to the other, calmly but quickly. Ahead in the channel a waiting tug gave two blasts of its whistle. Between the hull and the buoys marking there was scarcely 30 feet clearance. The channel steadily narrowed and the ship slipped quietly through the deceptive, menthol-green shallows, a few scant feet from the jagged brown spine of the reef.

"Dead ahead two."

Salamah smiled. The captain, standing quietly at the side, frowned at the water. Behind him, As'ad watched intently, his face expressionless.

"Tug on port quarter."

The ship inched between the buoys and edged past the burned-out wreck on the reef. Salamah, legs apart, one hand behind his back, stood stock-still, his eyes darting in all directions as the junior officers paced soundlessly behind him. Captain Watson, his hands behind his back, knotted his fingers.

"Starboard ten."

"Twenty midships."

"Steady ... port 20." Salamah smiled broadly, pushed one foot further into its sandal, slapped the creased cap and readjusted it at a jauntier angle on his head and suddenly everyone knew that it was over. The ship was through and only berthing remained. "Midships," he called. The Malayan boy at the wheel repeated the command.

"Steady!" The echo came back, "steady!"

"Sir, tug is fast on port quarter."

The ship moved in toward the pier, its advance marked by its own deep whistle blasts and the shrill answers from the tug. On the bridge, amid bells and buzzers, Muhammad snapped off crisp commands until at last the ship swung around, its stern easing toward the pier where men scurried about ready to receive the thick hawsers that would lash it to the shore.

Ashore, on the roadway leading to the pier, trucks and buses, their roofs piled high with baggage, began to line up at the gate. In them were pilgrims—now *hajjis*—nearly 2,000 strong, eager to press aboard the ship which would take them back with the good news of their pilgrimage to their families and neighbors in Southeast Asia.

On the bridge the silence continued, broken only by Captain Watson's admiring murmur: "Four and a half million dollars worth of property here and he handles it like a motor car. Excellent. Excellent."

Finally the *Kuala Lumpur* nudged the Jiddah pier and Muhammad, with the authority of four generations of seamen behind him, finished his job and his story.

"Stop engines," he said.

William Tracy, is a graduate student at the American University of Beirut and a regular contributor to Aramco World.