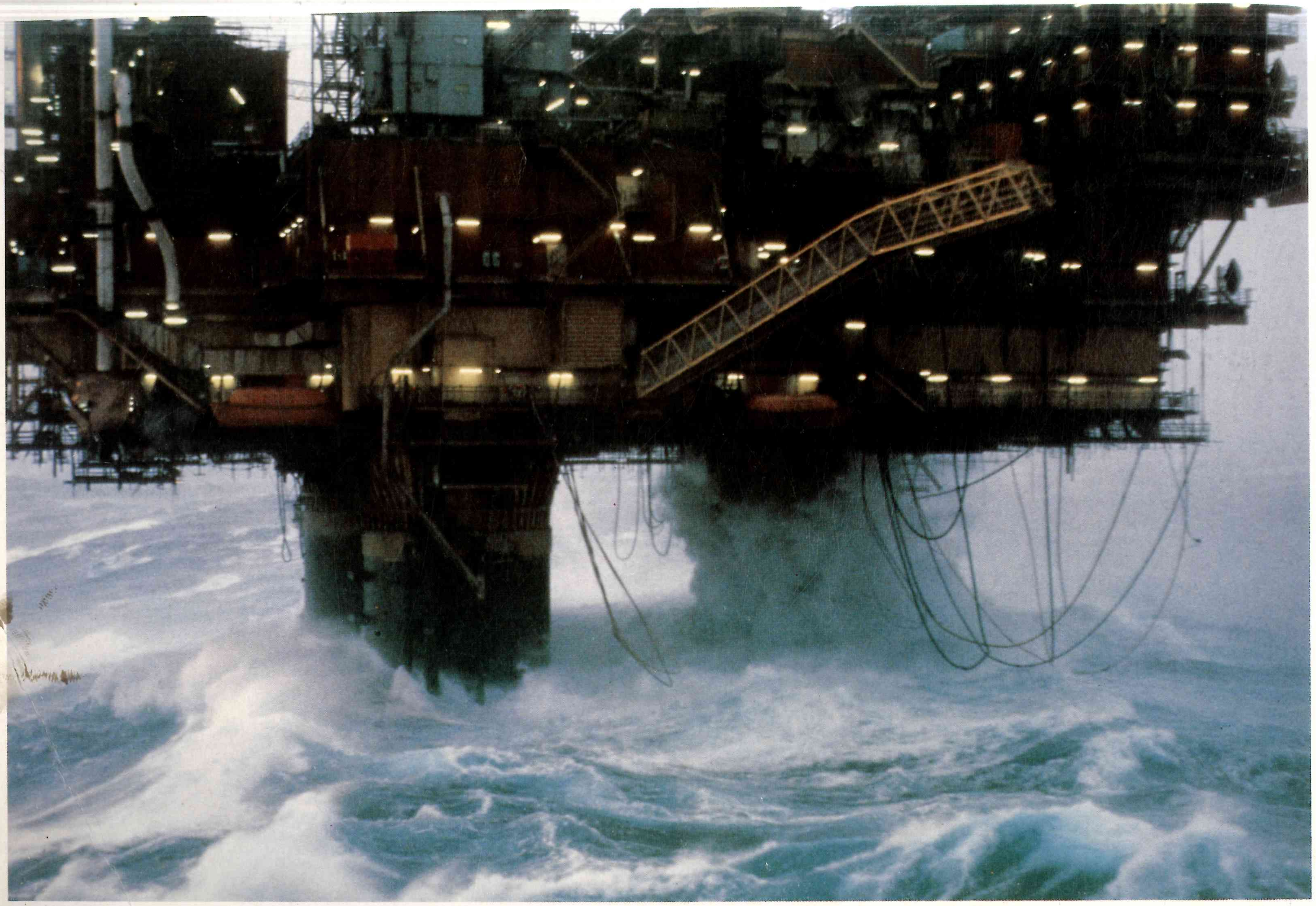
Oil



Oil

Everybody needs oil. It fuels our land, sea, and air transport, and heats our homes and offices. It generates electricity, and provides power and process heat for industry. Oil products lubricate the world's machinery and surface our roads. Countless new chemicals made from oil help clothe us, feed us, and improve the quality of life.

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The Shell/Esso Brent 'B' production platform in the North Sea is lashed by 100 mile per hour winds, and by waves which reach the underside of the deck, 23 metres above sea level.

How oil was formed

Oil is a legacy from the distant past. It is an organic substance, believed to be formed from the remains of animals and plants which lived in the sea 50 million or more years ago. Over long periods of time, and under immense pressures, complex physical and chemical processes turned these once-living tissues into crude oil and natural gas.

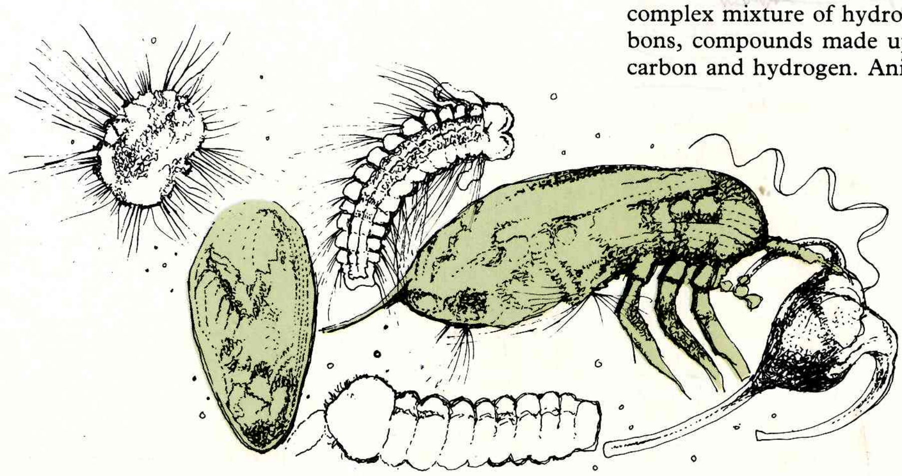
In that far-off time, land plants and animals were very different from those we are accustomed to, but a vast life cycle went on in the sea much as it does today. Countless millions of tiny marine plants – phytoplankton – converted carbon dioxide from the atmosphere into vegetable matter. Vast numbers of minute sea animals – zooplankton – fed upon the plants, and both plants and animals provided the food supply for abundant fish.

As successive generations of this teeming ocean life died, their remains sank to the sea floor. Down with them went particles of mud and fragments of rock eroded from the land surface by wind and water, and carried out to sea by rivers. Over millions of years, organic material and mud piled up in layers hundreds of metres thick. The immense weight of the upper layers compressed the lower layers into rock.

Such rocks, formed by deposition of materials from water, are called sedimentary. They acted as the 'chemical factory' in which crude oil was made from the remains of dead marine life. Crude oil is a complex mixture of hydrocarbons, compounds made up of carbon and hydrogen. Animal and vegetable tissues contained the carbon and hydrogen needed to make hydrocarbons. It needed the high temperatures and pressures, exclusion of air, and long time periods associated with the formation of sedimentary rocks for the reactions to occur and crude oil to form. Crude oil is often called petroleum, which means 'rock oil'.

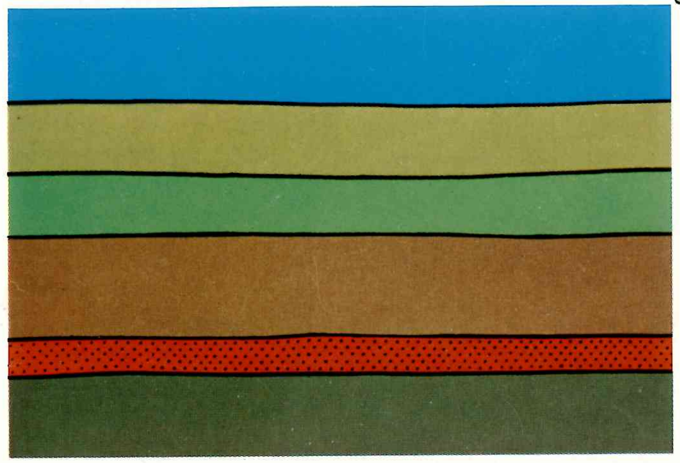
As further layers of sediment formed on top of rocks where oil had formed, their pressure squeezed the oil sideways and upwards through pores in the rock. Where porous rock or sand extended to the earth's surface, oil seeped through. The volatile constituents evaporated, leaving behind bitumen, often used for making ships' timbers watertight.

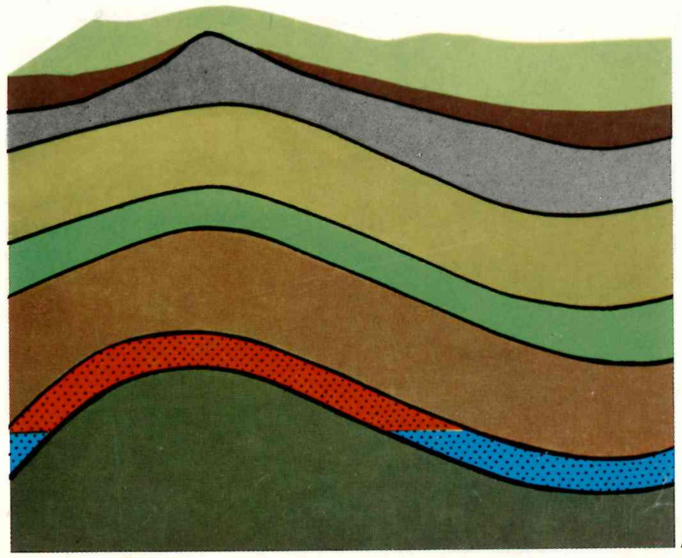
Fortunately for the modern world, much of the oil and gas formed so long ago collected in oil traps. An oil reservoir is like a sponge, in which the oil is held in the pores of rocks, not in an underground pool or lake. Overlying the porous rock, with its precious oil, is a layer of impermeable rock, through which oil and gas cannot travel. Here the oil stays until we are able to detect its presence and drill through the impermeable rock to produce it.



Tiny animals and plants float in the sea; this picture enlarges them 5,000 times.

Layers of mud have settled on the sea bed, burying the remains of myriads of sea creatures; the mud hardened into rock. Millions of years later, the rock layers are bent; oil has been formed, and is trapped in one of the layers. (Oil-bearing rock is coloured red).





Sometimes crude oil seeps to the surface, and forms thick bitumen, which was often used to make ships' timbers watertight.

The search for oil

No one can tell for certain where oil lies hidden in the earth. We have to make intelligent deductions on where oil may be trapped, and then test them by the expensive process of drilling wells. Men have been searching for oil for over a hundred years, but the search has intensified as the great value and versatility of oil has been appreciated.

The first successful well was sunk by Edwin Drake in 1859 in Pennsylvania. He struck oil at a depth of 21 metres. Other people followed his example, first in the United States, then all over the world. After the initial finds in America, oil was later discovered in South East Asia and the Middle East, and many companies were set up to produce, transport, and market this new commodity. Oil has since been found in all the continents, except Antarctica. In contrast to Drake's shallow well, exploratory wells are now often sunk several thousand metres below the earth's surface, and the sea bed off many coasts is being explored for oil.

In the early days of the industry, the search for oil was very haphazard. Apart from drilling in places where oil seeped to the surface, many 'wildcat' wells were sunk on the basis of 'hunch' and the results were often disappointing. Sometimes the pioneers sank wells in areas which have since been shown to contain oil, but they failed to discover it because they did not drill deep enough, or picked the wrong spot to drill.

Sometimes it is possible to see on the surface a rock formation that may be an oil trap, like the anticline opposite. Geologists can study fossils from the rock of such a structure; they indicate the age and type of the rock.

Exploration for oil has become much more scientific, but even with modern techniques and the services of highly-skilled geologists and geophysicists, oil exploration remains a high risk business. Knowledge of the kind of rocks and formations in which oil is found does help to cut down the areas of search, however. As we know that oil was formed in sedimentary rocks during certain eras of geological time, we can concentrate the search on rocks of the right type and age.

The search for oil is complicated by the fact that the earth's surface has undergone immense upheavals in the millions of years since oil first began to form. Huge earth movements have pushed up mighty mountain ranges like the Himalayas and the Alps, while other areas, which were once dry land, have sunk beneath the seas. Even the continents have moved: scientists believe that the Americas and Australasia were once joined to the land mass of Europe, Asia, and Africa, but shifted to their present positions by a process known as continental drift.

The oil-bearing formations could not be unaffected by these millions of years of upheavals. Some sedimentary rocks were pushed up out of the sea to form dry land, and others were buried deep under rocks of different kinds. Enormous pressures pushed whole layers of rocks sideways, so that they wrinkled or folded or were broken. Entire segments of the earth, composed of many different layers of rocks, bent and buckled and folded over in a great variety of formations.

Some of these deformation patterns are favourable to the collection of oil. One of the commonest is known as an anticline, where the layers of rock have been pushed upwards to form a dome or arch. Under the dome of the anticline oil or gas may have collected, trapped by a layer of impermeable rock which prevented it moving sideways or upwards. If a well is drilled to pierce the impermeable rock of the anticline, then the oil and gas can be reached and brought to the surface.

Essentially, the task in oil exploration is to locate sites where there are geological structures in which oil or gas might have been trapped.

The first step for the survey team is to study all the available geological and geographical information about the area under investigation, and to prepare detailed maps. Aerial photographic surveys are often undertaken, especially in remote locations where little exploration and mapping has previously taken place. From this preliminary information, the geologists piece together a rough picture of the rock formations which lie underground.

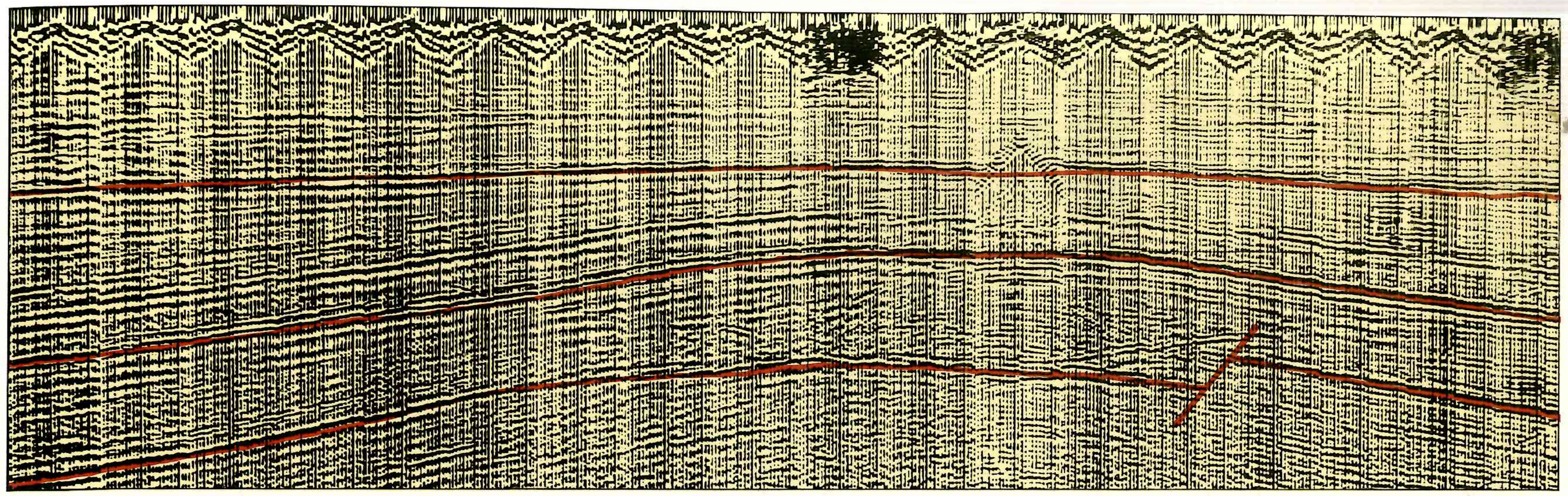
Certain districts are then chosen for more detailed survey. Often travelling on foot, trekking through forests or wading through swamps, geologists examine the earth with great care. They look for outcrops where underlying rocks jut out of the soil, and for exposed layers of rock in cliffs and river canyons. They chip off rock specimens for examination, and bore down into the earth for samples of underlying formations. They take a close look in the microscope at any fossils in the rock specimens, because they indicate the age of the rocks. Slowly they try to piece together the geological history of the district, recording the types and ages of the rocks and the patterns in which they lie.

Left, **one of the commonest oil traps is an anticline.**

Geological surveys are now usually supplemented by geophysical surveys to provide a more accurate picture of rock formations lying deep below the surface of the earth or the sea bed. One technique used by geophysicists, called gravimetric survey, makes use of the fact that underground rocks of different densities and depths cause slight variations in the force of gravity at the surface above them. These variations can be measured with very sensitive gravimeters, and they add further detail to the underground map of the area.

Seismic survey provides further accurate information on what lies underground. A miniature earthquake is caused by exploding a charge of dynamite in a hole in the ground, or by dropping a heavy weight on the surface, and the time taken for the shock waves to bounce back to the surface from hard layers of rock underneath is measured. The time interval indicates the depth of rock, and simultaneous measurements at different points show the slope of hard rock layers.

At sea, a compressed air gun is used instead of dynamite to create the shock waves for seismic survey. The technique plays a major part in the discovery of offshore oilfields, since detailed geological survey of the ocean floor is much

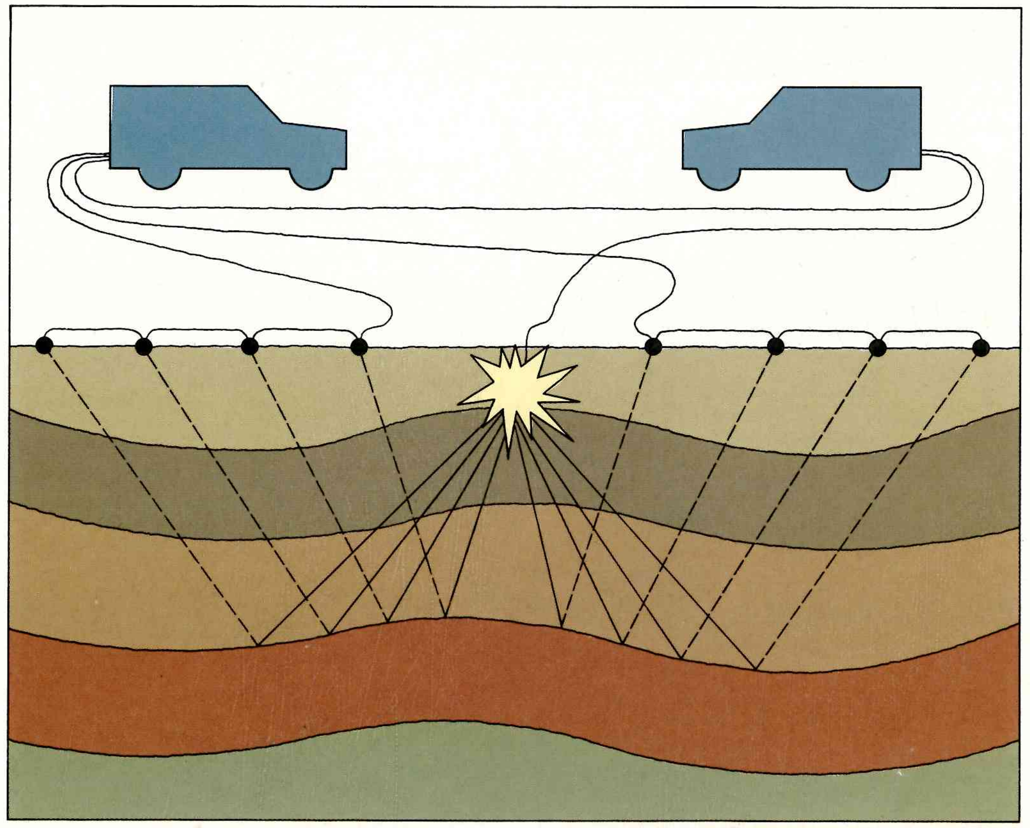


more difficult, partly because there are very few rock outcrops on the sea floor.

The geological and geophysical surveys produce masses of data which are analysed by computer in a great variety of ways. The computer results are studied and interpreted by geologists and geophysicists with long experience of oil production, and the moment arrives to decide whether the results look promising enough to justify drilling a test well. If so, the next decision must be to choose the exact spot, in the hundreds of square kilometres covered by the survey, where the well is to be drilled.

The search has cost a great deal of time and money, and the drilling will be even more expensive, especially if it is to take place offshore. Nevertheless, a final decision must be made. After long consultations the pencil point comes down on the map for the last time, and the spot is chosen.

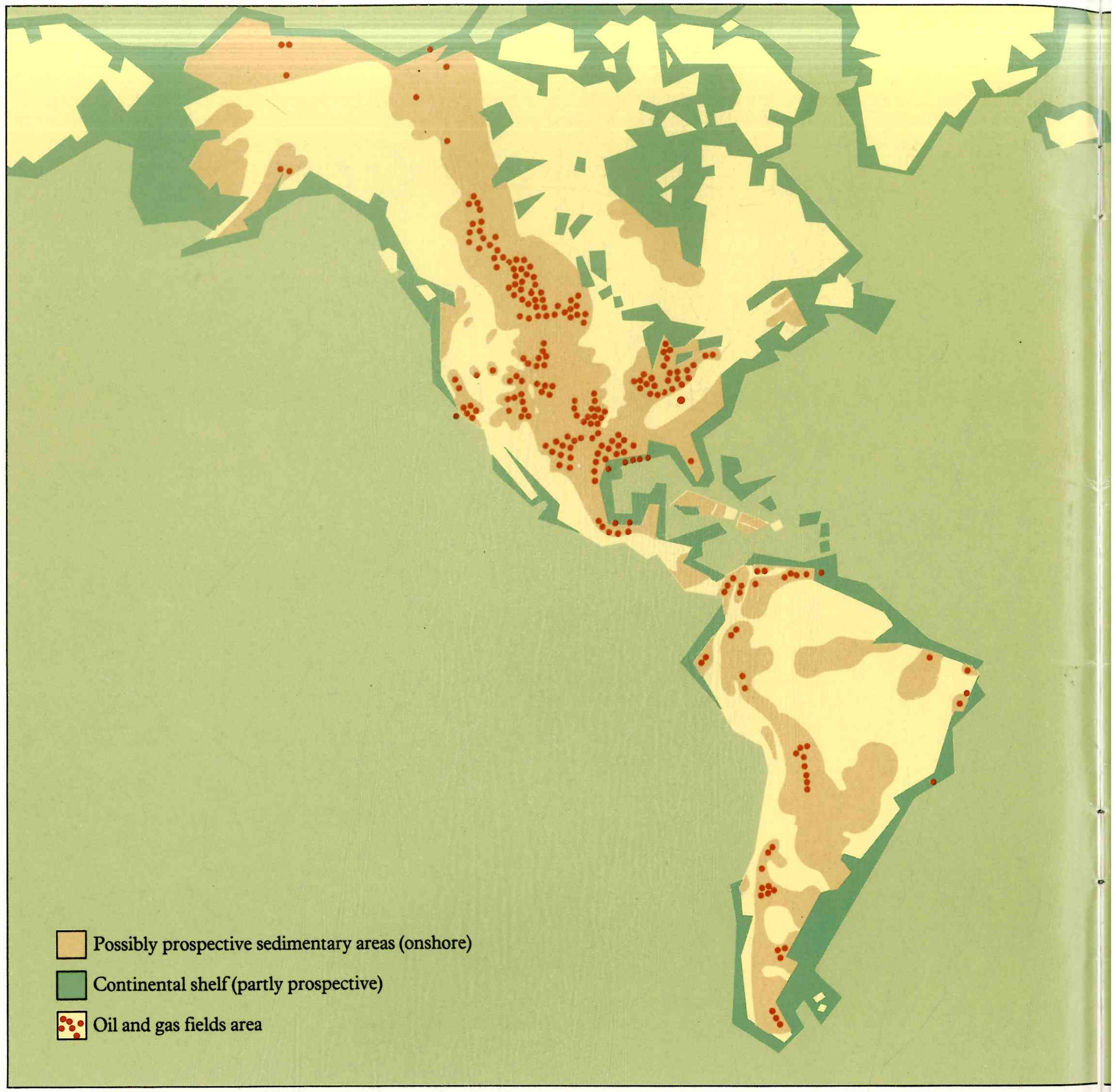
Shot-hole drilling during a seismic survey in the Camerouns.

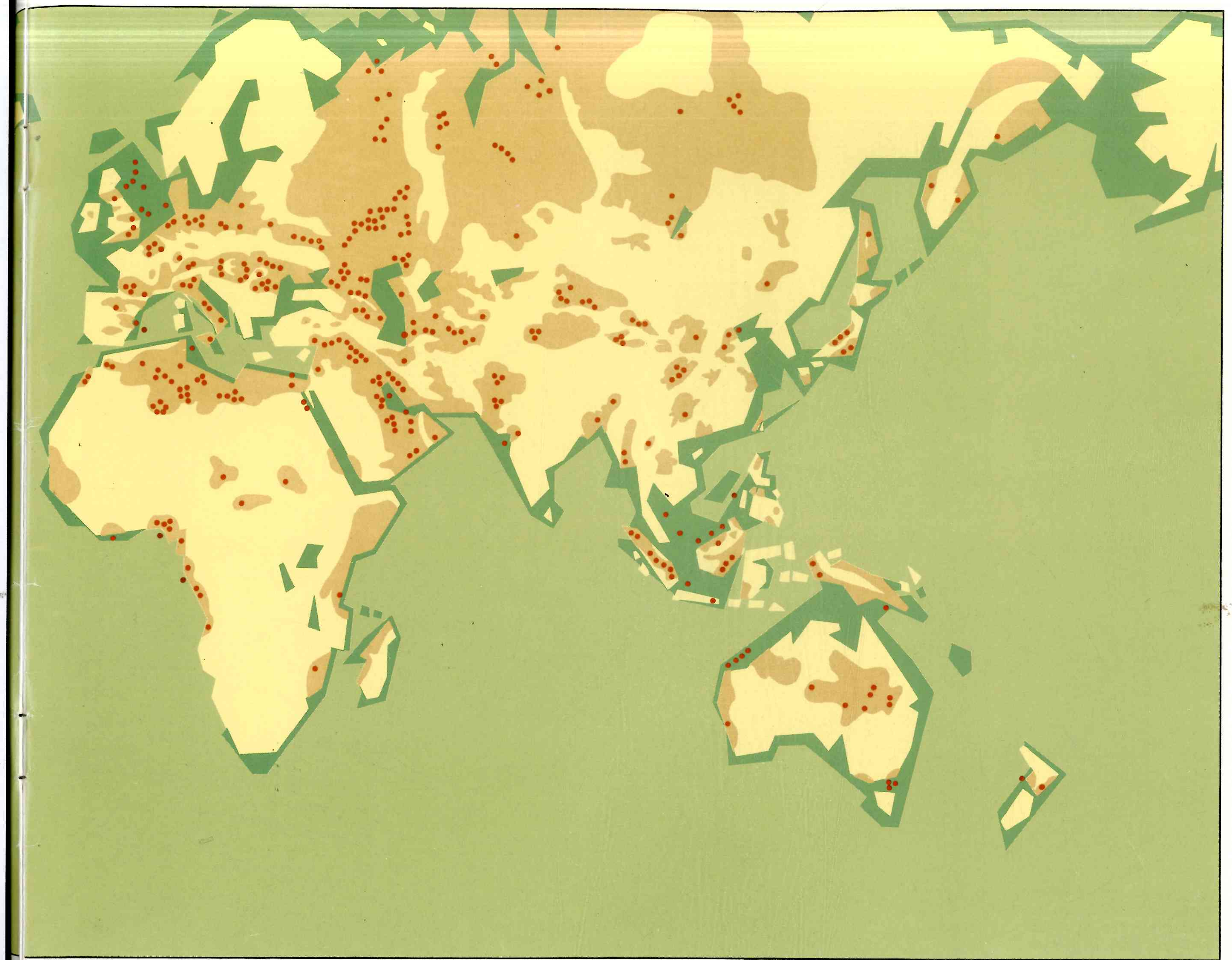


Seismic survey: the diagram, *left*, explains how the shock waves move through layers of rock, and are recorded by means of measuring instruments on the surface. *Above*, seismic records put side by side give a clue to the position and shape of the rock layers.

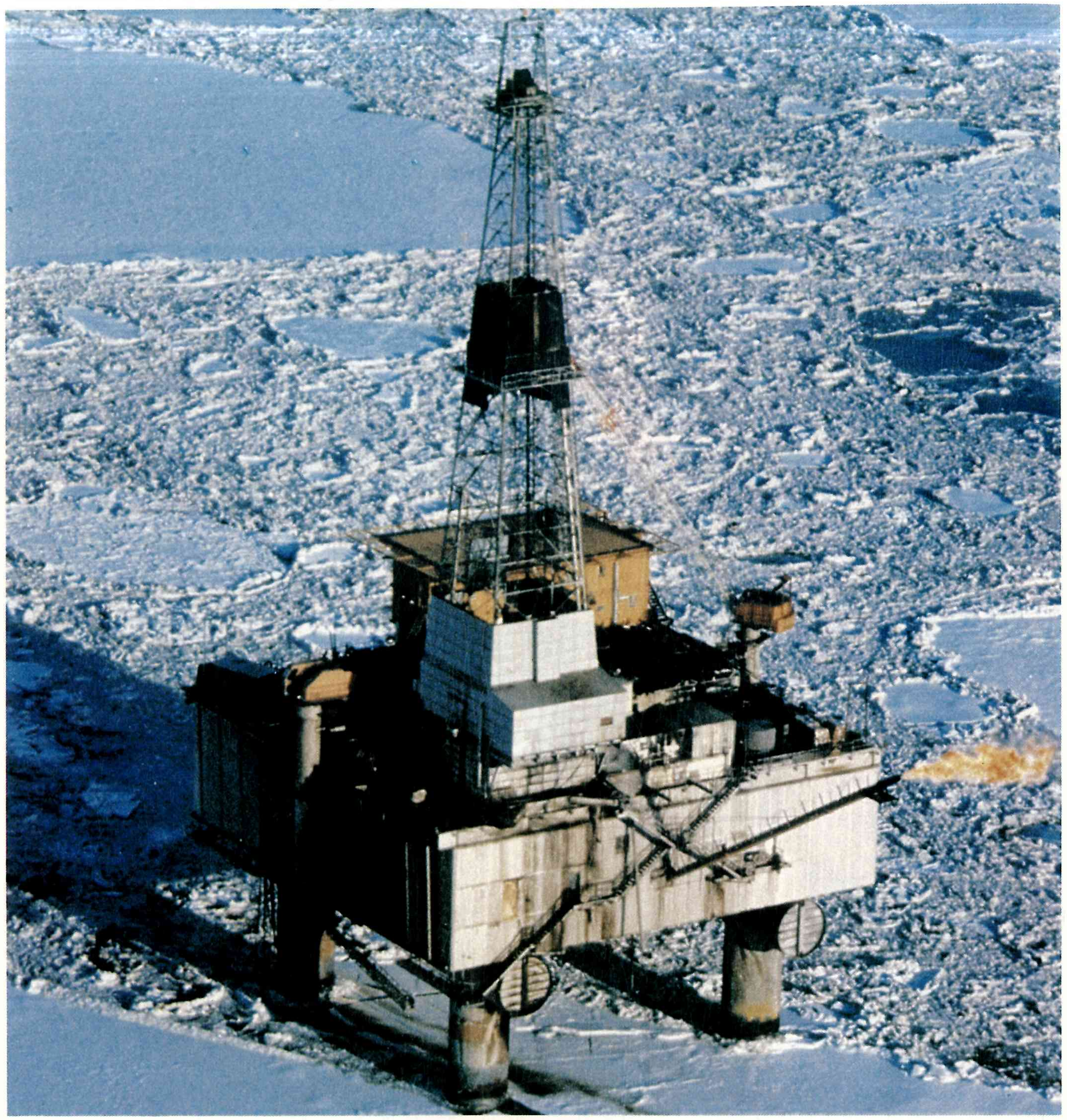
The world's oil

There are four main oil-producing areas in the world: the United States, the Middle East, the countries around the Caribbean, and the USSR. This map shows the most important oil and gas fields in these areas and elsewhere.

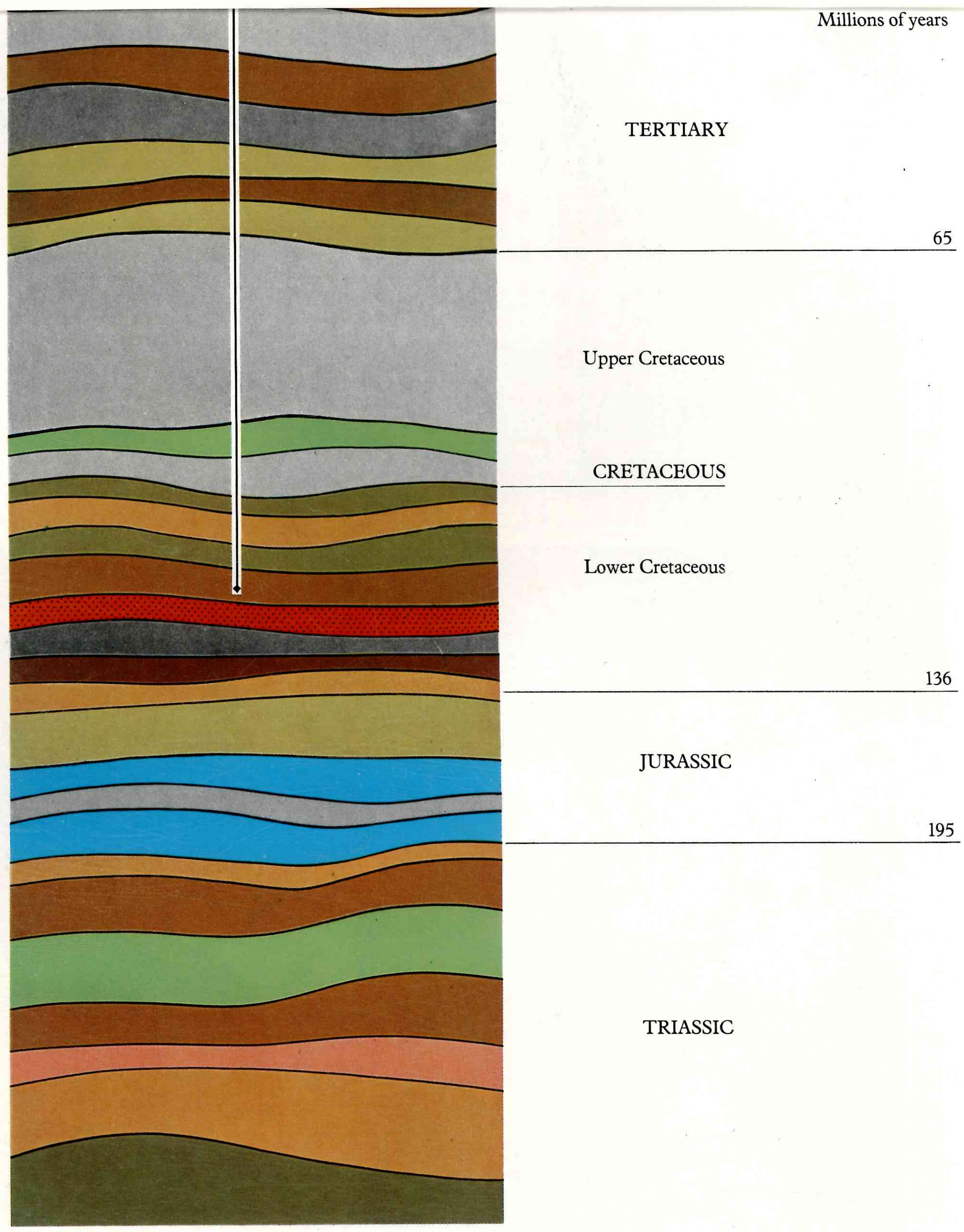


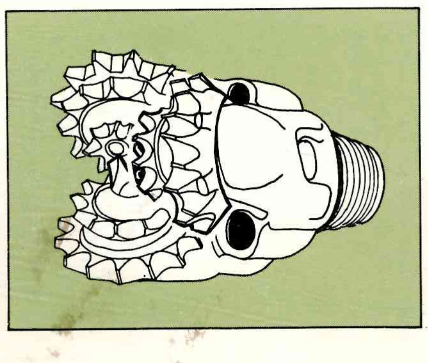


Drilling



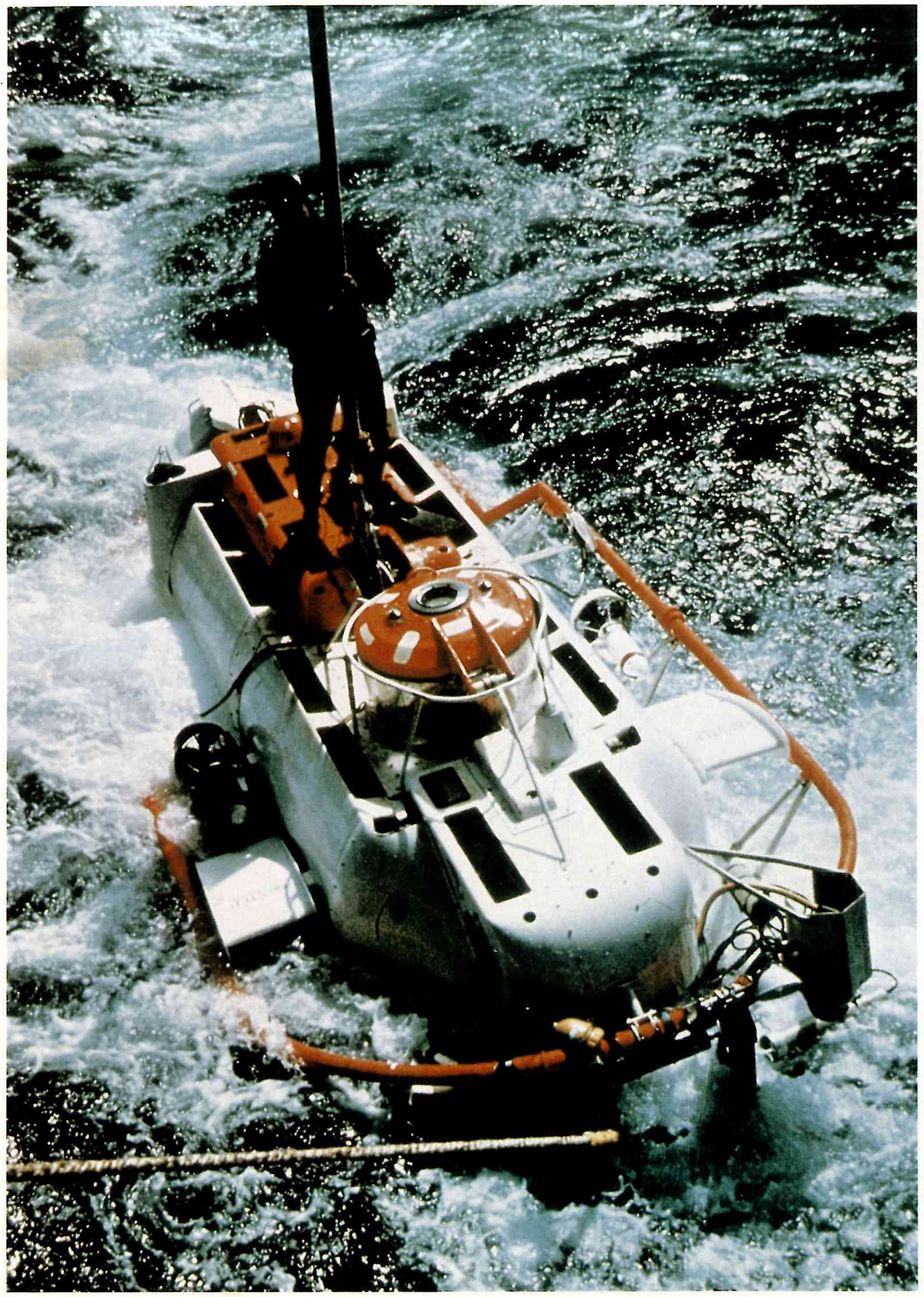
A platform in Cook Inlet, Alaska, which must withstand the ice floes which batter it four times a day, in rhythm with the tides.





A drilling bit.

A mini-sub assisting with the laying of pipelines in the North Sea in 1976; these vessels can dive for up to twelve hours at a time.



reassembled. This operation is called a 'round trip' and can, in a deep well, take most of a 12 hour shift, and involve the dismantling and reassembly of a drill string weighing well over 100 tonnes.

The rate of drilling varies according to the hardness of the rock. Sometimes the bit may cut through as much as 60 metres an hour, but in a very hard layer progress may be as little as 30 centimetres an hour. Drilling goes on until oil or gas is reached, or all hope of finding it is given up. Most oil wells are between 900 and 5,000 metres deep, but wells as deep as 7 or 8 kilometres are sometimes drilled.

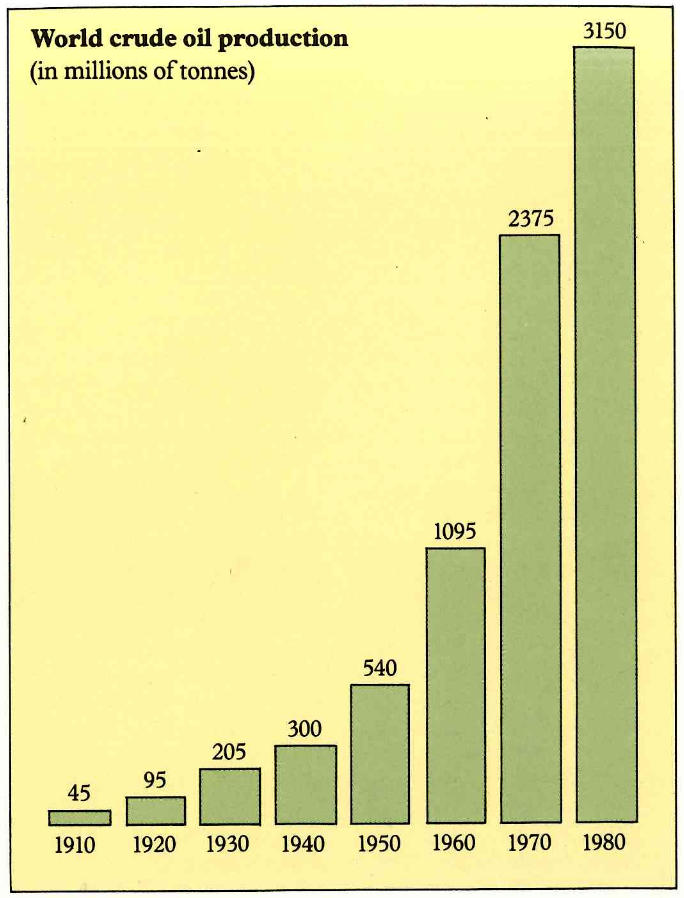
Drilling at sea does not differ in principle from drilling on land, but it poses some extra problems. The drilling rig has to be firmly supported so that it remains steady, whatever the state of wind and waves. Great technological ingenuity has gone into designing various types of platforms and drill-ships, so that oilmen can now drill in water over 1,000 metres deep.

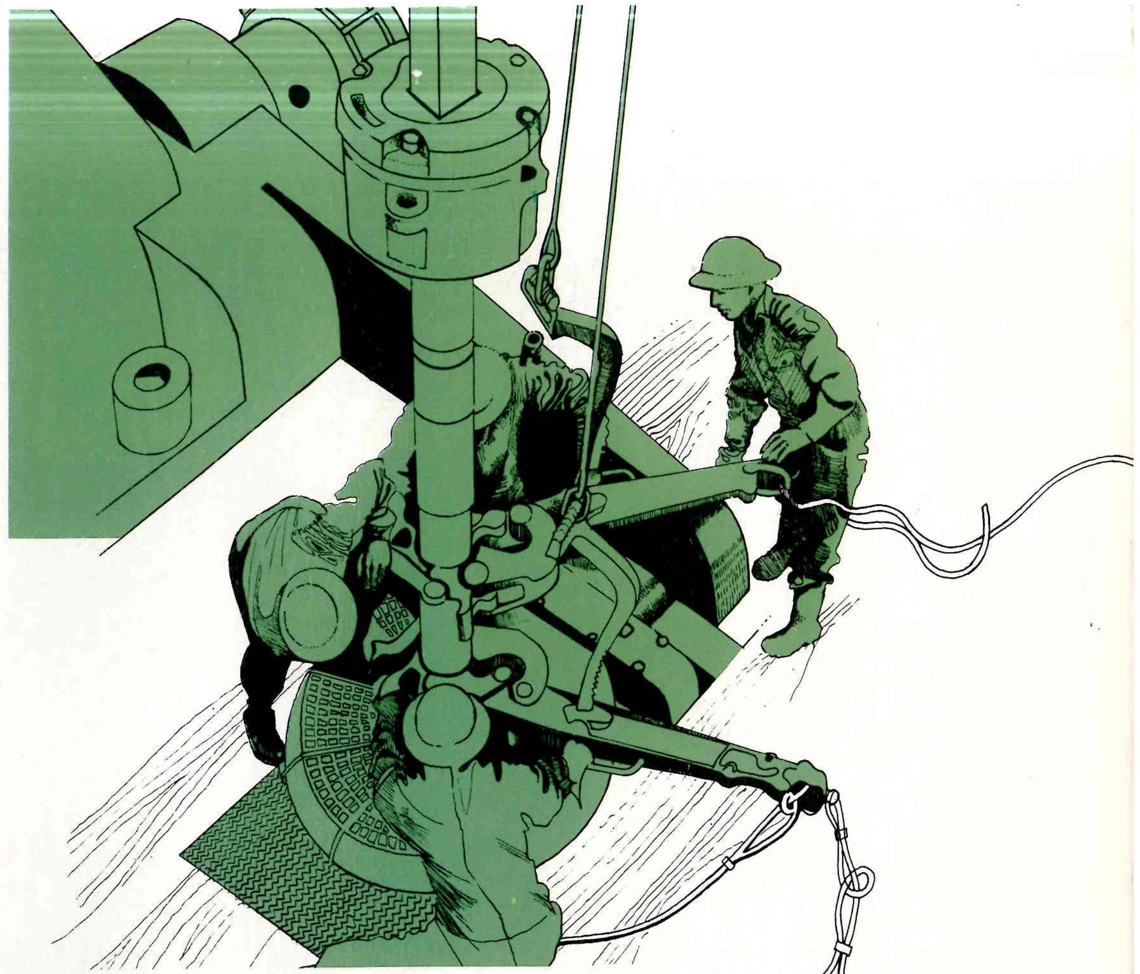
Wherever drilling is taking place, special care has to be taken as the drilling bit nears a formation containing oil and gas. The high pressure in an oil trap may force oil and gas up to the surface in a violent surge as the drill breaks through the impermeable rock. Such blow-outs or gushers were common in the early days of the oil industry, but oilmen are now trained to prevent them, as they waste hydrocarbons, pollute the environment, and carry a high fire risk. The 'toolpusher' in charge of drilling can anticipate the danger of a blow-out occurring when rock chippings from the well bottom show traces of oil, or when instruments on the derrick floor show rising pressures in the well. He can pump down heavier drilling mud to hold back the oil, or close special valves, known as blow-out preventers, fitted to the top of the well casing.

When a well is put into production, the derrick is taken away, and an assembly of pipes and valves, known as a christmas tree, is sealed into the well-head. The christmas tree controls the flow of oil from the well through a pipeline to a gathering station, where the oil from several wells is collected. Equipment at the station separates gas from oil, and drains off water, which often contaminates the oil flow.

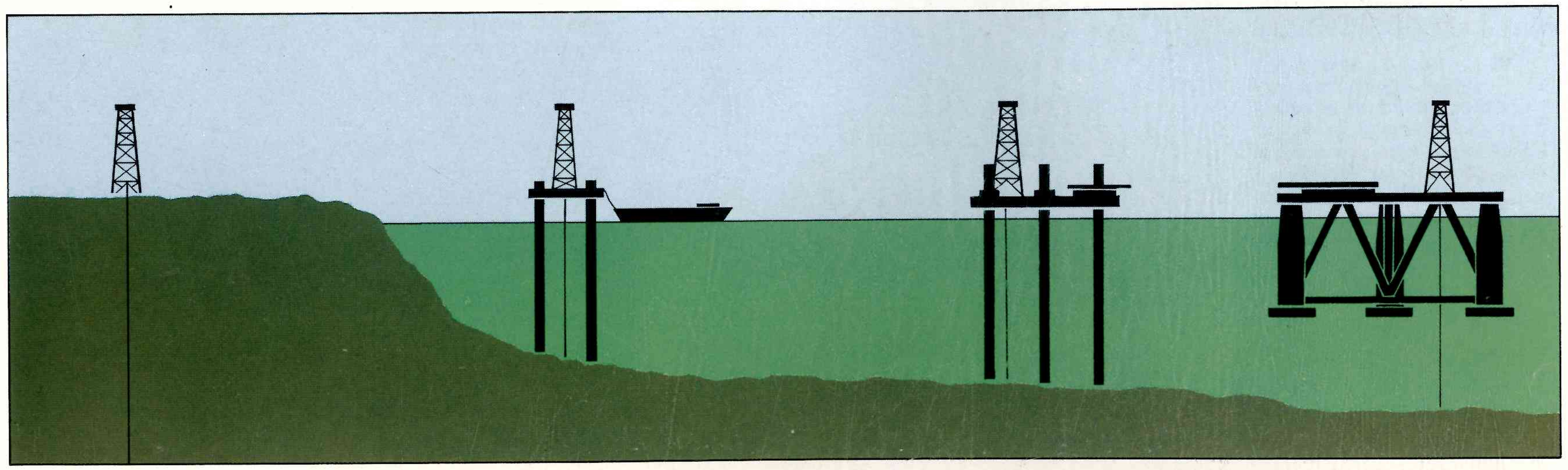
In the early years of an oilfield, underground pressure is usually sufficient to push the oil to the surface, but if the pressure is insufficient, a 'nodding donkey' plunger pump may be inserted in the well. As the field is depleted the pressure drops and the oil becomes more difficult to recover. In the past, wells were often abandoned when only 10 to 20 per cent of the oil they contained had been recovered, but the oil industry has introduced secondary recovery techniques which increase the yield of oil to 30 to 40 per cent. They include the injection of water or gas to increase pressure and flush out oil from porous rocks. Where fields contain thick, heavy oil, steam may be injected to make the oil flow more freely.

The oil industry is giving high priority to the development of enhanced recovery methods, such as the injection of chemicals or carbon dioxide gas, which will further increase the yield of oil.





On the derrick floor the drillers screw in an extra length of pipe to the drill string. While this is being done, the kelly and its bushing have been raised above the rotary table.



Four types of drilling rig; a land rig, an underwater platform with a drilling barge, a movable platform, and a floating rig held by anchors.

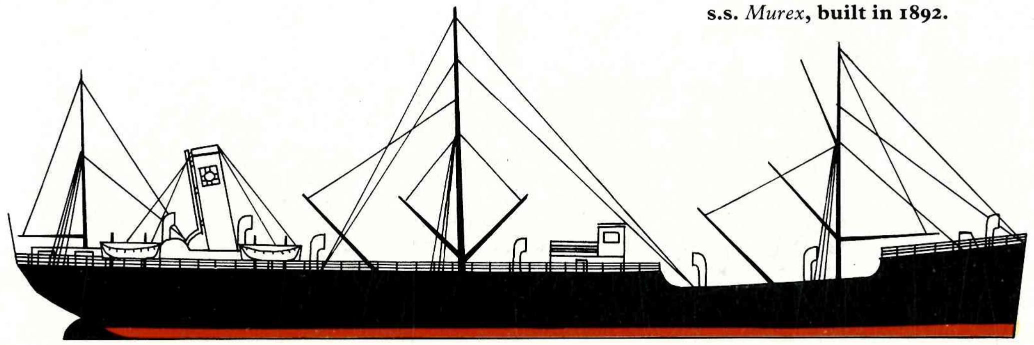
Pipelines and tankers

The crude oil that flows up from a well is of no use to anyone as it is. It must be changed into petrol, fuel oil, lubricating oil, and the many other products that can be manufactured from it. All this takes place in a refinery, but first there is the problem of getting the crude oil there.

It is no small problem, for the movement of oil and oil products is the biggest transport operation ever undertaken. At any given moment, over half the cargo crossing the oceans is oil, and further vast tonnages are flowing through pipelines.

The major traffic in crude oil is from the producing areas to the industrialised nations. In the early days of the industry, crude was usually refined near to where it was produced. Now markets have grown enormously, and the range of oil products has multiplied, and it has become more economic and convenient to refine oil in the countries where oil products are most in demand.

The most convenient way to move oil overland is to pump it along a pipeline. This is basically a long pipe built up from lengths of steel tube welded together. Crude oil pipelines are usually large in diameter, often over a metre across. Pumping stations are built at intervals along the line, so the pipeline can extend over any required distance – hundreds or thousands of kilometres if necessary. The pumps keep the oil moving at between five and seven kilometres an hour.



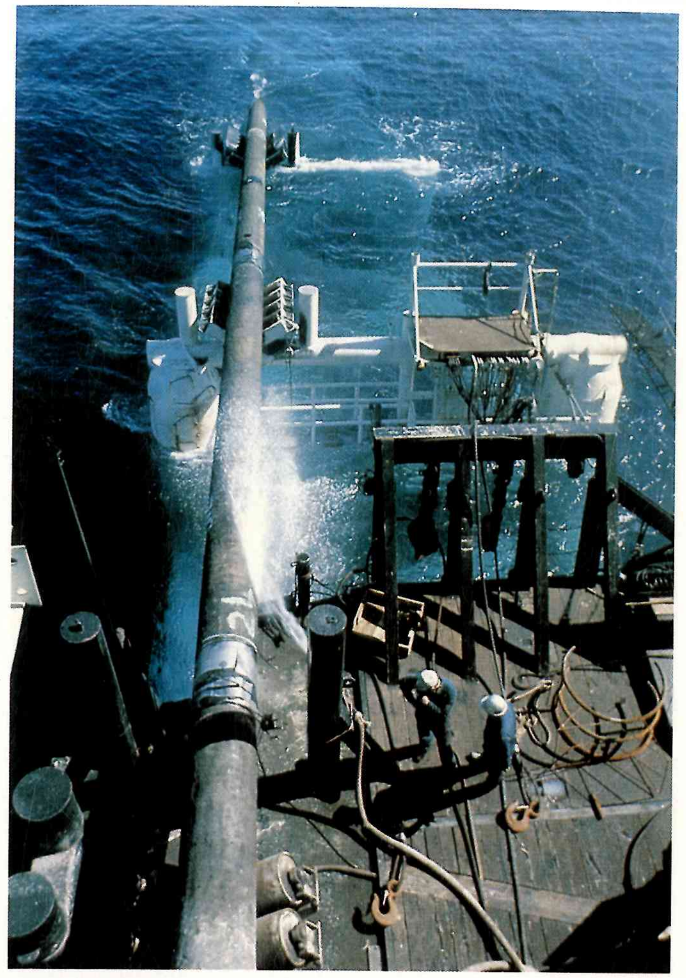
One of the earliest oil tankers: s.s. *Murex*, built in 1892.

Laying pipelines is an immense engineering task, especially in remote and rugged areas. They may have to cross mountains, or go beneath rivers, marshes and swamps. Across deserts or other sparsely populated areas the pipelines may sometimes lie on the surface of the land, but in inhabited areas they are always buried.

In many oil-producing regions, pipelines are built to carry crude oil to loading terminals where it is pumped into tankers for transport to refineries overseas. When oil was first transported by sea, it was filled into barrels containing 42 US gallons (35 imperial gallons or 159 litres) – the barrel is still the main measurement used by the oil industry – which were loaded into the holds of ordinary cargo ships. Nearly a hundred years ago, Marcus Samuel, the founder of Shell Transport and Trading, adopted the idea of building ships which were, in effect, floating tanks, and the oil tanker was born.

The main design feature of an oil tanker is the division of the oil carrying space into separate tanks, which prevent excessive movement of the cargo at sea, and enable different types of oil or oil products to be carried. Engines and living quarters are in the after parts of the ship, and so, too, in many modern ships, is the navigating bridge. This arrangement keeps the machinery and accommodation away from the inflammable cargo.

The most striking development in tankers over the years has been a great increase in size and carrying capacity. Per tonne of cargo carried, it is



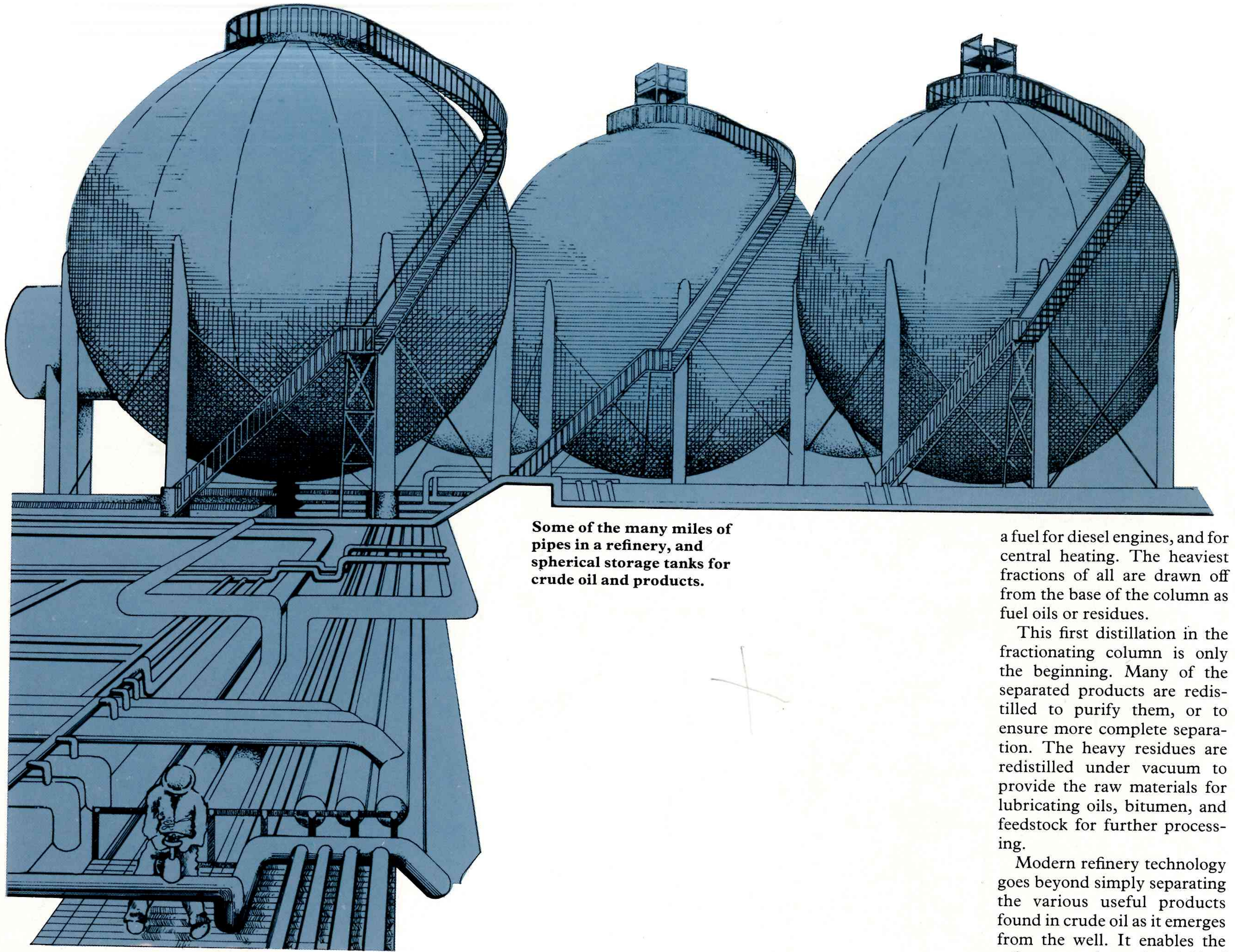
Left, **Semac I, a semi-submersible pipe-laying barge, at work in the North Sea.** *Above*, **another pipe-laying barge, showing welded pipeline leaving the barge and passing down the stinger which guides the pipe towards the seabed.**

cheaper to build and operate a large tanker than a number of smaller ones. Big tankers also contribute to safety at sea: one 'supertanker' can do the work of up to 20 smaller ships, thus reducing congestion in crowded sea lanes.

Unlike crude oil, natural gas does not need to be refined. After simple treatment, it is ready to use for domestic heating and cooking, as fuel for industry, or as chemical feedstock.

Until fairly recently, natural gas was only put to use when it

An aerial view of a refinery in Australia.



Some of the many miles of pipes in a refinery, and spherical storage tanks for crude oil and products.

a fuel for diesel engines, and for central heating. The heaviest fractions of all are drawn off from the base of the column as fuel oils or residues.

This first distillation in the fractionating column is only the beginning. Many of the separated products are redistilled to purify them, or to ensure more complete separation. The heavy residues are redistilled under vacuum to provide the raw materials for lubricating oils, bitumen, and feedstock for further processing.

Modern refinery technology goes beyond simply separating the various useful products found in crude oil as it emerges from the well. It enables the refiner to reshape the yield of products from crude oil so that it matches the pattern of demand.

Over half the products obtained by distilling crude oil are heavy fractions, but public demand is greatest for the lighter fractions, particularly gasoline. So chemists have found ways of changing the chemical structure of the heavier fractions and converting part of them to gasoline. These processes, known as cracking, break up the large molecules of the heavy fractions into smaller molecules such as those in gasoline.

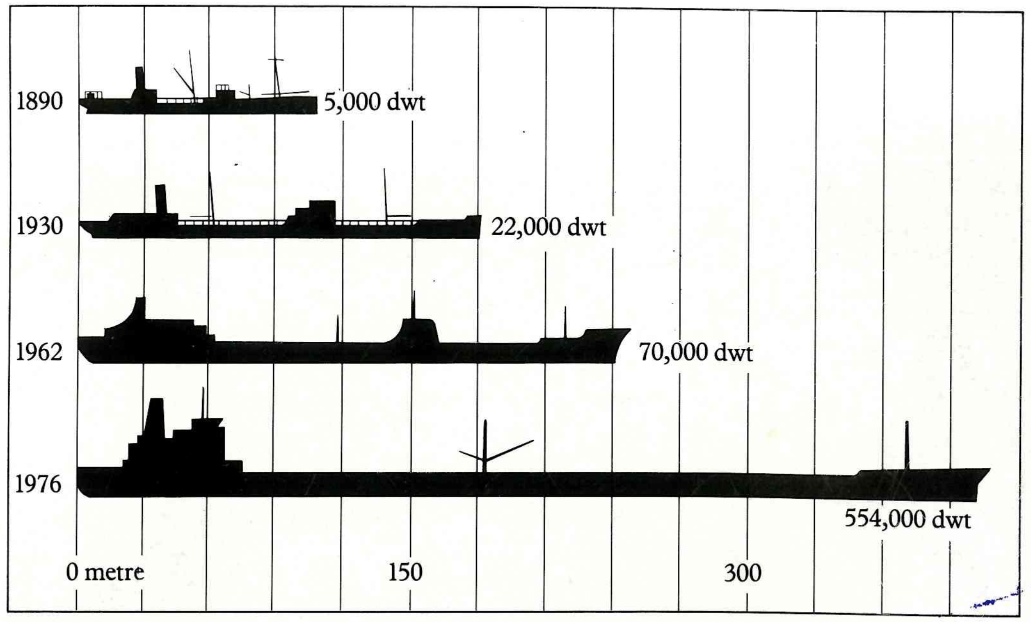
Heavy fractions are cracked by applying great heat. When this is done in the presence of a catalyst, a substance that helps to bring about chemical change without itself being changed, it is called catalytic cracking, or 'cat cracking' for short.

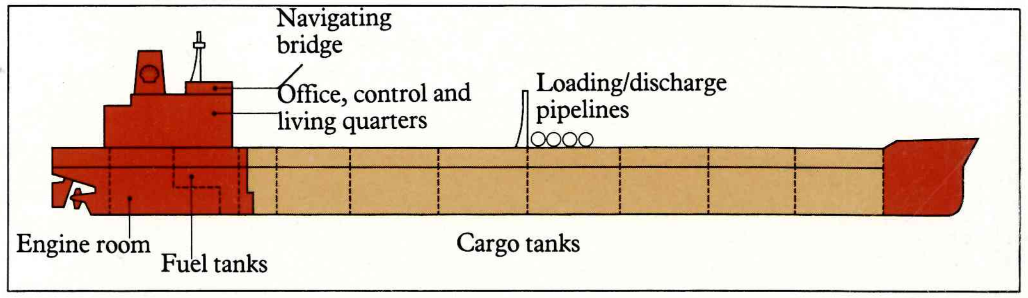
Cracking produces additional gasoline of very high quality. It is valuable for blending with the gasolines produced by distillation to give the top quality grades of petrol.

Low-grade gasolines obtained by distillation can also be improved in quality by reforming. This is a process which changes the molecular structure by heating under pressure, usually in the presence of a catalyst.

Cracking and reforming give the refinery much greater flexibility in meeting varying patterns of demand. The refinery manager has to be ready to increase or reduce, at short notice, the amount of any particular product being manufactured as demand changes with the weather or other factors.

The space age appearance of a refinery, with its strangely shaped towers and storage tanks and miles of connecting pipes is visual evidence of the many sophisticated processes which give us the oil products we need.





The size of oil tankers has considerably increased over the years; *above*, a cut-away diagram of a typical tanker; *right*, a tanker at sea.

Left, a tanker berthed along side one of the loading jetties at Sullom Voe, in the Shetland Isles.

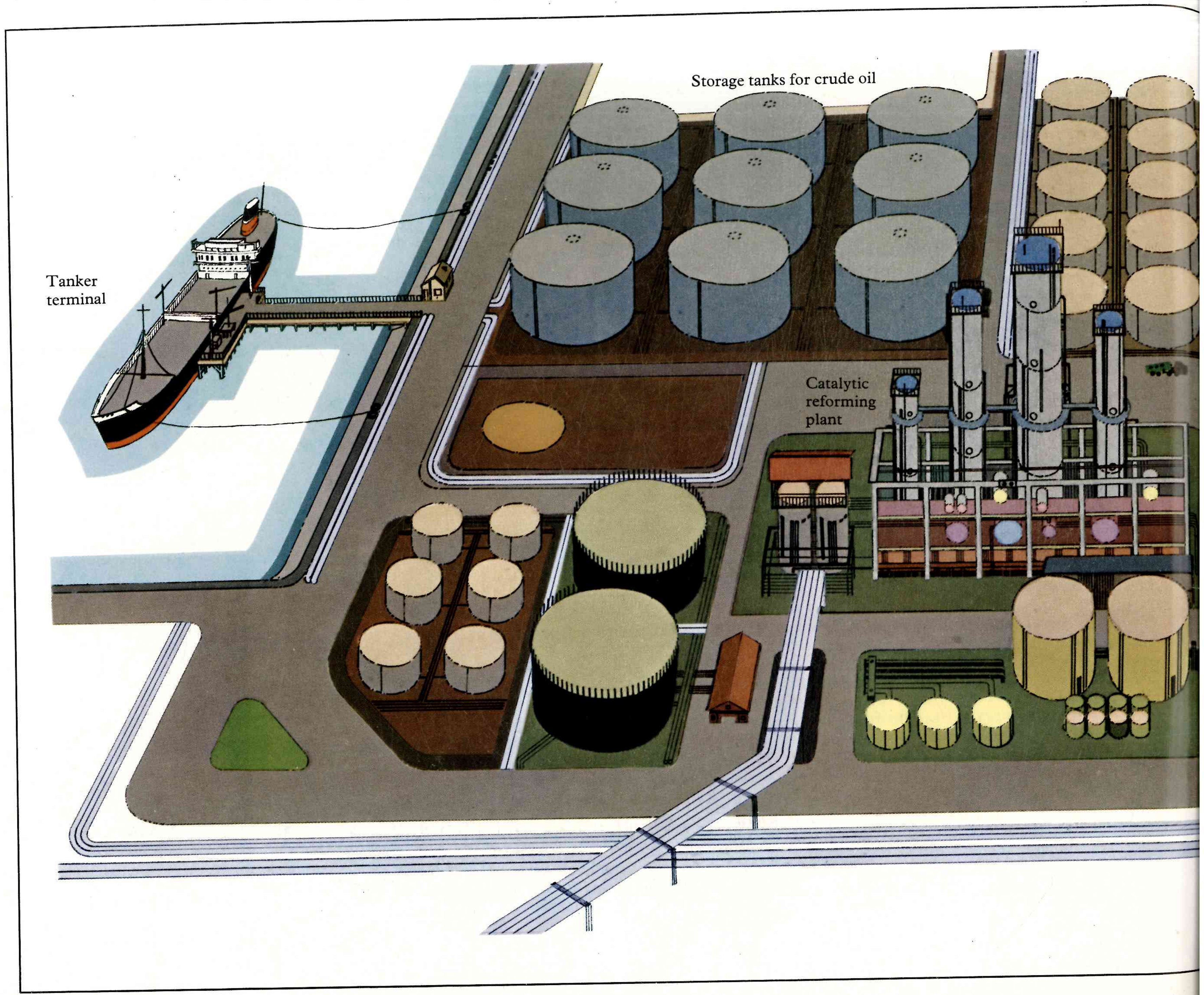
was produced in locations where it could be pumped by pipeline to populous areas. Gas pipelines are similar in design to those which carry oil, with compressors pushing the gas along the line.

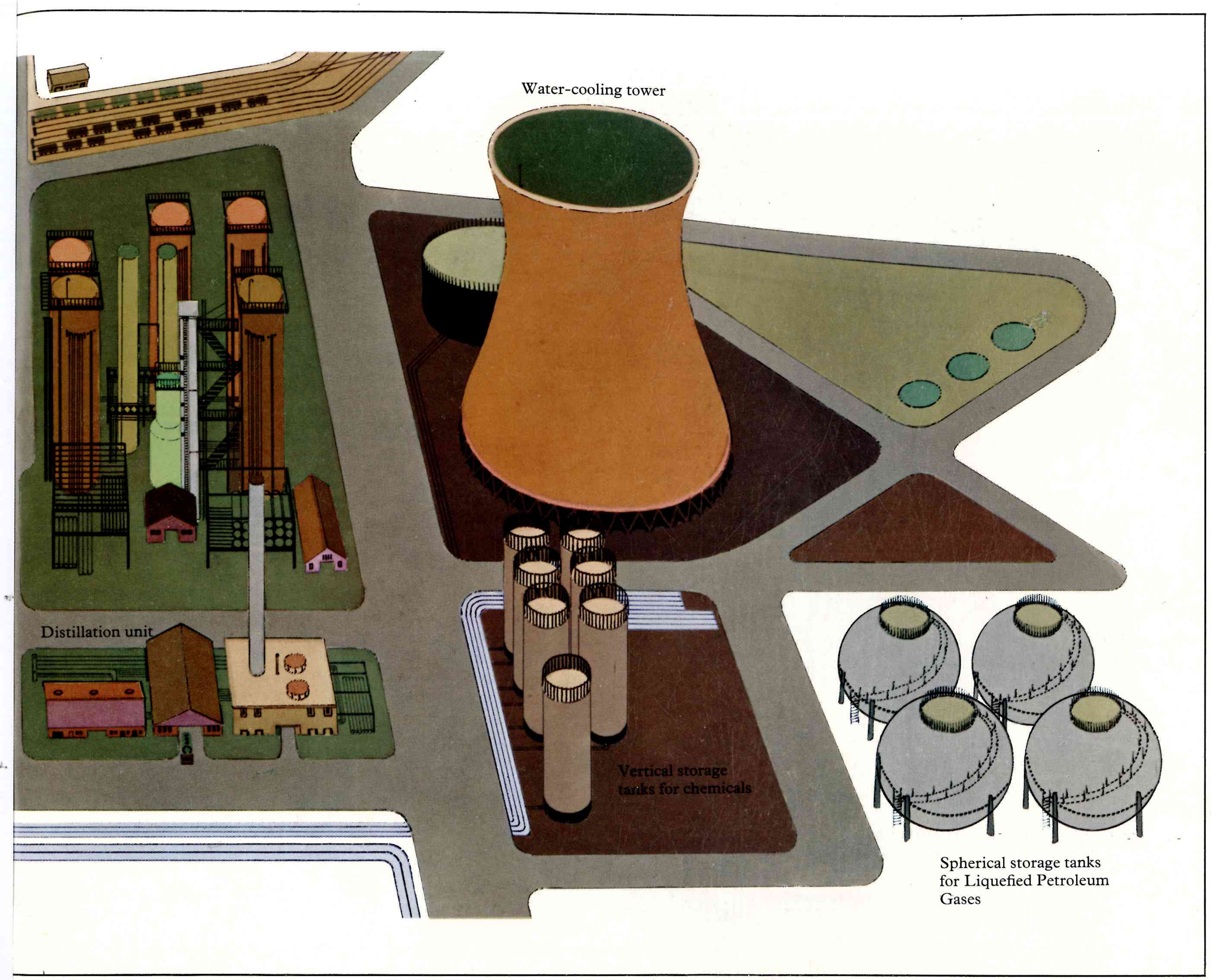
Transport of natural gas across the oceans started in 1964, and it has developed rapidly. Gas produced with oil in remote locations used to be flared, but in several oil producing areas there are schemes to collect the gas and ship it to markets overseas.

Before shipment, natural gas is turned into a liquid by cooling it to −161° centigrade. Liquefaction reduces the volume by a factor of 600.

Liquefied natural gas (LNG) is transported in a special type of tanker, with an insulated hull, and special steel tanks which can withstand the intense cold of the liquefied gas. The liquid is pumped ashore to storage at the end of the journey, and turned back to gas before use.

An oil refinery




Water-cooling tower
Distillation unit
Vertical storage tanks for chemicals
Spherical storage tanks for Liquefied Petroleum Gases

The refining of oil

Crude oil is not a simple substance, but a mixture of many different kinds of liquid. Before we can use oil as fuels, lubricants, road surfacings or chemical feedstocks, the liquids in crude oil have to be separated, purified, blended, and sometimes chemically or physically changed. This is the work of the oil refinery.

The first process in oil refining is distillation of crude oil. Distillation involves boiling a liquid to turn it into vapour, and then condensing the vapour on a cool surface. We can distil a single liquid, like water, to purify it. Or we can distil a mixture of liquids, like crude oil, to separate it into its different constituents.

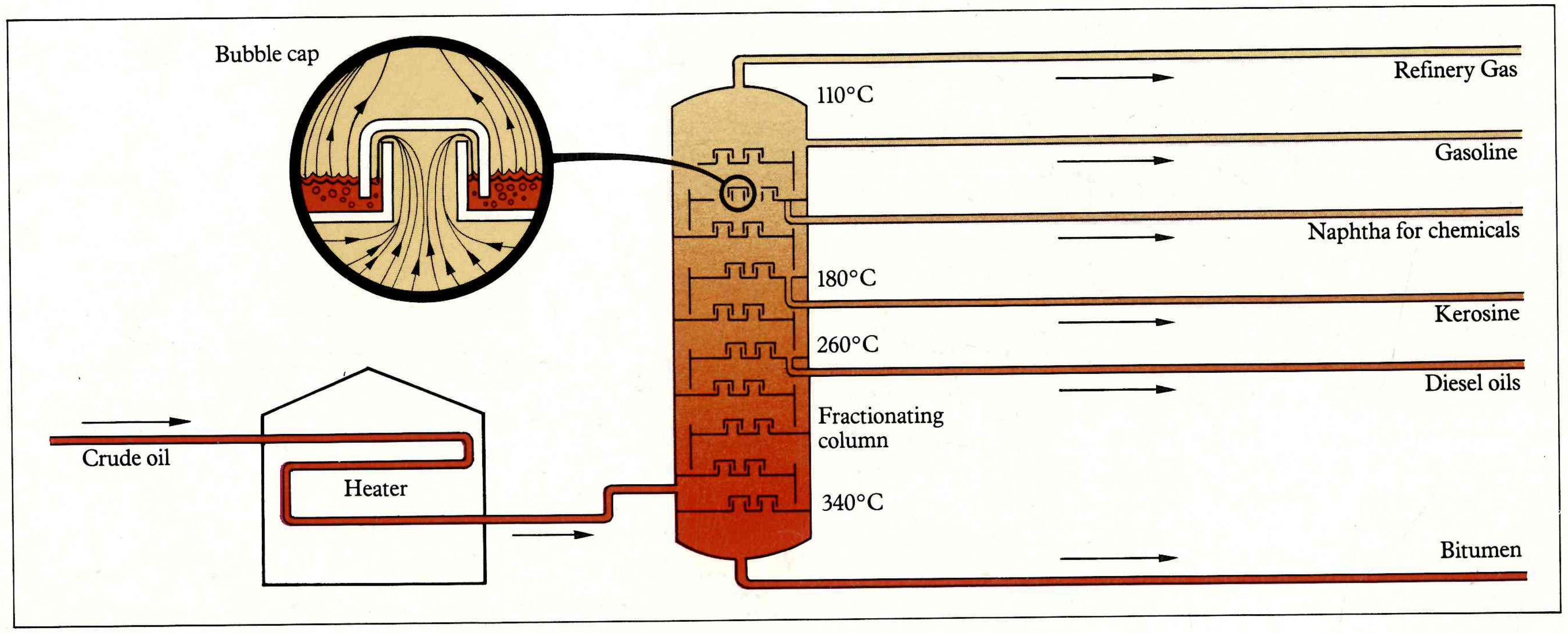
This separation relies on the fact that different liquids have different boiling points. If we cool their vapours along a temperature gradient, each constituent liquid condenses at the place where the temperature is just below its boiling point.

In a refinery, crude oil is distilled into separate liquids in a tall steel tower known as a fractionating column, so called because each separate constituent is known as a fraction. The column is kept very hot at the bottom, but the temperature gradually falls towards the top. The inside of the column is divided at intervals by horizontal trays with holes in them. In ascending order, each tray is cooler than the one below it, providing a temperature gradient on which separate vapours can condense.

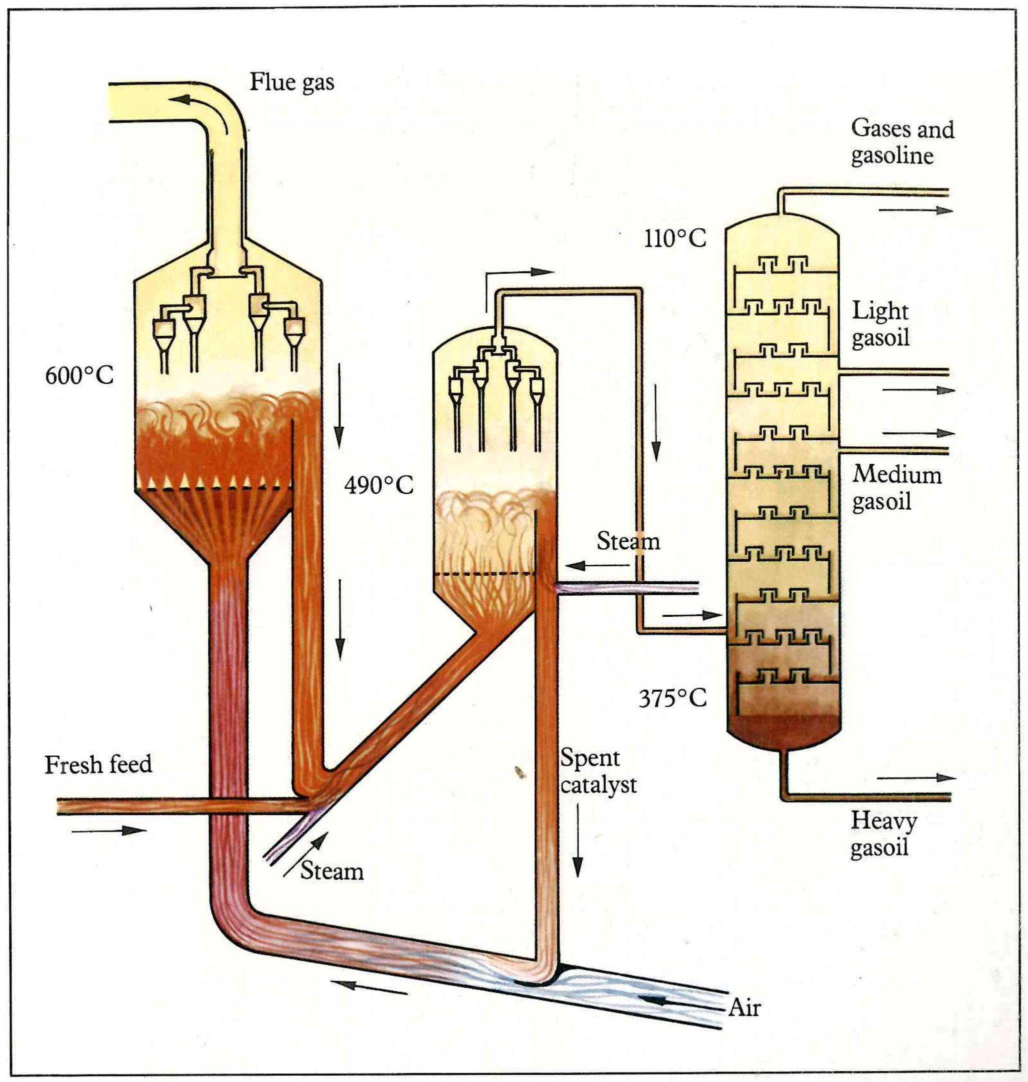
Over the holes in the trays are small domes called bubble caps, which deflect the rising vapours down so they bubble through the liquids condensing on the trays. This improves the efficiency of distillation.

The crude oil is first heated by a furnace, and then passed into the lower part of the column. Most of the fractions in the oil are already boiling, so they vaporise and rise up the column through the holes in the trays. They lose heat as they rise, and when each fraction reaches the tray where the temperature is just below its own boiling point it condenses and changes back into liquid. As the fractions condense on their separate trays they are drawn off by pipes. Distillation is continuous, with hot crude oil flowing in near the base of the column, and the separate fractions flowing out.

The fractions that rise highest in the column are called light fractions, and those that condense on the lower trays are called heavy fractions. The very lightest fraction, taken off at the top of the column, is refinery gas, which remains a vapour, and is used as a fuel in the refinery. Other light fractions are liquefied petroleum gases, gasoline (petrol), and naphtha, a major feedstock for the chemical industry. A slightly heavier fraction is kerosine (paraffin oil). Heavier again is gasoil, which is used as



Distillation of oil: the heated crude enters the column as vapour and rises through the trays and bubble caps. The enlarged picture shows a bubble cap: it forces the rising vapours through the liquid already formed on the tray by condensation. This helps to produce a thorough separation of different fractions.



The operation of an oil refinery is now largely automated; *left*, a typical control room.

Catalytic cracking: the catalyst powder passes to the reactor, in the centre, where the cracking process takes place. The cracked vapours then pass to a fractionating column, on the right. The used catalyst returns to the regenerator, at left, where it is cleaned for re-use.

Oil products

From the refineries oil products travel to a great variety of marketing outlets, ready for distribution to the people who will finally consume them. Without them, we would be largely immobile, and often cold. The wheels of industry would not turn, and the world's machinery would grind to a halt.

Oil products usually leave the refinery in bulk loads ranging from 30 to 30,000 tonnes, though some are packed in cans or drums ready for use by consumers. They travel by road and rail, by sea and river and canal, in product ships and barges, special bulk trucks and rail tank wagons. A few products, such as chemical feedstocks and heavy fuel oil, sometimes travel directly by pipeline to a few very large customers. In remote parts of the world, cans or drums of such products as gasoline or kerosine are carried by any transport available, on the backs of camels in desert countries or on bullock carts in the Far East. Helicopters or cable lifts may be used in mountainous areas.

By many routes and many different distribution methods, the products reach the people who use them. There are seven or eight main product groups, but customers need hundreds of different grades. There are, for example, several different grades of gasoline, the precise characteristics varying from hot to cold climates. There are dozens of different grades of lubricating oils: one oil was specially developed purely for use in the engines of Concorde. The distribution organisation of a major oil company has the task of supplying exactly the right products at the right time, in sufficient quantity, and in any place where they are needed.

In some applications, there are alternatives to oil, but in many areas of use, oil products are irreplaceable with the current state of technology.

Transport is an obvious example. Nearly 300 million cars, coaches, buses, vans and lorries carry goods and people along the roads of the world, and nearly all of them depend on gasoline, gas oil, or liquefied petroleum gases for their motive power. About 96 per cent of all merchant shipping uses oil fuels, and aircraft fly nearly five billion (five thousand million) miles a year on passenger routes, using specialised oil products as fuels.

The best known transport fuel is gasoline, which was burned as waste in the early days of the oil industry. Now more gasoline (petrol) is used than any other oil product. Kerosine, originally the most important of oil products, is now little used in its former role as lamp oil, but it plays an important part in aviation as the principal fuel for jet engines.

Commercial vehicles, such as lorries, buses, and coaches are mostly powered by high-speed diesel engines, which run on gasoil. So, too, do the diesel locomotives on the railways. Ships are powered either by diesel engines, burning a heavier grade of gasoil or fuel oil, or by steam turbines burning heavy fuel oil under the boilers.

Most of these products have important uses for purposes other than transport, for they can provide not only power, but heat. Kerosine, gasoil, and fuel oil are all widely used as heating oils in factories, hospitals, hotels, office blocks and schools, and on a smaller scale in our own homes.

In many countries the bulk of the electricity supply is generated by burning heavy fuel oil to drive turbo-generators, and industries all round the world use heating oils to provide process heat.

All machinery, from the simplest to the most complex, needs lubrication to minimise wear and ensure satisfactory operation. The lubricant may be a fine, clear liquid for a watch, or thick grease for the rollers of a steel mill. Lubricants technology is highly developed, providing 'tailor-made' products for an immense variety of functions. In automotive lubrication, technical advance has given us new oils which improve fuel consumption, reduce engine wear, and increase the interval between oil changes.

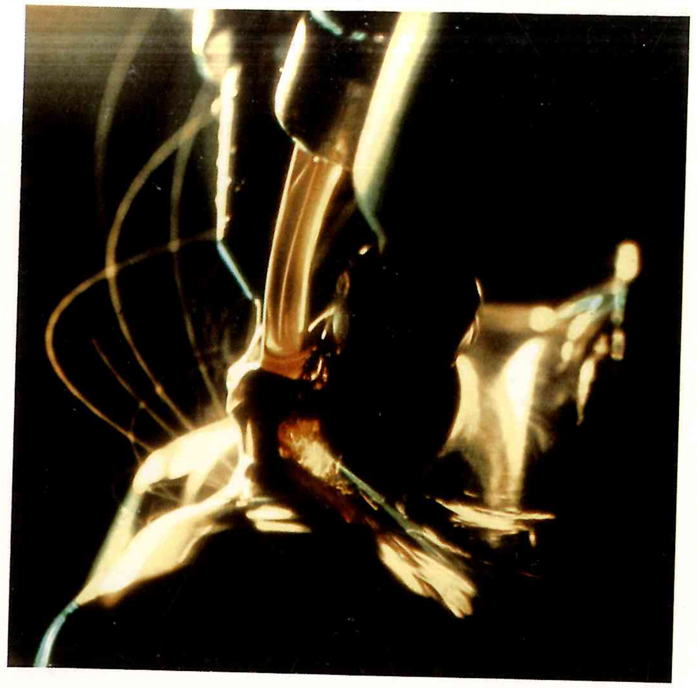
Paraffin wax extracted from oil during lubricants manufacture provides us with candles, and with waxed containers for packaging. Various fine oils and greases are specially purified for use in medicines and cosmetics.

Cooking is another significant use for oil products. Kerosine is a convenient and popular fuel for cooking in many parts of the world, and most of us are familiar with the use of bottled liquefied petroleum gases in caravans, boats, and holiday homes. Domestic gas supplies are increasingly provided by natural gas discovered, produced, and transported by the oil industry.

There are no waste products with oil. Everything, from the lightest refinery gases to the bitumen residues, is put to valuable use. The main bulk application for bitumen is road surfacing, and it is also widely used in building for waterproofing roofs, dams, and tunnels, and for the manufacture of roofing felts and waterproof wrapping materials.

This review of oil products is by no means complete. In particular, it takes no account of the chemicals which are now produced from petroleum.

Transporting products: ***left*****, a convoy of product barges and ice breakers leave Amsterdam with a cargo of fuel oil;** ***above*****, LPG on a reindeer sleigh;** ***below*****, a road train in Australia.**

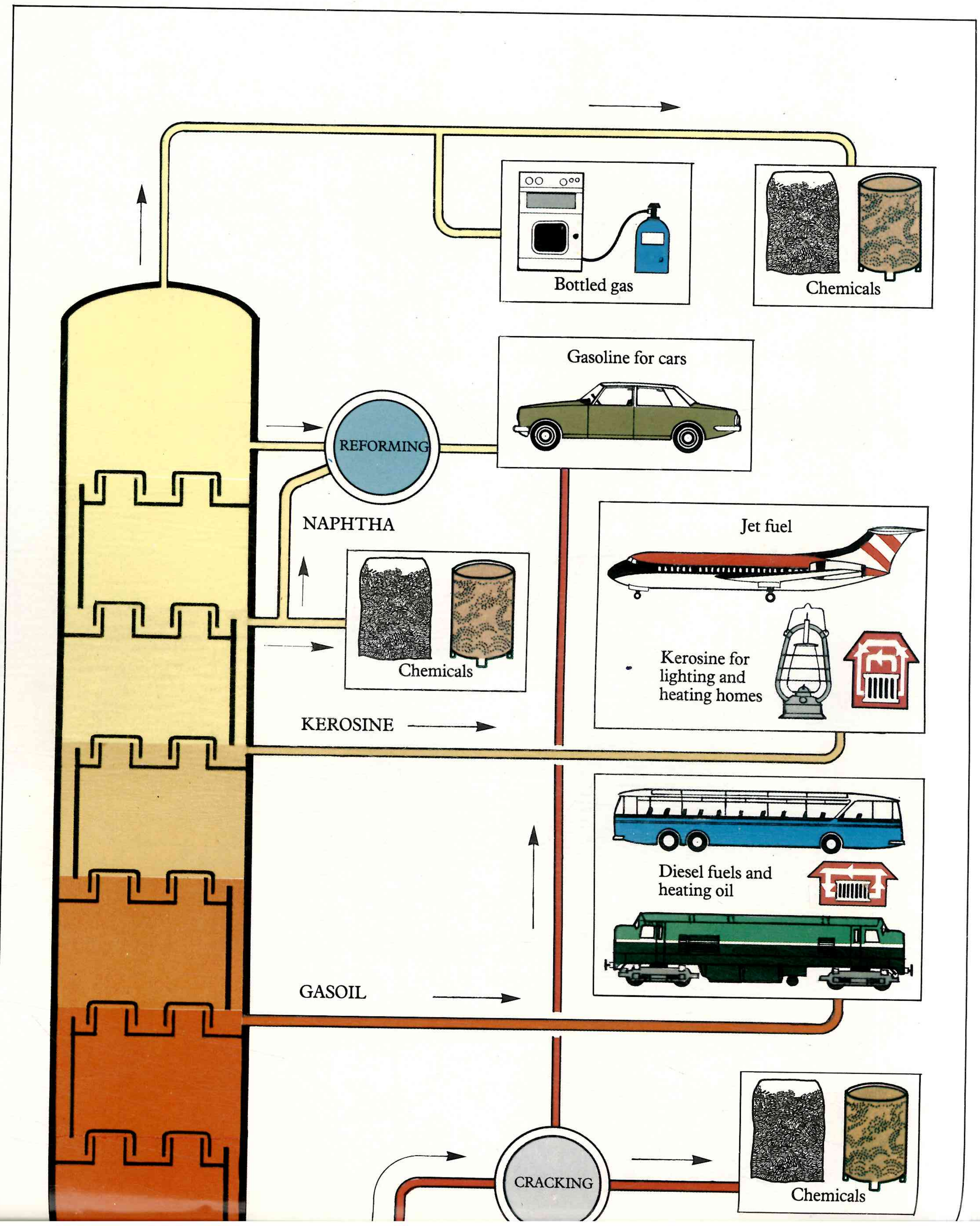


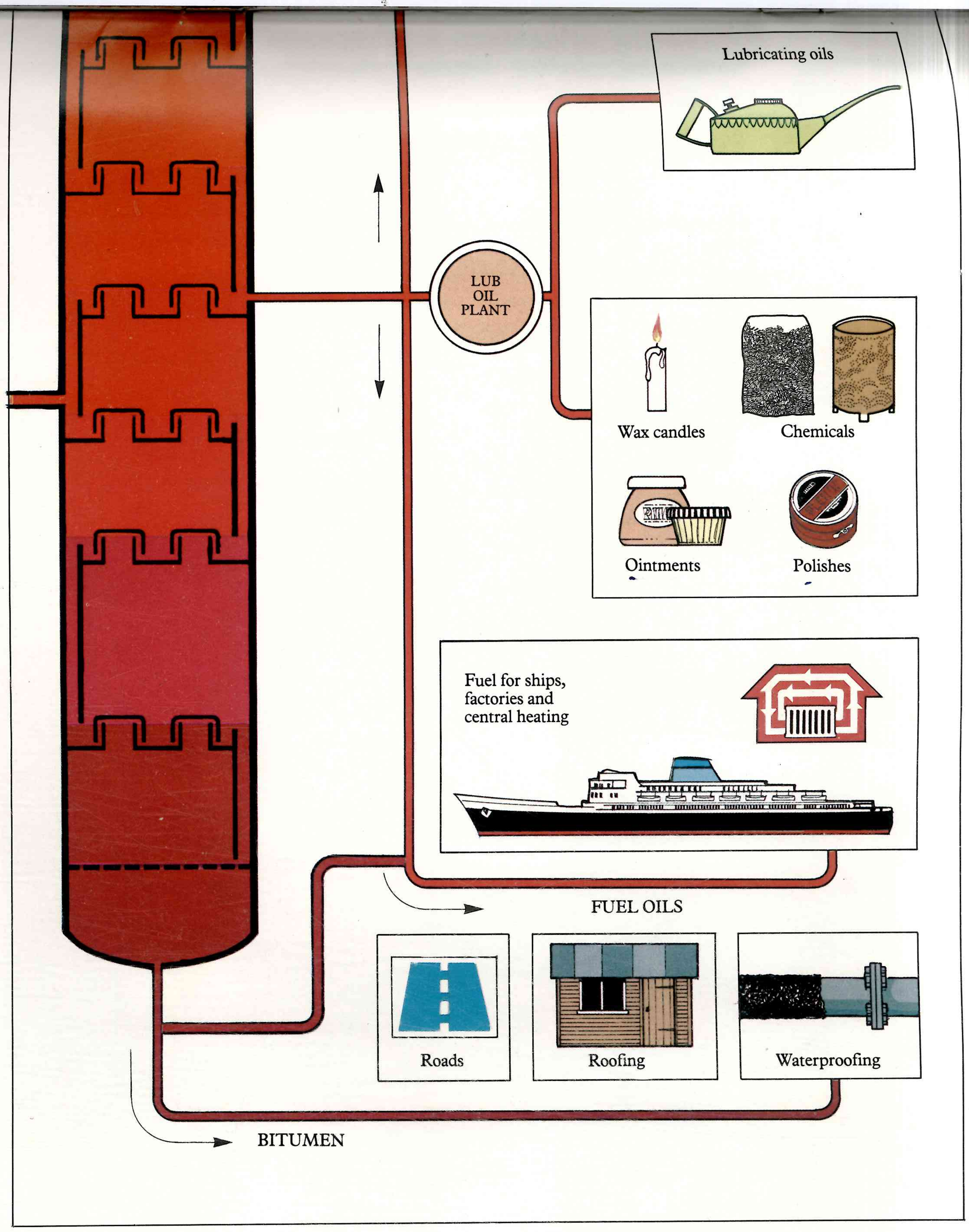
Lubricating oil in use at an optical instruments factory; it reduces wear and tear, and saves costs.

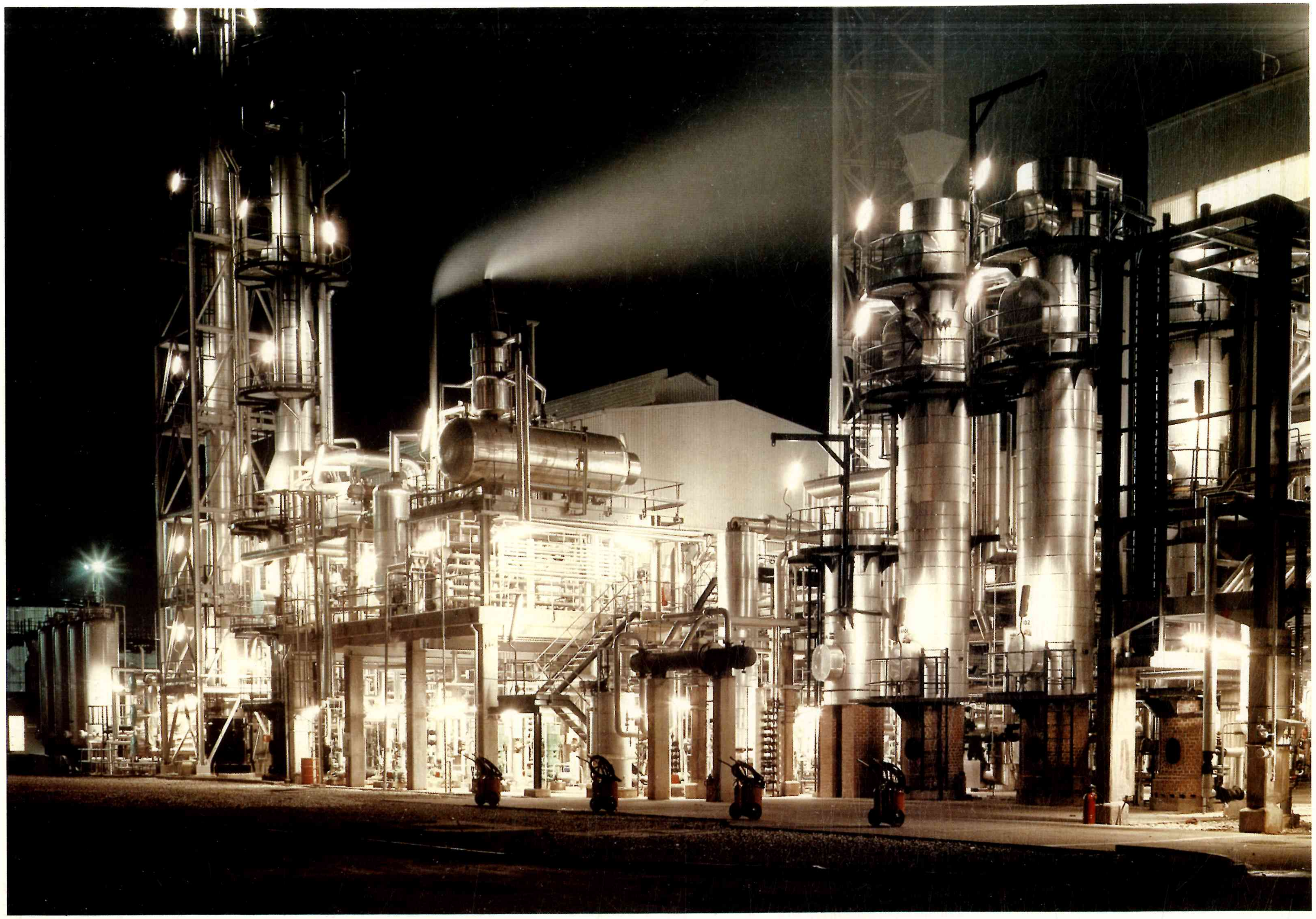
Fuelling Concorde.

A wide range of uses for products; ***above*****, motorway construction in Denmark;** ***above right*****, a gasoline station in Singapore;** ***right*****, warm air from LPG burners heats glasshouses in Nice;** ***far right*****, fuelling a light aircraft at Rotterdam.**

Oil products and their uses




Lubricating oils
LUB OIL PLANT
Wax candles
Chemicals
Ointments
Polishes
Fuel for ships, factories and central heating
FUEL OILS
Roads
Roofing
Waterproofing
BITUMEN



Chemical products

Some of the fractions obtained from the distillation of crude oil are highly reactive. They readily combine with each other, or with other chemicals to form more complex products of great value in industry and in our daily lives. Research has given us new materials unknown to our ancestors.

Naphtha, natural gas, and refinery gases are all produced on a huge scale by the oil industry. They are excellent raw materials for the manufacture of a huge range of organic chemicals, because they readily combine chemically with other substances. They can be broken down or converted into many other liquids or gases which act as building blocks for more complex molecules. Oil products are now by far the most important feedstock for the chemical industry.

In many cases, use of oil-based feedstocks has given us simpler and more economic methods of making chemical products which were already well-known and widely used. Solvents and intermediates like industrial alcohol, acetone, and benzene, which used to be made by cumbersome processes from molasses or coal, for example, are now much more simply manufactured from oil-based chemicals. The cheapest and most convenient way of producing nitrogenous fertilisers in bulk is to use natural gas as the starting point.

In addition, the use of oil-based feedstocks has given us many new products which have given us greater comfort or convenience, or improved industrial processes of many kinds. Plastics are a familiar and amazingly versatile example. Think of all the household articles that can be made from plastics: bowls and buckets; crockery; television cabinets; parts of refrigerators and washing machines; chairs, clothes

***Left*, a modern plant at Stanlow refinery in the United Kingdom.**

Using chemicals in agriculture. *Above*, spraying cotton with insecticide; *below*, spraying apples.

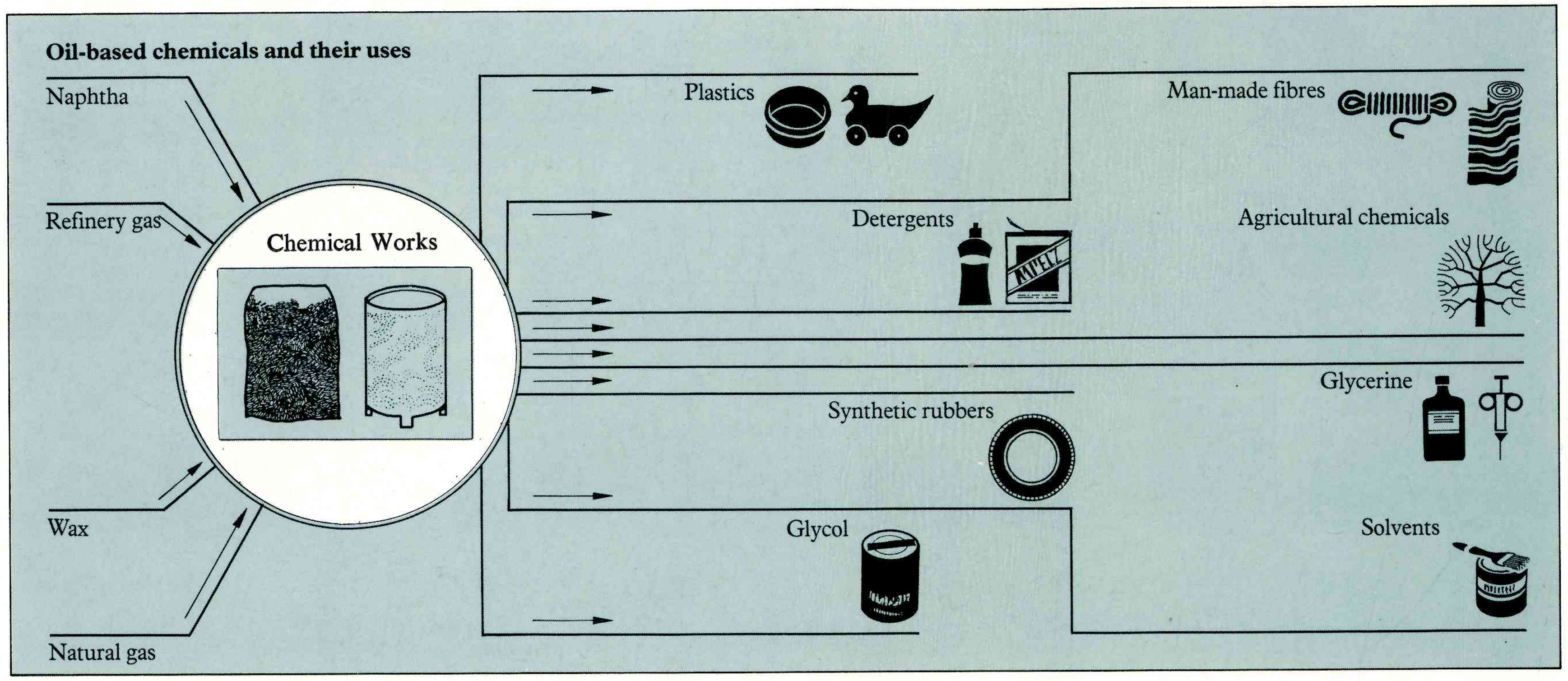
pegs, toothbrushes, toys, and many others.

Industry uses plastics in a great variety of ways. As adhesives and paint ingredients, for example, and as steering wheels and dashboards and surface coatings in vehicle manufacture. Builders use them as pipes and plumbing components, and the electrical industry uses them to insulate cables and components. Plastics have also revolutionised packaging – the modern supermarket could hardly function without plastic wrappings and containers. Other plastic materials give us synthetic fabrics, like nylon, polyester, and acrylics. These are hardwearing and attractive, and have brought new 'easy care' properties to clothing and furnishing.

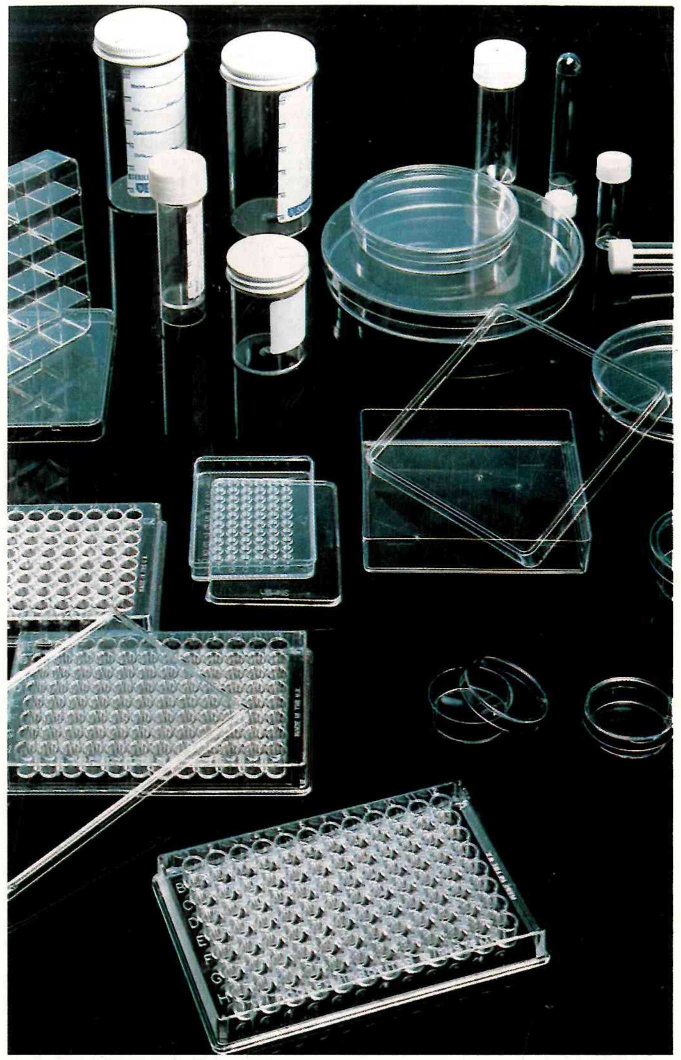
Many other oil-based chemicals are in daily use all round the world. Detergents make the laundry and washing-up easier, and they are used by textile manufacturers in cleaning, dyeing, and finishing.

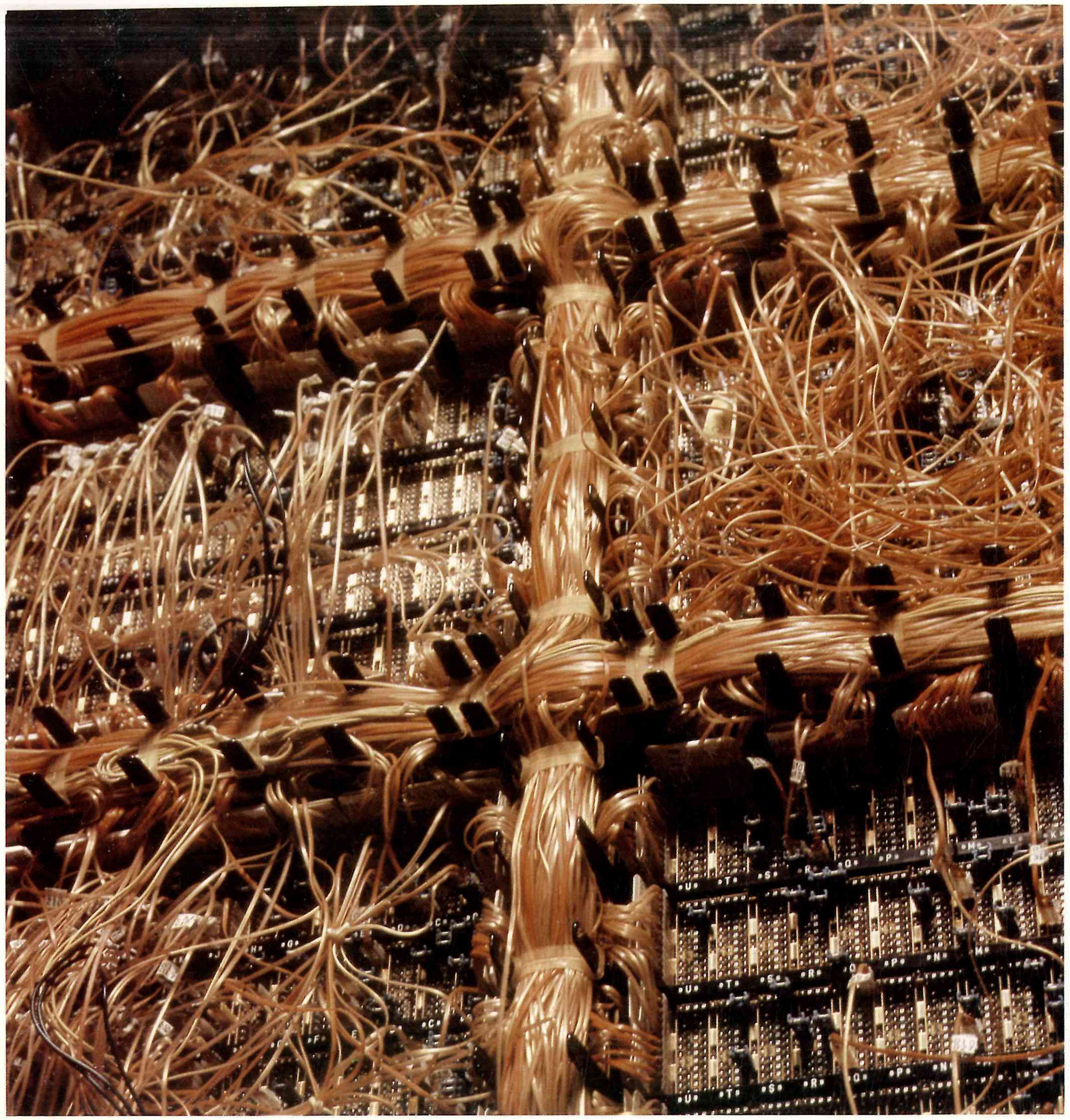
Agricultural chemicals play a substantial part in providing food for the world's expanding population. They help the farmer in two ways: by fertilising the soil, and by killing weeds and pests. One of the big achievements of agrochemical research has been the production of new materials which are selective in their action, like the chemical weedkillers which destroy the weeds without harming the crops. Apart from safeguarding the food supply, insecticides made from oil products have improved human and animal health. Whole countries have been freed of malaria, for example, by destroying the mosquitos which carry it.

Other chemicals made from oil include glycol for antifreeze; glycerine, used in the manufacture of drugs, foodstuffs, cosmetics and explosives; and synthetic rubbers. There are very few manufactured products in which oil-based chemicals do not play some part, and without the massive supply of feedstocks the oil industry provides for chemical products manufacture, our lives would lose a lot in comfort and convenience.



The many uses of modern chemicals. ***Far left,*** **polystyrene toys;** ***left,*** **low density polyethylene film used as a greenhouse cover;** ***below,*** **thermoplastic rubber used for impact-absorbing bumpers;** ***right,*** **crystal polystyrene medical ware.**



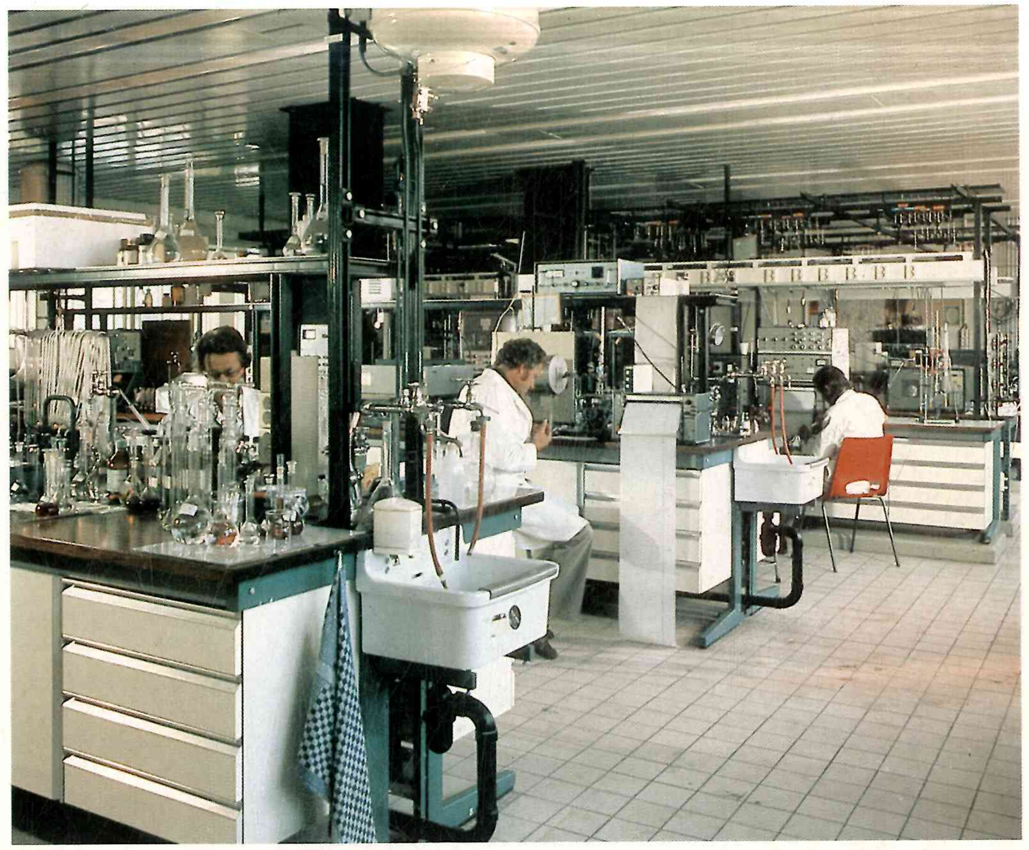


Another use for thermoplastic rubber – non-slip soles for yachtsmen.

Epoxy resins are extensively used in the electrical and electronics industry, for example in the interior of a computer.

Research

All the operations of the oil industry are science based. Research plays a major role, providing new products, and improving the efficiency and quality of existing ones. Particular attention is paid to the development of products and processes which save energy and protect the environment.



The gas analysis section of a laboratory in Amsterdam.

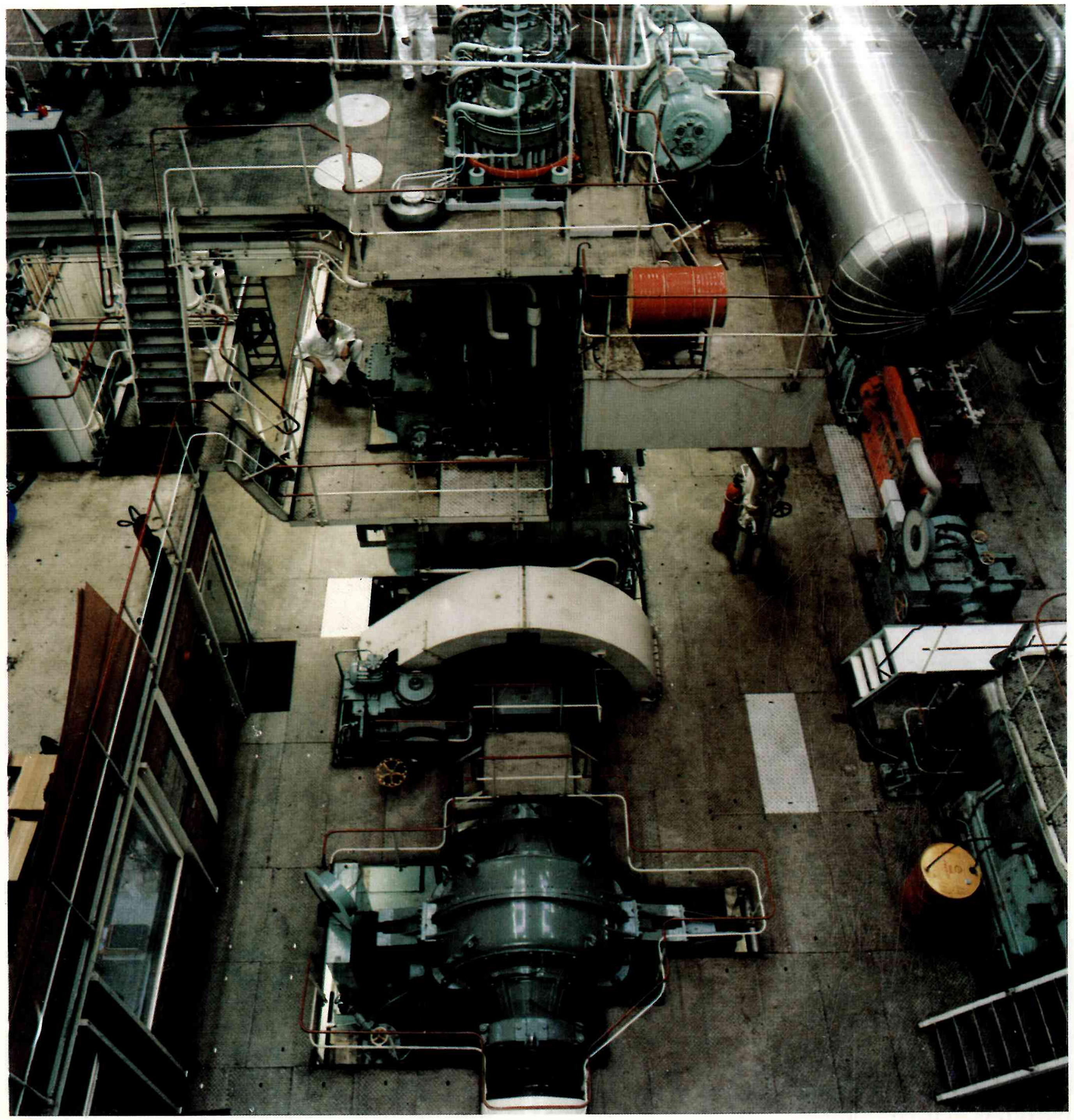
There are few areas of the natural sciences which do not affect the widespread and complex operations of the oil industry. Development of the North Sea oilfields, for example, has called upon virtually every scientific discipline. Added to the usual geological and geophysical problems of locating potential oil-bearing formations have been the challenges posed by an unusually hostile environment. This has required major scientific effort in such diverse fields as metallurgy and materials testing to find construction materials capable of withstanding these adverse conditions; development of navigational techniques for precise positioning of structures; new radio-communication developments; and research into the endurance of divers and other staff in North Sea conditions.

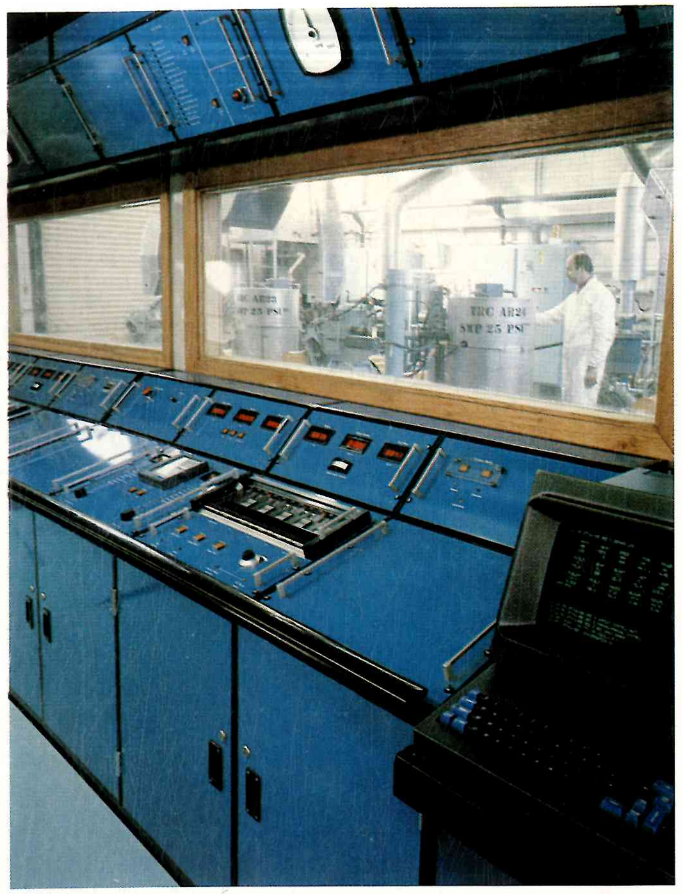
As the finite nature of the world's oil resources is increasingly appreciated, the recovery of a higher proportion of reserves from oilfields is a major target for research. Current developments include the use of chemicals to increase the amount of oil produced from a field. Other experimental work employs steam to recover heavy oils, and the industry is also investigating ways of recovering oil from shales and tar sands.

The counterpart to this effort to discover and produce more oil is to economise in the use of existing supplies. Again, many scientific disciplines are involved. Work to improve the fuel consumption of tankers by keeping their hulls free of barnacle and weed infestation, for example, involves marine biologists, biochemists, toxicologists, and paint technologists.

With their great energy expertise, the oil companies are involved in the development of alternatives to oil. Coal is far more abundant than oil, so research previously devoted to oil conversion is being extended to find means of converting coal into liquid fuels and chemical feedstocks.

Research to improve the quality of life and protect the environment goes on continuously. Improved detergents have reduced river pollution, banishing the foams which used to harm fish and wild life. Substantial research is devoted to the safety aspects of products and processes, to protect both employees and the public.





Lubricating oils for gasoline and diesel engines undergo extensive performance tests in the laboratory during development.

A full-size land-based marine engine, used in Amsterdam for evaluating marine diesel engine lubricants.

Oil economics

In the late 1970s the world outside the USSR, Eastern Europe and China produced and consumed over fifty million barrels of oil every day – two and a half billion tonnes (billion = thousand million) in a year. Huge amounts of money were needed to achieve this: in 1978, for example, the world oil industry made capital expenditures of over $68 billion.

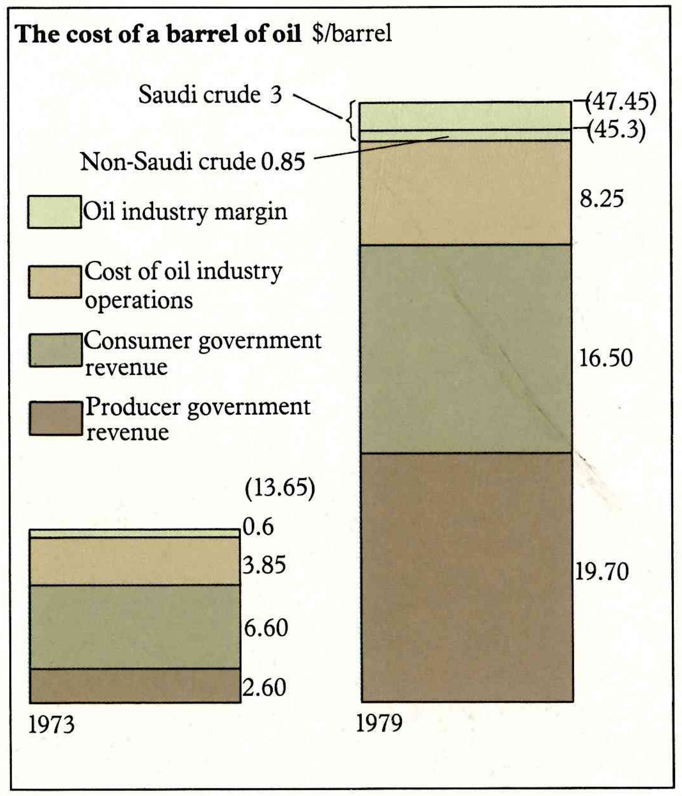
Each separate stage of the oil industry needs large investments: exploration and production, transport in tankers and pipelines, refining, manufacturing and chemical plants, and marketing networks. Exploration and production are the most expensive areas, and in 1978 they took almost US $38 billion, over half of all the industry's capital expenditure. The sheer size of its capital needs and the value of its business have obliged the oil industry to generate most of the necessary capital from its own activities. Earnings therefore need to keep pace with investment demands, and to maintain the confidence of outside sources of finance.

The oil industry, however, cannot use all its margin (the difference between sales proceeds and the costs of producing, transporting, refining, and marketing) from sales of oil and oil products due to the taxes it pays to the governments of the producing countries and the importing countries. A high price for oil and products can encourage people to conserve oil, develop alternatives to oil, and use it only where necessary. The governments of most oil-producing countries tax oil production to raise revenue, and also to limit oil consumption and thus prolong the life of their valuable oil resources. The governments of industrial countries also raise considerable amounts of revenue by various taxes on oil products, especially gasoline. In 1979, the cost of producing, transporting, refining and marketing an average barrel of crude oil from OPEC (Organisation of Petroleum Exporting Countries), in Europe was $46; of this over $36 (79 per cent) was paid to the producer and consumer governments in taxes.

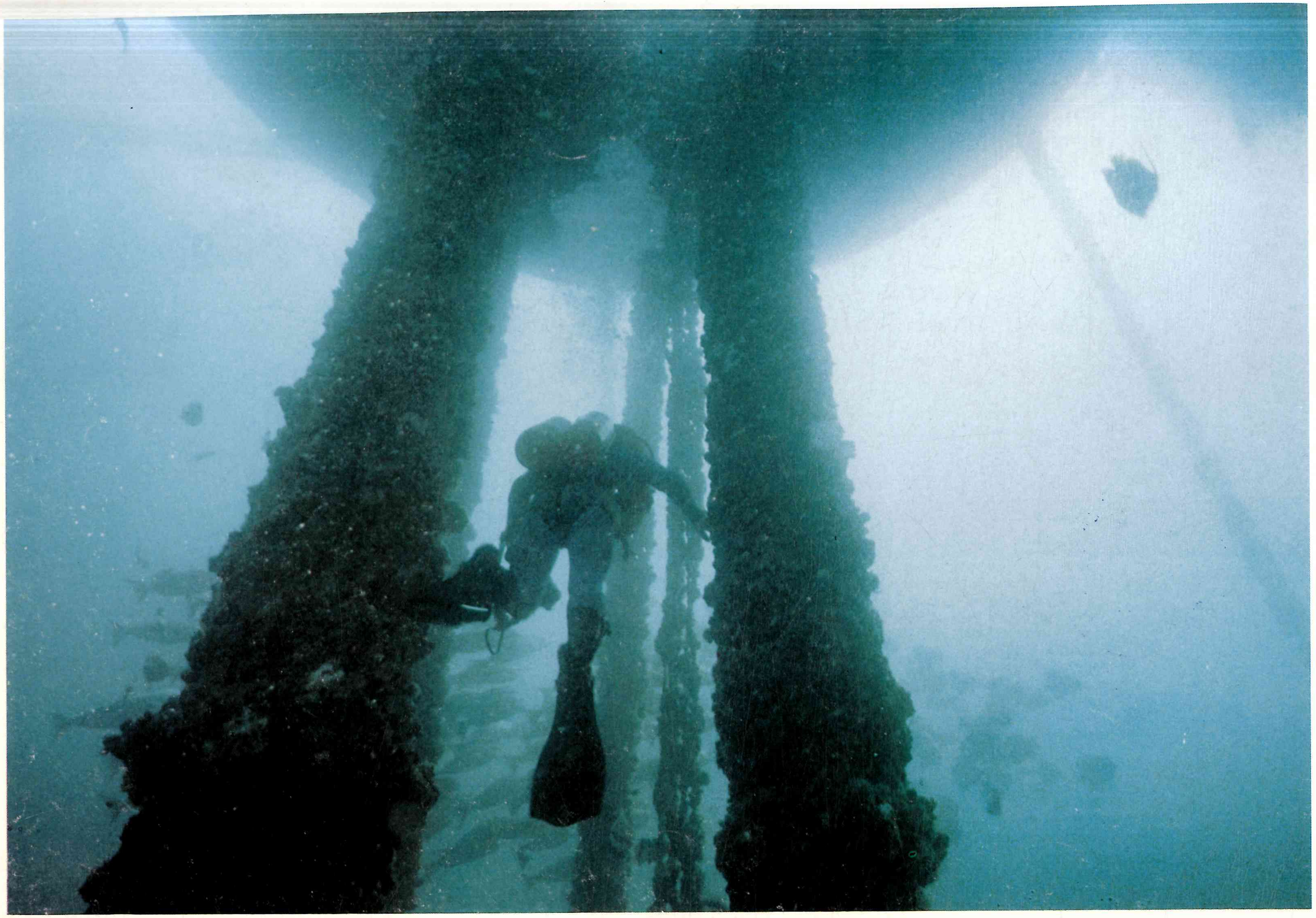
The price of any limited resource – and events since 1973 have underlined that oil is certainly in this category – will eventually rise to the level of the costs of providing alternatives. Producing countries wish to maximise their revenue, and resources in the main consuming countries are also very expensive. This is because most of the world's 'easy and cheap' reserves have already been found, and are providing less and less of the oil the world uses every day. The very big and easily accessible oilfields of the world have probably almost all been found, and as the most likely areas were naturally explored first, the chances of further finds tend always to diminish; more and more exploration will therefore be needed to find oil in the future. The oilfields which are found are likely to be smaller, and therefore less economic to develop. They may well also be in remote areas, such as the northern part of the North Sea and Alaska, where water depths and bad weather make operating technically very difficult and extremely expensive.

As an example of this, look at the North Sea. The Fulmar field, which will start producing in 1982, is costing almost £800 million to develop; this investment is for some 500 million barrels, enough to supply the world's present consumption for a mere eight days. One of the world's most complex offshore oil and gas projects, the development of the large Brent field, together with its associated oil and gas pipeline systems and onshore terminals and gas handling and separation facilities, will cost the Shell/Esso partnership over £4,000 million altogether.

The speed of investment is almost incredible: between now and 1985, Shell alone will be investing approximately £2 million *every day* in exploration and production, refining, chemicals and marketing just in the United Kingdom. This scale of investment will need to be multiplied many times in other countries throughout the world, if oil for the coming decades is to be available when it is needed.



In the graph, *left*, the costs of producing, transporting, refining and marketing an average barrel of OPEC crude oil sold in Western Europe are broken down. In 1979, the oil industry margin is shown separately for Saudi Arabian crude and for other OPEC countries' crude, as Saudi crude was relatively cheaper over almost all of 1979.



Maintenance survey on a Single Buoy Mooring. A diver examines the riser pipes and mooring chains of the SBM in Oman; a large fish population and marine growth indicates a clean environment and no oil polution.

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