EXTRACTION AND USES

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Introduction

At present oil is the most important source of energy and for some applications it is irreplaceable, but till when will it be able to satisfy the growing demand of energy? The day will come when the production of oil shall reach a peak, after which it shall inexorably decrease with a consequent increase in prices. The distribution of the main oil basins around the world is not uniform, however it is not even random. In fact it depends on the geological conditions that are necessary for the formation of large deposits and the difficulty encountered to explore and search for oil in isolated scarcely known areas, as for example areas characterized by environmental conditions that are particularly severe (vast areas in Siberia, the rain forest area in South America and deep offshore areas). The geological history of our country is very complex and has given the peninsula a complicated and not very "tranquil" structural and sedimentary order. This has not favoured the formation of large extensive oil basins but has created local situations that are favourable for the formation of a number of oil provinces that are quite important, even though their extension is not great.

Research and extraction

Before becoming petrol and plastic, oil needs to undergo a very complex artificial production process which starts with the search for oil fields and, through the extraction, processing and transportation stages (often taking place in countries very far away from each other), it ends with the petrol available at the local gas station or the rubber hose at the shop round the corner. Drilling wells is the only way to assess the value of a field, i.e. the type and quantity of the hydrocarbons contained therein.

The search for new fields

The search for new field is very expensive, and therefore it must be carried out with great care. The initial information is obtained by studying aerial photographs made from planes or satellites, which provide a map of the surface rocks, using the Geographic Information System (GIS) mapping to integrate the data, and for the reconstruction of digital models of the ground. Subsequently, geochemistry, micropaleontology and petrography provide all the information that is required with regard to the physical and chemical characteristics of the rocks, their age and composition.

When a potentially interesting area is located, a series of inquiries are necessary in order to classify the nature of the rocks and their geological structure in the deeper layers underground, many thousands of metres in depth. In particular, the scope of the inquiries is to identify the presence of rocks containing hydrocarbons (reservoirs) and traps that enclose them. For this, geophysical investigation is carried out, and in particular reflection seismology. Shock waves are generated using small explosive charges and using systems that make the land vibrate (on the earth's surface) or with a rapid expansion of compressed air (in the sea). The waves spread in the ground or in the water, and are reflected differently, depending on the layers they meet. When they return to the surface they are recorded by suitably positioned geophones. The elaboration of the recordings provides a sort of “map” of the composition of the underground layers, and from which the presence of any traps may be deduced. The final scope of the preliminary inquiries is to calculate the volume of hydrocarbons present in the field. This is calculated by studying the structure and size of the traps with the help of sophisticated software that can manage all the data collected in the research phase. For this three-dimensional model of the structures are created, in order to calculate the volume, and these models are subsequently used to decide the number and optimum locations of the exploration wells. Not all the traps, in fact, contain oil and only by drilling wells, the presence of oil in the traps can be confirmed.

Drilling of onshore oil wells

Before becoming petrol and plastic, oil needs to undergo a very complex artificial production process which starts with the search for oil fields and, through the extraction, processing and transportation stages (often taking place in countries very far away from each other), it ends with the petrol available at the local gas station or the rubber hose at the shop round the corner. Drilling wells is the only way to assess the value of a field, i.e. the type and quantity of the hydrocarbons contained therein. Drilling a well is a long and expensive, albeit simple, operation. Rocks are drilled with a rotating bit mounted at the end of a series (battery) of mutually screwed steel pipes (rods), which is extended as the well becomes deeper. The rods are supported by a 50-meter tall tower (derrick) and their rotation is ensured by a rotating plate operated by means of a dedicated electric engine. The bit is made of very hard material and, in some cases, equipped with components of synthetic diamond.

The rod battery is as long as the well is deep. In some cases, an extension of 6/7,000 metres is reached, whereas the weight supported by the derrick can reach 500 tonnes. The rods are empty to ensure the circulation of an ad hoc mud which greases and cools the bit supports the well walls and, when it goes back to the surface, removes the debris resulting from drilling the rocks. At pre-defined depth, the hole is covered with steel pipes (casting) to reduce its diameter gradually from 75 to 15/20 centimetres. Modular drilling plants transported by truck are used on the mainland. A 1,000 metre well is drilled in less than a month, but in the case of wells exceeding 6,000 metres, over 45 million Euro and one year of constant round-the-clock drilling are needed.

Offshore drilling techniques are the same although the plant features vary. Up to a 100-metre depth, mobile self-lifting platforms (jack-up) including a hull supported by a sliding scaffolding (legs) are used. The legs of the structure stand on the sea bottom and keep the hull 15-20 metres above the sea surface to avoid the impact of waves and tides. In the case of 6/700 metre wells, floating platforms are used. After they are fixed to the sea bottom, they float above undersea hulls. If the well is deeper (up to 2,500 metres), drilling ships are necessary, featuring a hole in the hull to operate the telescopic pipes (riser).

During the drilling, the debris produced is continuously analysed, in order to evaluate if the quantity and quality of extractable hydrocarbons is sufficient to pay the production costs back. During this stage, before going on with the actual well development and production stages, other “perimeter wells” are drilled. The drilling stage is one of the most critical and delicate of the petroleum life cycle and can cause strong environmental impacts. In fact, during drilling a lot of rock fragments are produced which are covered with the so-called “drilling mud”. Drilling mud is a complex mixture made up of water-based and oil-based chemical additives, utilised to prevent the borehole from collapsing during drilling. In the past, drilling mud was accumulated and abandoned on the site. Nowadays, disposal techniques have changed and the mud is treated and then properly disposed of in order to reduce the environmental impact to zero. First, depending on the composition of the mud, the water- or oil-based fluid is separated from the mud and all the potentially harmful substances are eliminated. Both the base oil and water are recovered and recycled, while the solid decontaminated component can follow three different courses: it can be taken to the dump, it can be reused as building material, for roads or bricks for example, or lastly it can be incorporated into the soil.

Offshore drilling

The need to transfer drilling and production facilities off the coasts, with the consequent difficulties in setting up a plant capable of enduring particular environmental conditions, has resulted in innovative and state-of-the-art offshore research and engineering as far as technological development is concerned. Offshore facilities are of different types and differ depending on the seabed, water depth and the prevailing climatic conditions. Up to a depth of 100 metres, movable jack-up rigs are used. These consist of a hull supported by retractable structures (legs). These rest on the sea floor, leaving the hull 15-20 metres above the water surface so waves and tides cannot affect it. For depths up to 1,500 metres, floating platforms are used. These, once moored, rest on submerged hull structures. For greater depths (up to 3,300 metres) drillships are utlised. These are equipped with an opening in the hull through which telescopic pipes (risers), which connect the floating structure to the wellhead, pass. Drillships can operate without fixed moorings, maintaining their position using dynamic systems with numerous computer-controlled propellers that generate thrust in different directions.

Oil rigs

The first offshore drilling operations took place in the Gulf of Mexico in the late 1930s. The first predecessors of modern offshore platforms were installed at the beginning of the Fifties, but it was not until the Seventies that the offshore industry really started booming. In the Eighties, there were advances in drilling technology for moderately deep sea exploitation, while in the Nineties, more attention was focused on oilfields of small dimensions (but not economically attractive) and on the search for deep sea hydrocarbon reserves.

An offshore platform is equipped with the following components:

- machinery for drilling and maintenance of oil wells;
- machinery for extracting hydrocarbons;

- oil, gas and water separation system;
- security and emergency systems;
- systems that transport hydrocarbons ashore;
- laboratories, staff accommodation and common rooms;
- gas flares to burn gases during emergencies or when activating the facilities.

These different components can be found on a single platform or on interconnected, independent structures. The drilling unit is usually separate and can be removed at the end of the operations for reuse in another extraction site. Since offshore drilling and extraction are very delicate operations, offshore rigs are equipped with state-of-the-art security systems designed to minimise the environmental impact of the activity. The security systems present on an offshore platform are the following:

- emergency generator system: activated in the case of malfunction of the main power supply;
- UPS (Uninterruptible Power Supply): security system activated in case of failure of the emergency generator system;
- emergency shutdown system: steps in to shutdown production in case of an accident;
- detection systems: detectors are installed on the platform in order to detect the presence of fires, smoke or gas;
- fire extinguishing systems: the facilities are equipped with fire-fighting systems installed on the platform that use water, which is pumped directly from the sea, foam, carbon dioxide and inert gases. Moreover, the platform itself is made of high temperature-resistant materials to avoid the collapse of the structure in case of a fire. In particular, the area of the wells is isolated from other areas of the platform with blast-resistant walls;
- safety and evacuation systems are located in strategic positions on the platform;
- alarm and communication systems: required to signal an emergency situation both internally and externally, and ask for help in case of an accident.

The extraction

In terms of extraction and processing, during the production stage a sufficient number of wells is drilled to maximise the exploitation of the oil field. Every day, over a period of approximately 20-30 years, a well produces between 500 and 1,000 tonnes of oil (a few thousand barrels) and a few hundred thousand cubic metres of natural gas. Initially, the oil flows up the pipes owing to the pressure of the water and the gas contained in the field. Thus, 30% of the oil and 90% of the natural gas are extracted. An additional 10-15% can be extracted by keeping up the pressure and adding more water or gas. Finally, an additional 10-15% can be extracted by injecting emulsions, steam or solvents washing the rocks and removing more oil.

Approximately 1/5 of the world production of oil comes from the sea, a percentage bound to increase in the next years. In this case, during the first stages many wells are drilled a few meters away from each other. Then, to drain all the fields, also horizontally, the wells are deviated to reach locations up to a few kilometres away from each other. If the sea bottom is more than 400-metre deep, undersea plants are necessary and the opening of the well is on the sea bottom.

During the petroleum production phases, hydrocarbons are extracted along with large quantities of liquid wastes. These effluents must be treated adequately to avoid contamination of the environment. The liquids produced during the drilling phase consist mainly of produced water and injection water. The former is extracted together with the hydrocarbons; in fact, in deposits, oil and natural gas are associated with a large amount of water, much saltier than ocean water. Moreover, as the reservoir reaches depletion, the amount of hydrocarbons extracted decreases and the volume of produced water increases, until, at the completion of the production stages, the volume of water extracted is greater than the volume of hydrocarbons. Produced water contains organic and inorganic compounds, often toxic, that must be treated before the water is disposed of.

Injection water is the water that returns to the surface after having been pumped into the reservoir to maintain adequate pressure. In the majority of cases, the water is injected back into the well; in the case of offshore oil activities, it can be discharged into the sea, but only if it does not contain pollutants, in other cases it can be reused for other purposes, such as agriculture.

Disposal of sulphur-containing compounds in associated gas. Associated gas that is found associated with petroleum fields can contain large amounts of sulphur compounds (mainly H_2S). In this case, the associated gas is treated in specific desulphurisation plants that can eliminate up to 99.9% of the H_2S present. A waste product of desulphurisation plants is solid sulphur (S_8); however, after having been protected by an adequate moisture barrier, it can be reused or stored at the production site for future use. One of the main uses of solid sulphur is the production of fertilisers, but there are other applications: for example, it can be used to make sulphur concrete. The latter is more resistant than regular concrete and has a double advantage: it uses waste material that would be taken to the dump and it reduces the consumption of fresh raw materials.

Treatment and storage

On extraction, crude oil contains a mixture of hydrocarbons along with water, dissolved natural gas, salts, sulphur and inert substances such as sand and heavy metals. Prior to being introduced into the pipelines, crude oil must undergo a number of processes such as degasification, dehydration, desalting and desulphurisation. During the degasification stage, crude oil is separated from associated gas. In order to do this, crude oil is made to pass through a series of separators (3 or 4); separators are particular pressure vessels. This separation process in different stages allows the maximum recovery of liquid hydrocarbons. During the dehydration stage, water is removed from crude oil. Water in oil can be free or emulsified. In the former case, water can be separated easily due to differences in specific gravity, using a separator; in the latter, separation is more complex and can be carried out with the help of chemical emulsifiers (tensio-active agents) or by heating the mixture.

Often crude oil must undergo another important refining process, desulphurisation. Very often, in fact, crude oil contains hydrogen sulphide, a very corrosive and toxic gas, which must be removed.

The most commonly used process is "stripping", which consists in bringing crude oil into contact with a sweet natural gas within special vertical, cylindrical vessels (stripping towers) in counterflow with the gas. In this way the stripping gas removes hydrogen sulphide from crude oil.
Lastly, a desalting process is carried out to remove sodium chloride and possible sediments present in crude oil. This process also allows the removal of other contaminants which are soluble in water, such as carbonates or sulphates along with heavy metal chlorides. After having undergone the different processes, crude oil is generally stored in cylindrical steel tanks, which are fire resistant and equipped with a cooling system and containment basins in case of rupture of the tank, until it is transported to refineries by oil tankers and transmission pipelines.

The transport

Oil is present in sufficient quantities to start production only in certain areas of the world, therefore most of it needs to be transported to reach refineries and the place of consumption. Italy, for example, imports 91% of the oil it consumes. In terms of transport, there are two complementary ways to transport oil: pipelines and oil tankers. Pipelines include a system of 10-12-metre-long steel pipes electrically welded together. They are generally buried at a depth of 3-15 metres or positioned on the sea bottom. The flow of crude oil along the pipeline is ensured by large pumps distributed along the route at distances ranging from 50 to 250 km according to the characteristics of the territory to be crossed. Control and safety stations distributed along the route ensure transportation to ports and refineries. The oil transportation stage is particularly delicate by sea, since it can turn into one of the main pollution sources of seas and oceans if shipwrecks occur. A modern tanker is equipped with separate double hull storage compartments (i.e. equipped with a double metal shell to protect the oil being transported) and other complex failure prevention systems to minimize the risk of oil spills in the sea. Before the oil crisis in the 1970s, oil tankers were huge (450 m long, 500 tonnes of tonnage), but this trend was changed by the re-opening of the Suez Canal (which called for smaller ships crossing it), the changed market conditions and, during the last years, environment preservation and safety considerations. To reduce the environmental impact of those ships, new tank cleaning systems were introduced which allow the collection of the oil residues to be treated in plants on the mainland instead of discharging them into the sea.

Refining

Crude oil includes a large range of hydrocarbons with different quantities of carbon atoms. The ratio of the components varies according to the place of origin. For example, the oil of Venezuela is rich in long molecules making it thicker, whereas the crude oil from the North Sea is more liquid. To subdivide crude oil into its components, while providing its optimum exploitation, a fractioned distillation (or refining or cracking) is necessary.
The various hydrocarbons are separated according to their different boiling temperature. Liquid crude oil is heated up to 400° C at the base of the refining tower and turns into a gas mixture rising up. While they rise, the gases cool down and, according to different condensation temperatures, are separated. Heavier hydrocarbons condensate immediately and are deposited at the bottom. The

others rise up and liquefy again at different levels, where they are collected. **Residues** contain over 20 carbon atoms, condensate first and can be further separated by means of vacuum distillation to produce lubricants, paraffin, wax and bitumen. **Gas-oil** contains 14/20 carbon atoms and condensates at a temperature of 250/350°C. It is an oil fuel used to propel diesel engines and for household heating purposes.

Kerosene contains 10/15 carbon atoms and condensates at 160/250°C. It is an oil fuel used to propel jet planes and heating systems. **Naphtha** contains 8/12 carbon atoms and condensates at 70/160°. It is a yellow liquid used as fuel and processed to manufacture plastic materials, pharmaceuticals, pesticides and fertilisers. It is also a solvent to treat rubber. **Petrol** contains 5/10 carbon atoms and condensates at 20/70°. It is used as fuel for cars and planes but also to manufacture plastic materials and detergents. At 20° C only methane, ethane, propane and butane remain gaseous. Most of them are used as energy sources and to produce petrochemical substances and plastic materials. Butane and propane in particular are used in the production of the fuel called liquid natural gas.

Vapour plants

Thermoelectric plants exploit vapour energy, which is produced by a "boiler" that burns a liquid fuel, such as fuel oil and naphtha or methane (usually modern boilers can burn the three types of fuel without distinction). Usually, large thermoelectric power plants are installed close to big consumption centres and need suitable water supplies for vapour production and fuel storage. The combustion occurs in a part of the boiler that is called "combustion chamber", with the walls made up of a series of pipes where water heats and gradually converts into vapour. The combustion chamber receives the fuels by means of adequate openings through which air passes, pushed by special ventilators. According to a determined route, the gases resulting from the combustion release a part of their heat and, at the boiler exit, they pass through the pre-heaters that release the air, which will enter the boiler. Then, they pass through a series of treating filters and finally they get to the chimney, that disperses them into the air. The vapour turns the blades of a turbine, which is connected to an alternator for the production of electric power. Vapour turbines are approximately similar to hydraulic ones, but they differ a lot because they do not work with water, but with superheated vapour, with all the subsequent temperature and resistance problems deriving from it.

Pollution abatement. Flue gas of thermoelectric power plants contains pollutants produced from fuel oil combustion. These include:

- sulphur dioxide (SO_2): arises from the oxidation of the sulphur contained within fossil fuels;
- nitrogen oxides (NO_x): arise from the oxidation of the nitrogen contained within fossil fuels and present in air;
- dust particles: produced during the complex physical and chemical processes which the fuel particles undergo inside the combustion chamber;
- carbon dioxide (CO_2): produced in all combustion reactions.

It goes without saying that the effects on the environment of the above-mentioned substances depend on their concentration. To reduce polluting emissions modern thermoelectric power plants are equipped with systems which are based on different technologies:

- denitrification: nitrogen oxides are converted to water and molecular nitrogen (not polluting) through a reaction with ammonia and oxygen;
- dust precipitators: thanks to the effect of electrical fields or filtration devices, solid particles are trapped and are not released into the atmosphere (currently precipitators collect 99.9% of the dust);
- flue gas desulphurisation: an operation which allows the removal of up to 97% of the sulphur compounds present in fossil fuel power plant flues;
- water treatment: there are different uses of water in power plants; in all cases, however, before being discharged, water must be treated in order to eliminate possible polluting substances, and it can be released among the flue gases or into the sea only when the concentration of hazardous substances and the temperatures comply with legal regulations.

Ultimately all substances are filtered and treated by the pollution abatement systems present in the power plants. In order to favour the dispersion at higher altitudes of the remaining flue gas components and hence avoid soil pollution, flue stacks are very tall, in some cases over 200 metres high.

Turbogas plants

Another type of plant uses a gas turbine instead of a boiler. The gas turbine is a rotating thermal machine that converts the heat into work, by directly using combusted gases as working fluid, supplying mechanic power on a rotating shaft. The air sucked by the compressor is compressed and sent to the combustion chamber where the fuel is burnt (gas oil, “benzinone”, or methane) and the high temperature air and gas mixture is directly sent into the turbine, where thermal energy is converted into mechanic energy. A part of the mechanic energy is converted by the alternator, together with the turbine, into electric energy. The other part is used to activate the compressor. In a few words, a turbogas plant is based on the same principle as reaction plane propellers, with the difference that in planes the turbine only produces that part of the energy required to activate the compressor, while the remaining part is exploited as pressure gas to provide the necessary propelling force to fly.
This type of system has several advantages: reduced costs, possibility to start also in absence of network energy, simplicity and rapidity of construction and finally it does not need cooling water (as a consequence it can be positioned anywhere, even without water supply).

Decommissioning

When an oil field is depleted, the decommissioning of the production facilities follows. The activities carried out during the decommissioning phase include the safe removal of the pre-treatment plant, the platform structures, the compression structures and the hydrocarbon dispatch facilities and the removal of the wellheads and the pipelines that connect to the collection points. Following the dismantling of the production facilities, there is the environmental restoration phase. The areas where the wells and the treatment facilities were located are reclaimed and restored to pre-mining conditions, with the planting of grasses and trees. As far as the decommissioning of offshore facilities is concerned, operations to safely plug and abandon the well must be carried out and the installations and pipelines that connected the platform to treatment facilities on land must be removed. These operations are very delicate and require specialised personnel in order to avoid adverse environmental impacts. Once the installations have been removed, suitable sites must be identified for materials that cannot be reused and for the disposal of potentially polluting products. An alternative to the dismantling and removal of offshore installations envisages the reuse of disused platforms in-situ as artificial barriers, for example. In fact, it has been observed that many artificial structures placed in open water are soon colonised by benthic macrofauna and by a large number of fish species that find a suitable habitat to reproduce. Another alternative is the installation of offshore wind turbines on the disused platforms. In fact, these offshore platforms can support wind turbines with the advantage that they are far from the coast, where the winds are strong and constant, and where there they do not have a negative effect on the landscape. The option of leaving disused offshore platforms in place must be carefully evaluated from an environmental and a legislative point of view.

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