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- **Engstrøm, Finn**
1263 København K (DK)
- **Schulte, Willem**
2106 ES Heemstede (NL)
- **Van Vark, Wim**
2106 ES Heemstede (NL)
- **Kapteijn, Pieter Karel Anton**
1263 København K (DK)

(71) Applicant: **MAERSK OLIE OG GAS A/S**
1263 Copenhagen K (DK)

(74) Representative: **Zacco Denmark A/S**
Hans Bekkevolds Allé 7
2900 Hellerup (DK)

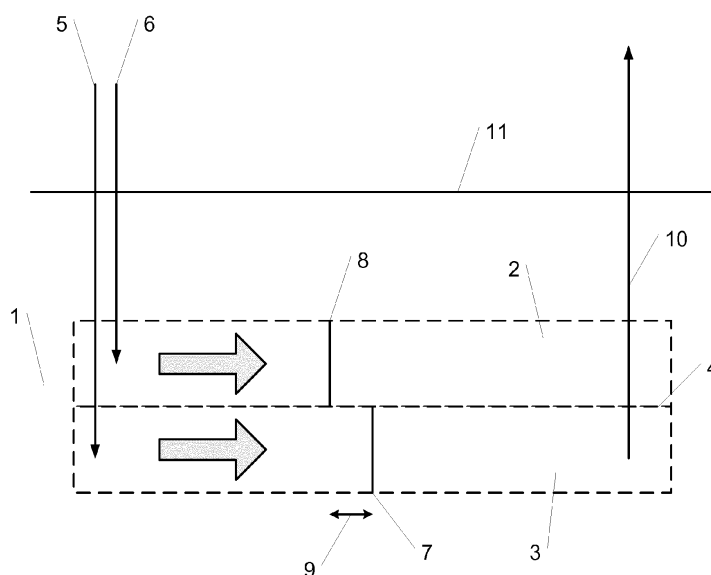
(72) Inventors:
• **Hasbo, Klaus Bent**
1263 København K (DK)

(54) **Method and apparatus for producing hydrocarbons from a multilayer system**

(57) The invention relates to method for producing hydrocarbons from a multilayer system, and an apparatus for use in such a method. The multilayer system comprises at least one high permeable layer and at least one low permeable layer, wherein the high permeable layer is adjacent to the low permeable layer, wherein a first injectant is injected into the high permeable layer and simultaneously a second injectant is injected into the low

permeable layer, wherein oil replaced by the first and second injectants from the high and low permeable layers is collected, wherein the rate of injection of injectants for the high and low permeable layers is monitored and adjusted to keep the fronts of displacement of oil from the high and low permeable layers within predetermined limits.

Figure 1



Description

FIELD OF THE INVENTION

[0001] The invention relates to method for producing hydrocarbons from a multilayer system, and an apparatus for use in such a method.

BACKGROUND OF THE INVENTION

[0002] In the recovery of hydrocarbons from oil fields, various techniques are employed to optimize oil and gas production.

[0003] Traditional displacement methods use water to displace oil in a field, effectively pushing the oil to a collector point. Chemicals such as surfactants may be added to alter the flow and mixing properties of the oil/water mixture that is obtained. A disadvantage is that relatively large fractions of oil are left in the field, and that the injected water may leave residual oil fractions harder to recover.

[0004] An alternative method is to use gas to displace oil. However, in many cases the availability of large volumes of pressurized gas is limited, making the method relatively expensive. It may also be troublesome to maintain the pressure once a major part of the oil is recovered, and collapse of the field structure may also become a problem. In addition, not all gasses are suitable or desirable to have injected into an oil field. Nitrogen gas is fairly inert but is relatively expensive to obtain. Oxygen as a pure gas leads to combustion hazard when combined with flammable materials such as oil and methane gas. Another known method is to re-inject the natural gas (mostly consisting of methane) produced from the oil field.

[0005] Combined methods include water-alternating-gas (WAG) which uses intermittent injection of water and gas, and SWAG wherein water and gas are injected simultaneously or sequentially. Carbon dioxide is a favoured gas to inject in the WAG method. Such methods are believed to yield 5-10% recovery improvement under favourable conditions, compared to continuous water injection.

[0006] In oil fields having layered systems comprising relatively low permeable and relatively high permeable layers, the existing methods have shown recovery levels that leave desire for improvement. Many of such high permeability contrast reservoirs are considered difficult cases, and therefore less attractive for production purposes.

OBJECT AND SUMMARY OF THE INVENTION

[0007] It is an object of the invention to provide an improvement over the existing methods. The invention relates to a method for producing oil from a multilayer system, wherein the multilayer system comprises at least one high permeable layer and at least one low permeable

layer, wherein the high permeable layer is adjacent to the low permeable layer, wherein a first injectant is injected into the high permeable layer and simultaneously a second injectant is injected into the low permeable layer, wherein oil replaced by the first and second injectants from the high and low permeable layers is collected. Preferably, the permeability of the high permeable layer is at least a factor 2, preferably a factor 3 or 4, higher than the low permeable layer, as measured in millidarcy (mD) at the operating pressure and temperature for the first or the second injectant.

[0008] This method has shown to lead to an improved oil recovery in multilayer systems. The multilayer may consist of only two adjacent layers, or multiple stacked layers of different consistency. A relatively low permeable layer may be above a relatively high permeable layer, but it is also possible that the relatively high permeable layer is above a relatively low permeable layer.

[0009] The difference between a relatively high and a relatively low permeable layer would be at least an order of magnitude 2 as measured in millidarcy (mD), preferably at least 3 to 4 orders of magnitude under the operating conditions as selected. Preferably the contrast between the high and low permeable layer is within 2-40 orders of magnitude, more preferably within 2-10 orders of magnitude. The amount of cross-leaking of injectants between the low and high permeable layers will depend on the nature of the layers in a given situation. The layers can be essentially horizontal but in practice are often inclined or arched.

[0010] The injectants can be in various fluid phases. Liquid and gaseous injectants relate to the physical state of the injectant at atmospheric pressure; many gaseous injections would become liquid, dense phase or supercritical fluid under the pressures that may occur at great depths, which may lead to a significant change in the viscosity of the injectants.

[0011] It is preferred if the first injectant has a higher viscosity than the second injectant. This makes it easier to control the progress of the front of the first and second injectants to displace oil. Viscosity may be controlled by selection of the injectant or mixture of injectants, for instance water, carbon dioxide, or nitrogen. The viscosity of injectants can be adjusted, for instance by adding surfactants, polymers or other additives.

[0012] Preferably, the points of injection for the first and second injectant are adjacent to each other in the horizontal plane. Injection positions can be arranged in various different arrangements, depending on the specific parameters of a certain location. For optimal control, the injection positions are preferably closely grouped together.

It is preferred if the rate of injection of injectants for the high and low permeable layers is monitored and adjusted to keep the fronts of replacement of oil from the high and low permeable layers within predetermined limits. It was found that keeping the flood fronts relatively close to each other, a higher oil recovery is achieved. It is postulated

that a piston-like displacement of the oil can be achieved if the flood front controlled by the injectants in adjacent layers progresses simultaneously. Preferably, the progress of the fronts of displacement of oil in the high and low permeable layers is monitored through seismic or volumetric methods.

[0013] Most preferably, the rate of injection is adjusted to keep the front of replacement for the liquid injectant essentially ahead of the gaseous injectant. This was found to yield better results than cases where the gaseous injectant is ahead of the liquid injectant.

[0014] It is advantageous if at least one of the first and/or second injectants comprises a combustion product from natural gas or oil. Such combustion products are often considered waste, and it is cost effective to re-use such waste products. In a preferred embodiment, at least part of the combustion product is obtained by combustion of gas and/or oil produced from the first and/or second layer. This ensures a supply of injectant is readily available at the site, making the method less dependent on external supplies. It is desirable if the combustion product is CO₂ used as a gaseous injectant. CO₂ is one of the main combustion products obtained from hydrocarbons, along with water, and it is an excellent gas for recovering oil. Also, the injecting of CO₂ prevents the gas from entering the atmosphere and contributes to global green house effects. The combustion product may also comprises water that can be used as an injectant.

[0015] Advantageously, the first and/or second injectant is selected from CO₂, N₂ or mixtures thereof. Carbon dioxide and nitrogen gas as suitable gases for oil recovery. Nitrogen may be obtained in large quantities by air separation methods. It is advantageous if the second injectant comprises N₂ obtained from an air separation method, and wherein O₂ from the same air separation method is used in the combustion of natural gas and oil produced, to yield water and CO₂. Thus all products from the air separation method are used in other useful method, yielding water, and carbon dioxide from combustion, and nitrogen gas from the air separation method. Besides, useful energy is generated in the same process. This makes the method at least partially self-sufficient, which is a great advantage in the remote areas oil recovery may take place.

[0016] It is preferred if the second injectant is an essentially aqueous injectant. Water may for instance be obtained from a water supply, water production or from a combustion method as described above. The aqueous injectant may comprise other compounds in addition to water, such as surfactants, polymers and other chemicals that may alter the properties, for instance the flow properties under high pressure.

[0017] It is preferred if the salinity of the aqueous injectant is lowered by the addition of low salinity water. Reduction of the salinity of production water gives a significant effect in improved oil production. Water with a salinity lower than the water present in the oil reservoir showed an improved oil recovery, which is postulated to

stem from the improved capability to form oil-in-water of aqueous solutions having a lower salt or ion content. Mixing low salinity water with produced water lowers the overall salinity, and significant effects were found even when amounts as low as 10% w/w of lower salinity water is added. Low salinity water could for instance be distilled water or water treated in other ways to lower its dissolved salt content. A convenient and efficient way to obtain low salinity water is to capture the water produced in the combustion of hydrocarbons recovered on the production site, collected for instance by a distillation/condensation method. Preferably, at least part of the low salinity water is obtained as a combustion product of natural gas and oil recovered.

[0018] It is preferred if the viscosity of the first and/or second injectant is controlled by adjusting the temperature. Temperature is a convenient way of fine-tuning the viscosity of an injectant, and offers a relatively simple way of controlling the progress of fluid fronts in the layers. For instance, hot water for example, has a viscosity of from 0.2 to 0.3, whereas the cold water has a viscosity of from 0.9 to 1 cp. By changing the temperature of the water the viscosity can be adjusted by a factor of 2-5 times. Similar viscosity adjustments can also be made for other injectants such as carbon dioxide or nitrogen. Preferably, at least part of the heat to control the temperature of the first and/or second injectant is obtained from the combustion of natural gas and/or oil, more preferably oil and/or gas produced by the process.

[0019] The invention also provides an apparatus for use in the method as described herein, comprising at least one first injector for injecting a first essentially liquid injectant into a first layer, at least one second injector for injecting a second essentially gaseous injectant into a second layer adjacent to the first layer, monitoring means for monitoring the progress of injection for the first and second injectants, and adjusting means coupled to the monitoring means and the first and second injectors. This apparatus is particularly suitable to perform the method as described above. The rate of injection of injectants for the high and low permeable layers is monitored and adjusted to keep the fronts of displacement of oil from the high and low permeable layers within predetermined limits.

[0020] The monitoring means could for instance comprise temperature, pressure, chemical, flow, and acoustic analysis, monitoring both the injection positions and the production well using techniques such as chemical tracers, observation wells and/or seismic contrasting. Preferred monitoring methods include surveillance by direct observation using seismic methods or surveillance wells; or indirectly through volumetrics, tracers and methods analyzing the pressure drop at production and/or injection wells.

[0021] The adjusting means could include valves and regulators for controlling the pressure and throughput of the first and second injectants. It is possible to adjust both the first and second injectants, but it is preferred if

one of the first and second injectants is kept at a constant rate and the other injectant is varied depending on the monitored signals. The monitoring means and adjusting means can be manually controlled, but are preferably automated.

[0022] It is advantageous if the adjusting means are programmed to keep the progression of the first and second injectant within predetermined limits. Preferably the progression of the displacement front of the first and second injectant are kept within 10% as measured by volume.

[0023] It is preferred if the apparatus comprises a combustion unit, wherein an outlet for CO₂ produced by the combustion is coupled to the second injector, and wherein an outlet for water produced by the combustion is coupled to the first injector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

Figure 1 shows a method.

Figure 2 shows a system for use in a method.

Figure 3 shows a system used in a method.

Figure 4 shows a system to control the method.

Figure 5 describes examples of flow profiles that may be used in the method.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0025] Figure 1 schematically shows the method according to the invention. The figure shows a multilayer system 1, comprising an upper layer 2 and a lower layer 3. In this example, the upper layer has a relatively high permeability/low density, whereas the lower layer has a relatively low permeability/high density. However, the relative vertical position of the relatively high and low permeable layers could also be inverted. It is also possible to have multiple alternating layers. The adjacent layers 2,3 are in communication; fluids may migrate from one layer into the other through the interface 4 between the layers. By injecting a liquid such as water, into the lower layer 5, oil is displaced through the layer in the displacement direction indicated by the arrows. Simultaneously, a gaseous injectant 6 such as carbon dioxide, nitrogen gas or a mixture thereof is injected into the upper layer 2. The front of the liquid injectant 7 does not necessarily run at the same rate as the gaseous injectant 8. For optimal results, the difference 9 in progress should however be controlled and kept within predetermined limits, dependent on the parameters of a specific field. Oil from the multilayer system is pushed towards the one or more production pipes 10, where the oil is collected and transported towards the surface 11. Although the figure shows a vertical pipe, the production pipes may also comprise vertical or angled pipes, as known in the art.

[0026] Figure 2 shows a system 20 that can be used for the supply of injectants for the method described in

figure 1. The system comprises an air separation unit 21, that separates incoming air 22 into its main components, nitrogen gas 23 and oxygen 24. The nitrogen gas may be used as an injectant. The oxygen 24 is used to a combustion unit 25 that combusts fuel 26 that may be comprise oil and gas derived from an oil production method, in particular the method as described in figure 1. The combustion unit 25 produces energy 27, as well as carbon dioxide 28 and water 29, that may be used as injectants for the method described in figure 1. Before the produced injectants can be used in the method as described herein, they may be subject to further processing, such as mixing with other injectants, compression or decompression to achieve the desired pressure, and cooling or heating to achieve the desired temperature.

[0027] Figure 3 shows a method 30, wherein an air separator unit 31 separates air 32 into nitrogen gas 32 and oxygen 33. The oxygen is used in a combustion unit 34 to combust fuel 35, yielding energy 36, water 37 and carbon dioxide 38 as main products. The water 37 from the combustion unit, is lead to a first injector unit 39. In the injector unit 39, the water is brought under the desired temperature and pressure. Optionally, the combustion water 37 is mixed with additional liquids 40, such as additional water or other liquids and/or flow-affecting compounds such as surfactants. Subsequently, the liquid is injected into a first oil-containing layer 41 to displace oil and/or gas. Carbon dioxide 38 and/or nitrogen gas 32 are brought to a second injector unit 42. In the injector unit 43, the gaseous injectants are mixed and brought under the desired temperature and pressure. Optionally, additional gases 43 are added from external sources, such as additional carbon dioxide and/or nitrogen gas. The gaseous injectants are then injected into a second oil-containing layer 44 to displace oil and/or gas. The oil and/or gas displaced from the first and second layers 41, 44 is then collected at a distance from the injector positions through one or more oil wells 45 to a collector unit 46. From the collector unit 46, part of the collected oil and/or gas is transported away as produced gas and/or oil 47. Optionally, part of the produced hydrocarbons is lead to the combustion unit 34 as fuel 35.

[0028] Figure 4 schematically shows a system 50 for controlling a method as shown in figure 1 and 3, to control the progress of hydrocarbon displacement in multiple simultaneously producing layers. A control unit 51 receives input from monitoring sensors of the first injector 52 that regulates the injecting of a first gaseous or liquid injectant into a first layer, and a second injector 53 that regulates the injecting of a second gaseous or liquid injectant into a second layer. Optionally, the control unit 51 also receives external monitoring data 54, for instance pressure variations from the production well and injection well, using techniques such as chemical tracers, observation wells and/or seismic monitoring. The control unit compares the progress of the injectants in the first and second layers. If the difference in progress between the first and second layers exceeds a predetermined threshold, the

control units instruct an adjusting unit 55 to adjust the injection ratio of the first injector 52 and the second injector 53. This may be done by raising the rate of injection for the layer that lags behind, or lowering the injection rate for the layer that runs in front, or a combination of these adjustments. For ease of controls it is preferred if the rate of injection is kept constant for one layer and the other layer is adjusted. This system 50 can be extended to control run for more than 2 injectors 42, 53 simultaneously.

[0029] Figure 5 describes examples of flow profiles that may be used in the method.

[0030] Figure 5a shows a sequential injection profile, schematically showing the injected volumes of injectants over time. The time scale for this method is typically weeks, months or years. The upper line 60 shows a first injectant, whereas the lower line 61 shows a second injectant. The injectants are injected intermittently, in a predetermined sequence. The injectants may for instance be water, aqueous polymer solutions, nitrogen or carbon dioxide.

[0031] Figure 5b shows a simultaneous injection profile, schematically showing the injected volumes of injectants over time. The upper line 62 shows a first injectant, whereas the lower line 63 shows a second injectant. The injectants are injected simultaneously.

[0032] Figure 5c shows an alternative simultaneous injection profile, schematically showing the injected volumes of injectants over time. The upper line 64 shows a first injectant, whereas the lower line 65 shows a second injectant. The injectants are injected simultaneously. For the second injectant 65, a larger volume is injected in the second injection interval 67 relative to the first injection interval.

Claims

1. Method for producing hydrocarbons from a multilayer system,
Wherein the multilayer system comprises at least one high permeable layer and at least one low permeable layer,
wherein the high permeable layer is adjacent to the low permeable layer,
wherein a first injectant is injected into the high permeable layer and simultaneously a second injectant is injected into the low permeable layer,
wherein oil replaced by the first and second injectants from the high and low permeable layers is collected,
wherein the rate of injection of injectants for the high and low permeable layers is monitored and adjusted to keep the fronts of displacement of oil from the high and low permeable layers within predetermined limits.
2. Method according to claim 1, wherein the permeability of the high permeable layer is at least a factor 2 higher than the low permeable layer, as measured in millidarcy (mD) at the operating pressure and temperature for the first or the second injectant.
3. Method according to claim 1 or 2, wherein the first injectant has a higher viscosity than the second injectant.
4. Method according to any of the preceding claims, wherein the wherein the rate of injection is adjusted to keep the front of replacement for the first injectant essentially ahead of the second injectant.
5. Method according to any of the preceding claims, wherein the progress of the fronts of displacement of oil in the high and low permeable layers is monitored through seismic or volumetric methods.
6. Method according to any of the preceding claims, wherein at least part of the first and/or second injectant is obtained by combustion of gas and/or oil produced from the first and/or second layer.
7. Method according to claim 6, wherein the combustion product comprises CO₂ used as an injectant.
8. Method according to claim 6 or 7, wherein the combustion product comprises water used as an injectant.
9. Method according to any of the preceding claims, wherein the first and/or second injectant comprises N₂ obtained from an air separation method, and wherein O₂ from the same air separation method is used in the combustion of natural gas and oil produced, to yield water and CO₂.
10. Method according to any of the preceding claims, wherein at least one of the first and second injectants is an essentially aqueous injectant.
11. Method according to any of the preceding claims, wherein the viscosity of the first and/or second injectant is controlled by adjusting the temperature.
12. Method according to claim 11, wherein heat to control the temperature of the first and/or second injectant is obtained from the combustion of natural gas and/or oil.
13. Apparatus (20, 30) for use in the method according to any of the preceding claims, comprising
At least one first injector (39, 52) for injecting a first injectant into a first layer (41),
At least one second injector (42, 53) for injecting a second injectant into a second layer (42) adjacent to the first layer,

monitoring means (51) for monitoring the progress of injection for the first and second injectants, and adjusting means (55) coupled to the monitoring means and the first and second injectors.

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- 14.** Apparatus according to claim 13, wherein the adjusting means are programmed to keep the progress of the first and second injectant within predetermined limits.

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- 15.** Apparatus according to claim 13 or 14, wherein the apparatus comprises a combustion unit, wherein an outlet for CO₂ produced by the combustion is coupled to the second injector, and wherein an outlet for water produced by the combustion is coupled to the first injector.

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Figure 1

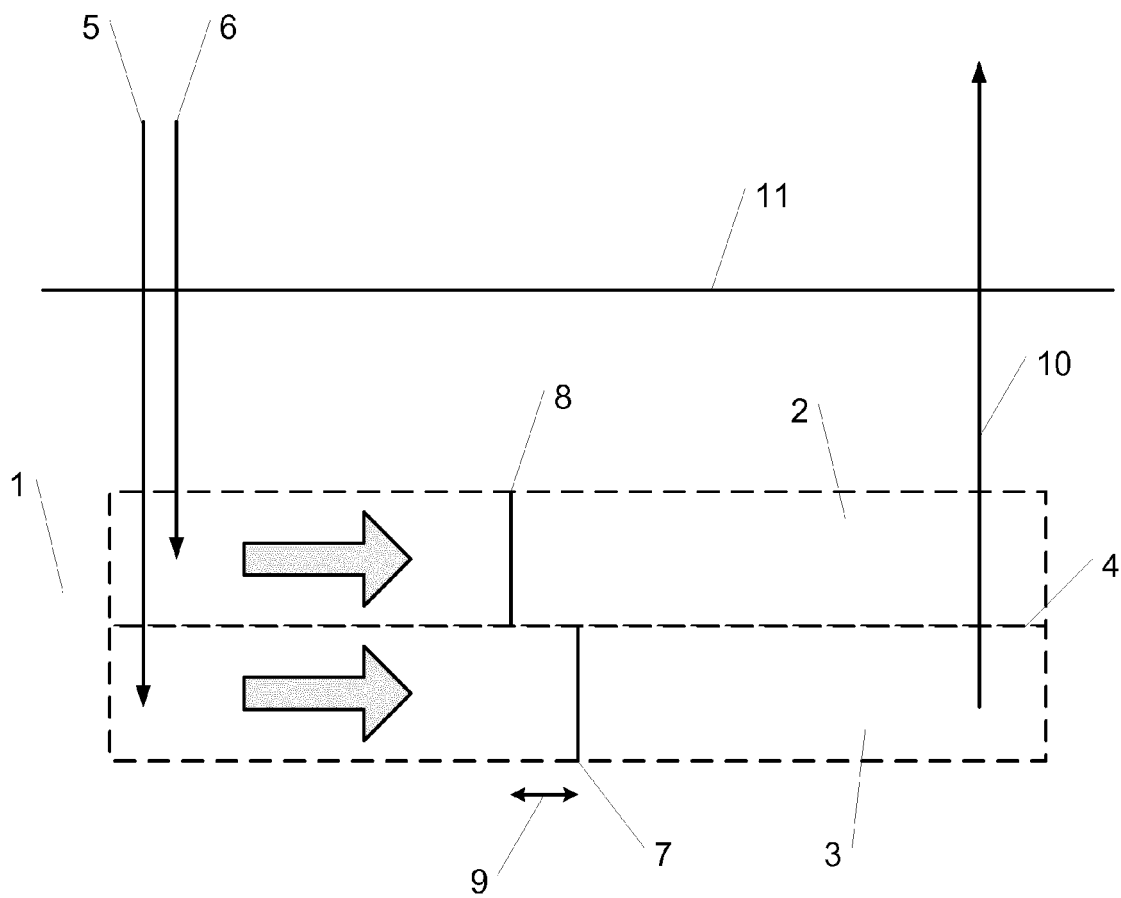


Figure 2

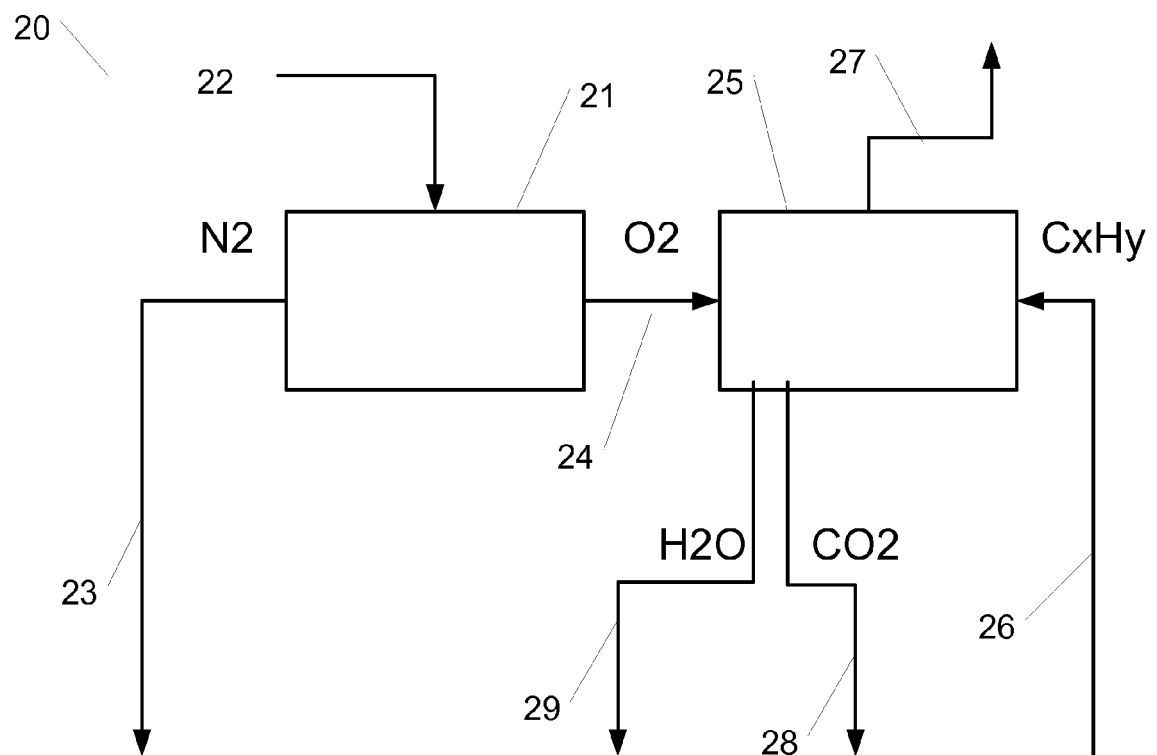


Figure 3

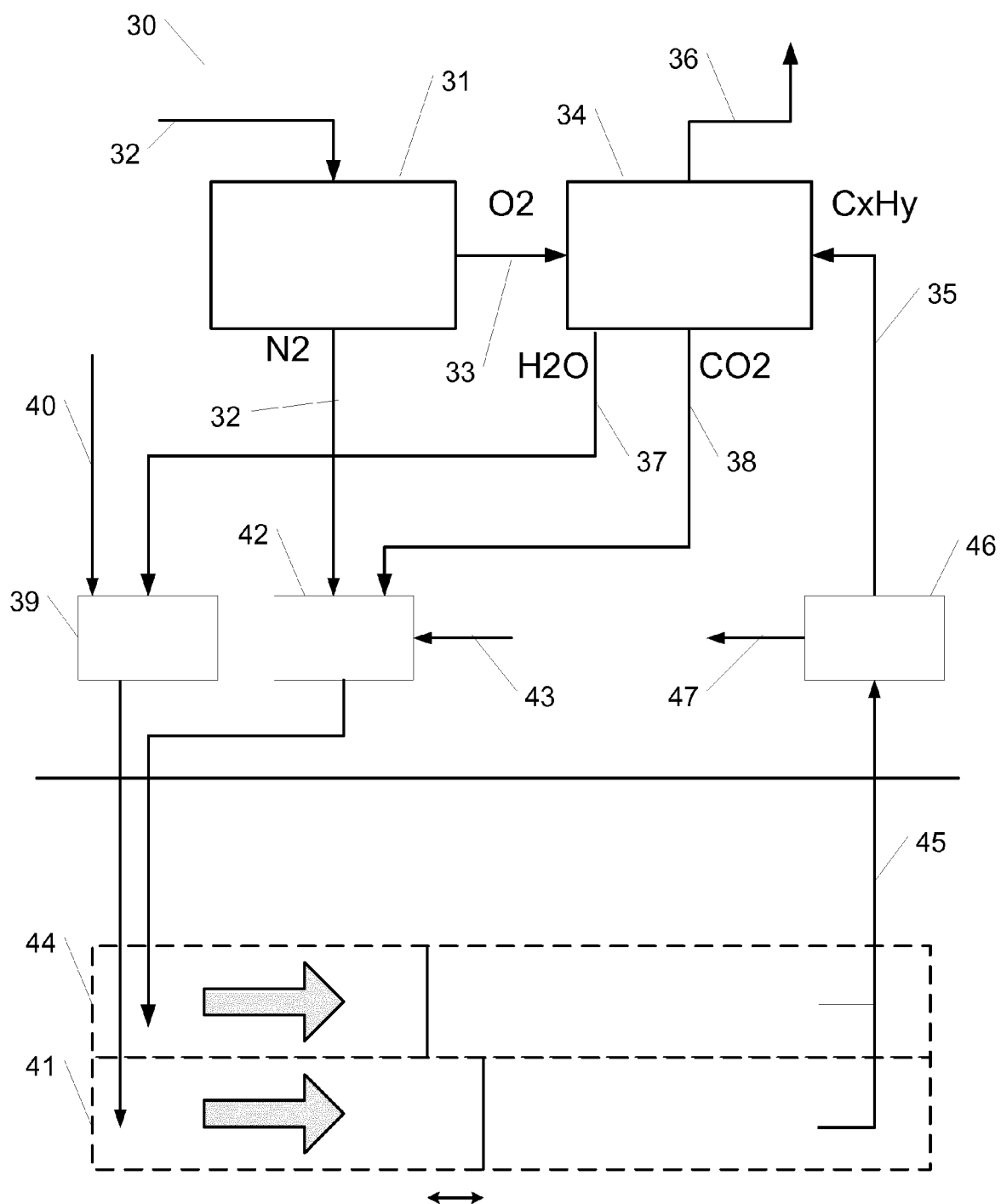


Figure 4

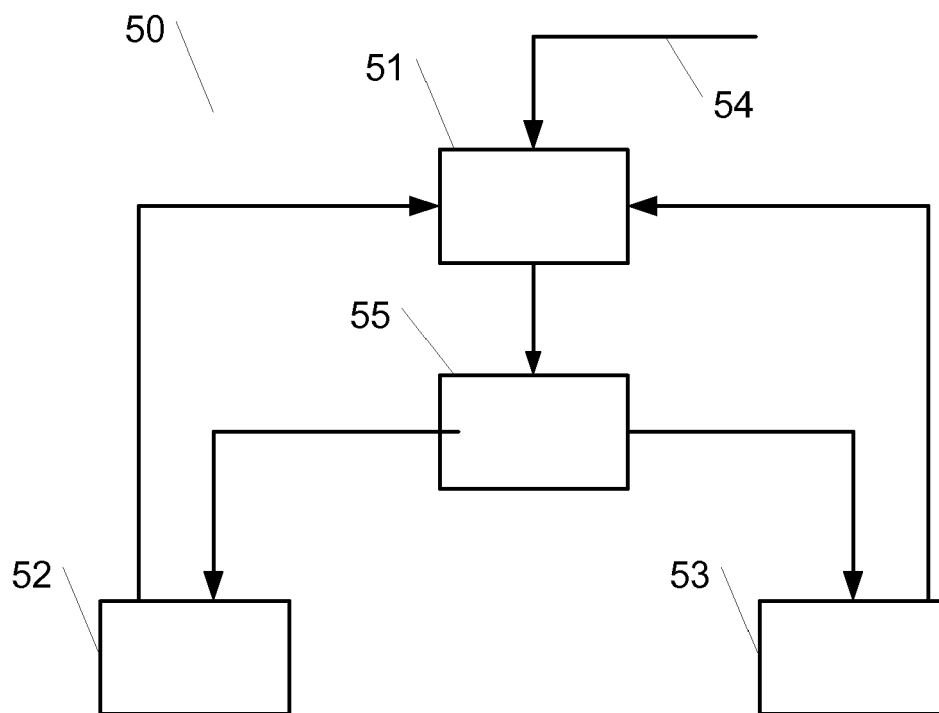


Figure 5a

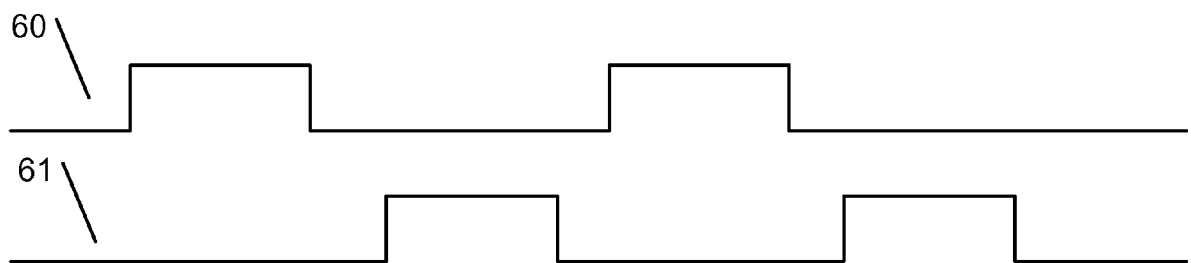


Figure 5b

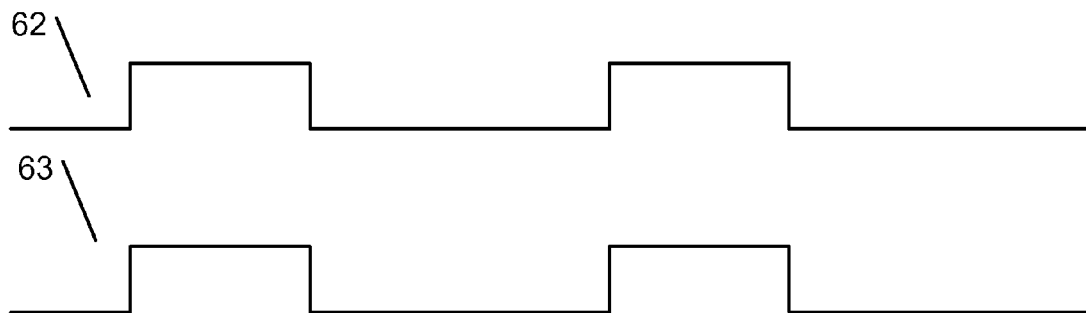
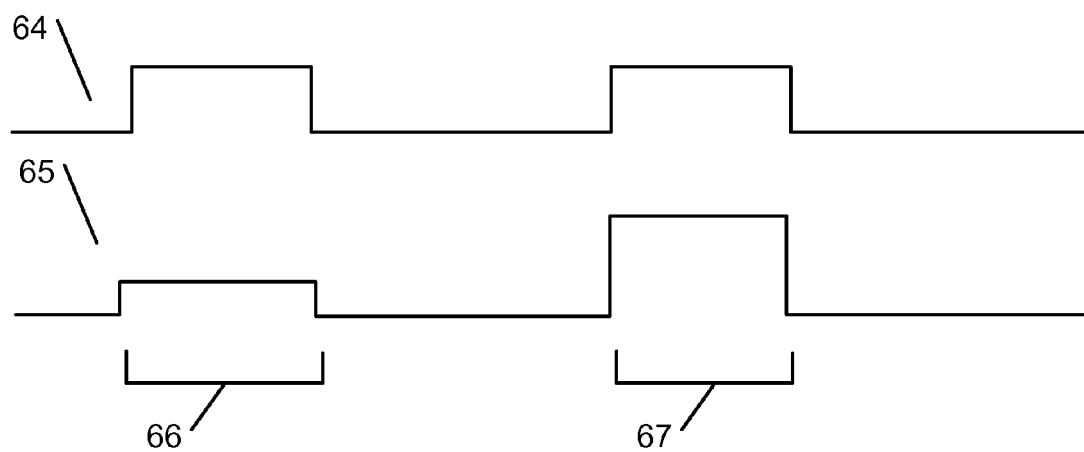


Figure 5c





EUROPEAN SEARCH REPORT

Application Number
EP 12 18 7691

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 2 239 415 A1 (SHELL INT RESEARCH [NL]) 13 October 2010 (2010-10-13)	1-4, 10-14	INV. E21B43/16
Y	* paragraphs [0027], [0028], [0034], [0036], [0037]; figure 1 *	5-9,15	
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			TECHNICAL FIELDS SEARCHED (IPC)
			E21B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 23 January 2013	Examiner Bellingacci, F
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 12 18 7691

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The members are as contained in the European Patent Office EDP file on
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82