A buoyant capsule for producing oil from a plurality of underwater wells, the buoyant capsule being held in submerged position by conduit means anchored in the floor of the body of water which permit controlled lateral movement of the capsule resulting from wave action. The pressure within the capsule is regulated to maintain an ambient environment, and means are provided within the capsule for compounding a nonexplosive, noncombustible gas mixture conducive to human operation.
FIG. 4.

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METHOD AND APPARATUS FOR PRODUCING OIL FROM UNDERWATER WELLS

This invention relates to oil production from underwater oil fields, commonly known in the art as offshore oil production. The conventional methods of producing oil from offshore locations involve either the installation of underwater pipelines from each well to the shore when the production is within a few miles offshore, or the construction of production platforms supported from the ground beneath the water and extending above the surface thereof. In some instances, particularly when the underwater field is far offshore, oil production platforms are used to collect the oil from the underwater wells and then pump it into a pipeline communicating with the shore. In other instances, production platforms which include associated storage facilities are used to collect, separate the waste products from the oil and store the oil until it is either pumped into a pipeline or transferred to a tanker. The present offshore oil production systems are complex and expensive, particularly when the wells are located 150 or more feet above the surface. In cases where production platforms are utilized, they must be designed to support the substantial weights of the huge structures which usually provide not only for oil storage but in addition, for living quarters for personnel as well as for separation and pumping equipment, and various mechanical handling equipment. The platform structures must also be designed to withstand the forces of the most severe ocean storms. These factors require the platforms to employ extremely heavy structural sections, resulting in substantial material, fabrication and installation costs. The platforms are still vulnerable to damage by surface marine traffic as well as by storms, and numerous cases of complete loss of the structures as well as of substantial damage thereto have already been recorded.

Several additional problems of a major nature are associated with the use of offshore production platforms. Since many production platforms are designed to handle the production from 20 or more wells concurrently, a significant time delay in beginning production from any of the wells is usually required until after the drilling of many wells has been completed from the same platform. The reason for this is that ordinarily, it is extremely hazardous to produce oil from previously drilled wells from a given platform concurrently with the drilling of new wells from the same platform because of the possibility of fires or explosions. The magnitude of this delay in production can be substantial, resulting in a serious loss of revenue. For example, if a typical well requires 1 month of drilling time, a platform equipped to produce oil from 20 wells would usually delay production from any of the wells for a period of as much as 2 years.

Another major difficulty is that many areas of the country consider offshore platforms unsightly in appearance as well as a hazard to marine navigation, and have accordingly passed legislation which greatly restricts the number of such platforms permissible within view of the shore. The effect of the restrictions is that only the most productive oil fields are placed into production; frequently, many small oil fields with known reserves are left unatapped. This is particularly prevalent when the smaller fields are relatively far offshore or in relatively deep water.

Still another major problem in the systems of the prior art using production platforms and or pipelines, with wellheads on the bottom of the body of water is that the systems are substantially limited to the range of depths corresponding to present diving capabilities. The reason for this is that it is usually necessary, even in totally automated production systems, to require divers to perform maintenance and repair functions at the wellheads on the bottom of the body of water. Thus, although oil may exist in substantial quantities at deep levels, for example, 2000 feet or more, present systems are economically incapable of producing the oil.

Finally, the present underwater completion systems are complex as well as expensive in cost and installation. The reason for this is that present wellheads located adjacent to the ground beneath the water must provide for maintenance over the producing life of the well. The wells are presently maintained and serviced from locations remote from the well which in turn requires extremely complex and expensive wellheads and associated equipment.

An object of the invention is to provide a method and apparatus for producing oil from underwater oil fields which does not require the use of surface production platforms.

Another object is to provide an offshore production method and apparatus which does not require the use of flow lines from each well to the shore.

A further object is to provide an offshore production method and apparatus which is not affected by the full force of surface weather conditions.

Still another object is to provide a method and apparatus which is not vulnerable to collision from surface vessels or objects, e.g. icebergs.

Yet another object of the invention is to provide a method and apparatus which facilitates the production of oil from previously drilled wells concurrent with the drilling of additional wells without substantial hazards of fire and explosion. In accordance with the invention, the interior of the capsule is always at ambient pressure, and the gaseous mixture for breathing provided at this pressure is such as to permit a safe operating environment.

A further object is to provide an offshore production method and apparatus which is not limited to any depth of water.

A still further object is to provide an apparatus for producing oil which is substantially lower in cost, as compared with conventional surface production platforms.

Another object is to provide an apparatus which can safely operate completely submerged.

Yet another object is to provide a method and apparatus which enables the use of land-type wellheads and associated equipment of simple construction and lower cost than present underwater wellheads and associated equipment.

Still another object is to provide a method and apparatus which is easier and less costly to service and maintain than systems located on the bottom of the water.

A still further object is to provide an apparatus which is completely submerged and which includes means for collection, separation and storage of oil.

Another object is to provide a marine terminal tanker mooring and loading system connected to the production capsule.

Yet another object is to provide a submerged apparatus having provision for receiving and holding the base of a drilling structure.

Other objects and advantages of the invention will be apparent from the remaining specification and appended claims.

In the drawings:

FIG. 1 is a perspective cutaway view of an apparatus according to the present invention for producing oil from one or more underwater wells;

FIG. 2 is a sectional view taken along the line 2-2 of FIG. 1;

FIG. 3 is an enlarged fragmentary elevational view of a portion of the apparatus shown in FIGS. 1 and 2, illustrating a removable coupling means;

FIG. 4 is an elevational view of another embodiment of the invention;

FIGS. 5 and 6 are elevational views illustrating a method of installing the apparatus of the invention.

According to the invention a method is provided for producing oil from an underwater well by providing a submerged buoyant oil-time capsule intermediate the well and the water surface. The oil is extracted from the well and flowed into such submerged zone. Preferably, the sediment, water and gas is at least partially separated from the oil within the production zone. Thereafter the oil is either transferred to a submerged storage zone or discharged into a pipeline or tanker for transmission to the shore.
Apparatus for producing oil from an underwater well according to the invention is provided and comprises a buoyant capsule always maintained at ambient pressure; conduit means interconnecting the underwater well with the capsule, and a wellhead within the capsule and connected to the conduit means. Preferably the capsule is interconnected by suitable conduit means to a plurality of underwater wells thus enabling one submerged capsule to serve many wells. Preferably, the conduit means interconnecting the well or wells with the capsule are anchored into the ground and serve as means for holding the buoyant capsule in a substantially fixed vertical position. All casing is suspended within and anchored by the conduit means at the mudline, except for the production strings which extend vertically into the capsule and are attached to the wellhead.

Since, according to the invention, the capsule is buoyant, the conduit means serving to hold the same in a substantially fixed vertical position will always be in tension. As will be seen in FIGS. 1 and 4 to 6, the conduit means are inclined relative to the vertical thereby to permit controlled lateral movement of the capsule due to wave action and the like, notwithstanding the vertical buoyant forces applied to the conduit means. This permits relatively thin-walled conduits to be used. According to the preferred embodiment of the invention, the conductor tubes used during the drilling of the underwater wells are employed as the conduit means for a conventional oil producing casing arrangement to transfer the oil to the capsule and to hold the capsule in a substantially fixed vertical position. Thus additional holddown means for the capsule as well as separate oil transfer conduits from the wells to the capsule are not required. Preferably, the capsule contains means for separating sediment, water and gas from the oil as well as a storage compartment for holding the oil at ambient pressure pending its transfer into a tanker or pipeline.

According to another embodiment of the invention, a removable drilling structure having a buoyantly controllable base is connected to the submerged capsule. This drilling structure includes a rotatable drill table and derrick. This structure enables a plurality of wells to be drilled and produced without the aforementioned safety hazards, since the capsule forms a buoyant production zone located below the surface.

Referring to the drawings, particularly FIGS. 1 and 2, a buoyant capsule 10 is shown submerged intermediate one or more wells W. The water surface S, and constitutes a buoyant oil production zone. Conduit means 12 interconnect the wells W with the capsule 10, the upper end of each conduit being connected to a conventional wellhead 14 of substantially land type located within the capsule. Preferably, the conductor tubes used during the drilling of the wells are not discarded, but instead are employed as the conduit means 12 for housing a production casing arrangement (not shown) to transfer the oil produced into the capsule 10. Moreover, as aforementioned, since the capsule is buoyant, heavy structural supports are not required and thus the conduit means 12 anchored into the ground preferably serve to hold the capsule in a substantially fixed vertical position. Alternatively, if desired, the capsule could be held down by separate cables (not shown).

The buoyant capsule 10 is preferably constructed with a plurality of watertight compartments C, each of which may contain one or more wellheads. Additional watertight compartments E may be provided for living quarters, equipment rooms, storage areas, etc. Each of the compartments preferably includes vent means 20 for venting gases externally of the capsule and further preferably includes a bursting member 22 for relieving pressure in excess of ambient without affecting the operation of any other compartment.

The capsule has a passageway 11 closed off by removable hatch 19 for ingress and egress. The passageway and hatch are adapted to mate with the hatch of a pressure-controlled personnel transfer capsule which can also serve as a deck decompression chamber for the men working under ambient pressure conditions in the capsule.

Preferably, the capsule contains one or more separating means 18 connected to the wellheads 14 for at least partially separating sediment, water and gas from the oil flowing into the capsule. The separation means 18 is preferably connected by a submersible piping to storage compartments S and H for discharging sediment and water removed respectively from the crude oil entering the capsule. The gas produced in the separating means 18 is preferably transferred to compressors 42 and compressed therein to high pressures. Thereafter the pressurized gases are transferred from the compressors through conduits 15 into the wells as secondary recovery medium in order to increase the recovery of oil produced. Alternatively, the gas separated may be fed to gas transfer compressors 43, compressed therein, and transferred to a pipeline. In remote locations, it may be necessary to merely burn off the separated gases into the atmosphere via a flaring line (not shown) leading from the capsule to the surface. The capsule may also have a storage compartment 26 for storing the oil until its transfer to a vessel or pipeline. The capsule includes pumping means 40 for discharging the oil from the storage area into a pipeline. Alternatively the pumping means 40 may be used for discharging the oil into a marine terminal tanker mooring and loading system 50 connected to the production capsule as well as supplemental pumps 41 for transferring oil into the tanker and thereafter into the storage compartments. The marine terminal system may include a mooring whereby a tanker may be held in place, a hose connection for the transportation of fluids, control facilities, power generation and other systems necessary to accomplish the offloading process.

As shown in FIG. 2, in addition to containing wellheads 14, the capsule further includes second conduit means 15 extending into the ground for injecting secondary recovery fluids into the wells from a point within the capsule. The capsule also contains means 16 for controlling the ambient atmosphere therein in order to maintain same in a dry condition and to prevent the formation of explosive mixture due to possible oil or gas leaks from the wellheads or separation equipment. The atmosphere control means may include filters, precipitators, scrubbers, burners, absorption media, gas generators, gas analysis equipment, etc. The atmosphere control means may also have provisions for regulating the total pressure within the capsule to maintain the ambient pressure.

Preferably, the capsule has means 27 for receiving and holding the base of a drilling structure (see FIG. 4) in order to prevent relative motion between such structure and the capsule. Mechanical or electromechanical locking devices of conventional design are suitable for this purpose. This enables a drilling structure to be aligned with and held in place by the submerged capsule which in turn permits a plurality of wells to be drilled while adjacent wells are concurrently being completed and produced from.

As shown in FIG. 4, a removable drilling structure D is connected to the capsule 10. The drilling structure includes a buoyantly controllable base 31 extending between vertical legs 29. The legs 29 include a vertical shaft 33 which is attached to the means 27 on the capsule, and surrounding sleeve 34 movable over the shaft 33. The upper ends of legs 29 are attached to drilling platform 35 which supports a rotating drill table 36 and derrick 37. The base 31 includes a valved intake conduit 38 and a bleed conduit 39. By appropriate control of the intake and bleed valves the buoyancy of the drilling structure can be altered. In addition, in the same manner, the height of the drilling platform above the water can be regulated in order to position the drill table 36 so that it is approximately at the apex of the conductor tubes 12. With the drill table 36 located at the apex of the inclined conductor tubes, a plurality of wells can be drilled from the same position by making only minor adjustments to the derrick. This is an obvious advantage in that it substantially reduces the time and cost of bringing the plurality of wells serviced by each capsule.
into production. The inclination of the conductor tubes 12 additionally serves as above described to permit controlled lateral movement of the capsule due to the forces of wave action and the like. It is to be understood that although a buoyant drilling structure is shown, the invention can be carried out with conventional drilling structures as well, so long as the capsule and drilling structure as a unit are buoyant.

To install the capsule, it is first transported to the desired location. Thereafter a pulldown cable L (see FIGS. 5-6) is reeved through an anchor pile P to a tethered vessel V equipped with a winch or winch so that a downward pull can be exerted on the capsule. Depending upon conditions such as the size of the capsule and the depth to which it will be submersed, the capsule may be partially flooded to make it easier to submerge and later pumped out after the same has been secured below the surface. Gas may be admitted to the structure during the submerging step to control its buoyancy.

As shown in FIGS. 1 and 3, the capsule is provided with pairs of guide tubes 21 extending into the capsule through apertures A and being joined to the capsule wall. A removable coupling means 13 is connected between the guide tubes 21 to prevent water from entering the capsule. Prior to submerging the capsule, the conductor tubes 12 are installed through the guide tubes 21 and through the removable coupling means 13 so that the lower ends thereof extend beyond the guide tubes on the lower portion of the capsule as shown in FIG. 5. The conductor tube 12 is held in place after insertion through the guide tube 21 by locking means 44. Just prior to installing the conductor tube 12 into the ground G, the locking means 44 is unlocked. After the conductor tubes are installed to the desired depth, the locking means 44 are permanently locked and sealing means 45 is installed.

The locking means may consist of a split ring and the sealing means may comprise ordinary packing. Thereafter, a downward pull is exerted upon the capsule through the pull-down cable L in order to submerge the capsule to the desired depth with the conductor tubes 12 touching the ground G. Finally, while the capsule is held at the desired depth, the conductor tubes 12 are installed into the ground to the desired depth. Preferably, the number of conductor tubes and the depth to which they are installed is such, in relation to the buoyancy of the capsule, as to adequately hold down the same so as to maintain it in a substantially fixed vertical position.

The use of the invention as aforesaid enables the art to economically produce oil from offshore locations without substantial effects from weather conditions or marine traffic, since the production zone is submersed. Aesthetic problems associated with surface platforms are nonexistent for the same reason.

The use of a submersed enclosure enables the use of substantially conventional land-type wellheads which are of less complicated construction and lower in cost than wellheads located on the ocean floor. In addition, since the wellheads are located within the capsule instead of on the ocean floor, wells of almost any depth, far beyond present diving capabilities, can be drilled and produced without repairs and workovers may be carried out from within the capsule instead of on the ocean floor.

While the invention has been described in connection with a specific system for drilling and producing oil from an underwater well, it is obvious that many changes may be made in the system without departing from the spirit and scope of the invention as defined in the claims.

For example, conventional surface vessel drilling means may be used to drill the well in lieu of the combination drilling and producing structure shown in FIG. 5.

I claim:

1. Apparatus for producing oil from a plurality of deep underwater wells comprising:
   a. a buoyant capsule held underwater in a substantially fixed vertical position, the depth of said buoyant capsule below the water surface being determined by the wave force contemplated, surface hazards, and the pressure required of a gas mixture conductive to human operations and which is noncombustible and free of explosive hazards, b. conduit means inclined relative to the vertical and operatively connected at their upper ends to said capsule and anchored at their lower ends in the floor of the body of water, said conduit means being in tension due to the buoyancy of said capsule and serving simultaneously to hold said capsule in its submersed position and to permit controlled lateral movement of said capsule resulting from wave action, said conduit means serving also to transfer fluid from each of said wells to the capsule,
   c. a plurality of wellheads within the capsule and connected to said conduit means,
   d. means for regulating the pressure within the capsule to maintain an ambient environment, and
   e. means within said capsule for compounding a nonexplosive, noncombustible gas mixture conductive to human operation.

2. Apparatus as claimed in claim 1, wherein the capsule has a plurality of apertures disposed about the periphery thereof to provide access for advancing said conduit means through the interior of the capsule, and upper and lower guide means attached to the capsule about the apertures for guiding the advancement of each conduit means through the capsule into the ground, coupling means mounted with the capsule, said coupling means interconnecting the upper and lower guide means to prevent entrance of water into the capsule, means for locking each conduit means to said lower guide means after each conduit means has been advanced into the ground, and means for sealing said upper and lower guide means for preventing entry of water into said capsule when said coupling means is open.

3. Apparatus as claimed in claim 1, wherein said capsule further includes means for separating sediment, gas and water from the oil produced, said separating means being connected to said wellhead.

4. Apparatus as claimed in claim 3, further including additional conduit means communicating between the capsule and the ground for the injection of secondary recovery fluids.

5. Apparatus as claimed in claim 1, further including a removable drilling structure, said structure being connected to said capsule such that relative motion therebetween is prevented, said drilling structure including a rotating drill table and derrick.

6. Apparatus as claimed in claim 5, wherein said drill table is located approximately at the apex of said conduit means thereby permitting drilling of a plurality of wells from essentially the same drill rig location.

7. Apparatus as claimed in claim 5, wherein said drilling structure has a base, and further including separate means for controlling the buoyancy of said base.

8. Apparatus as claimed in claim 1, wherein said capsule is divided into a plurality of watertight compartments each of which contains one or more wellheads, said capsule further including separate vent means for venting gases externally of the capsule and a bursting member for relieving excess pressure from any compartment without affecting the operation of the remaining compartments.

9. Apparatus as claimed in claim 1, wherein the capsule includes a storage compartment for the collection of the oil produced, said oil being stored at ambient pressures.

10. Apparatus as claimed in claim 9, further including a marine terminal tanker mooring and loading system connected to said capsule, and pumping means within the capsule for discharging oil from the storage compartment into the tanker mooring and loading system.