April 7, 1970 C. O. BAKER ET AL 3,504,741

UNDERWATER PRODUCTION SATELLITE

Filed June 27, 1968 6 Sheets-Sheet 1

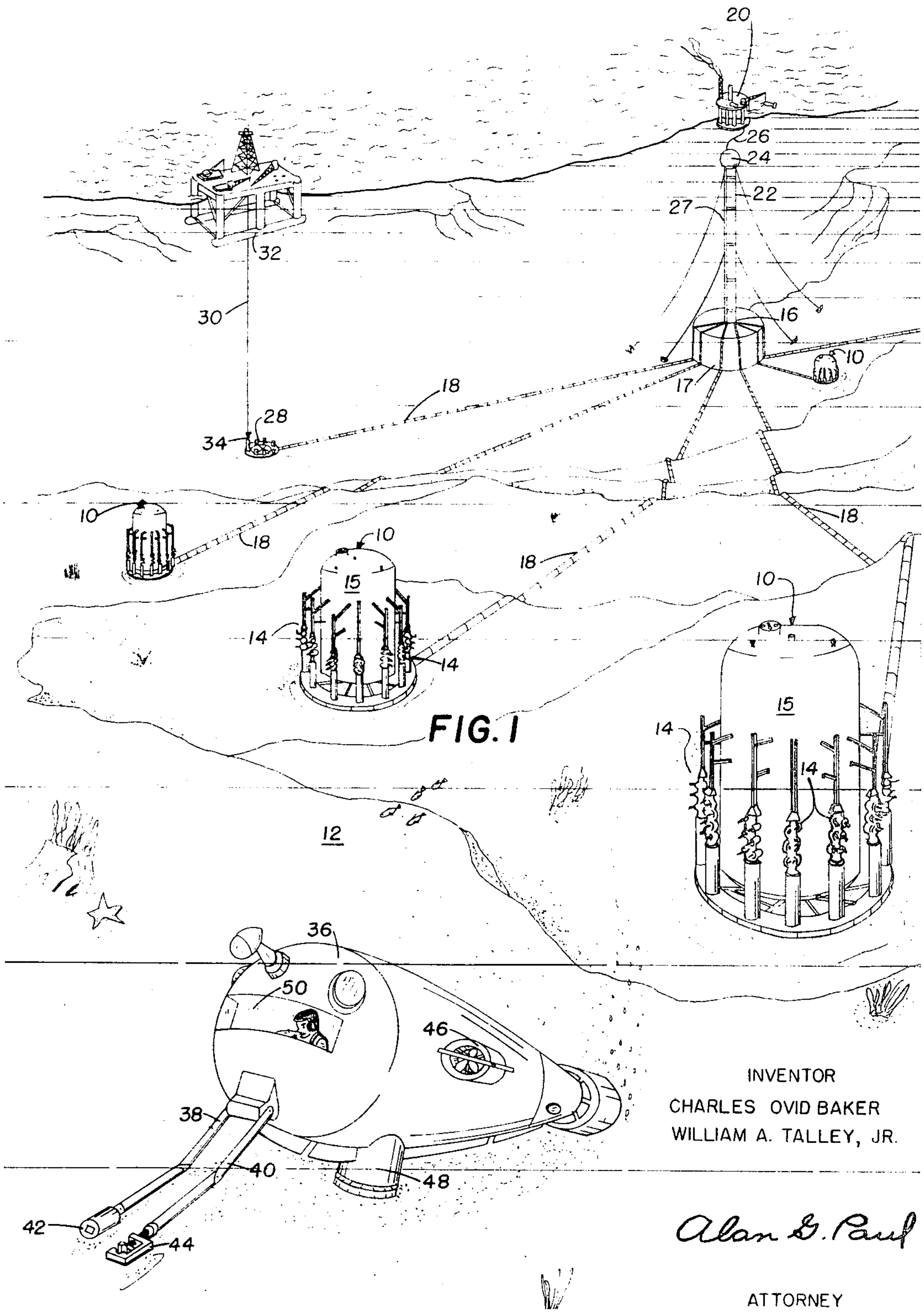

FIG. 1

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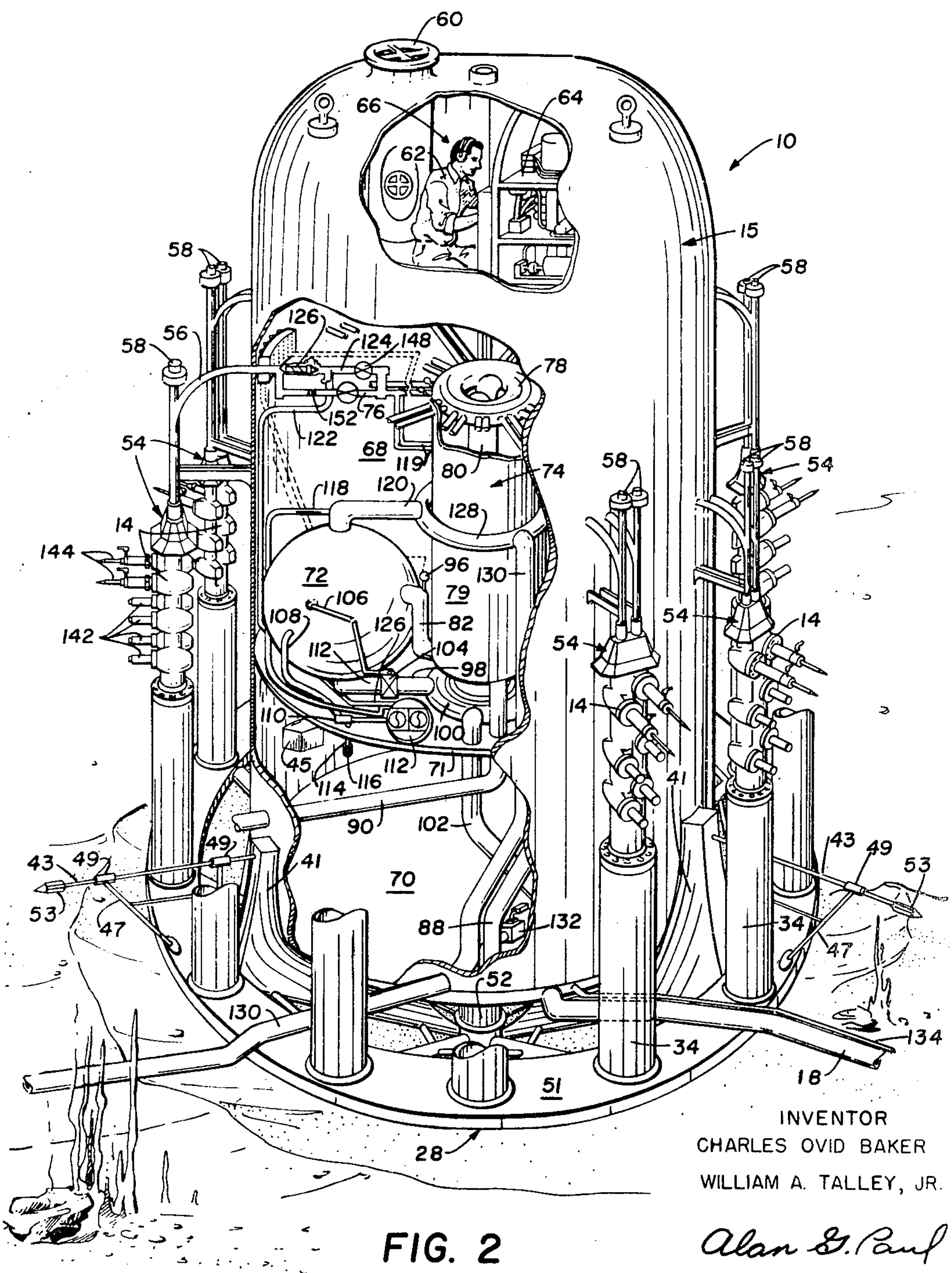

FIG. 2

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UNDERWATER PRODUCTION SATELLITE

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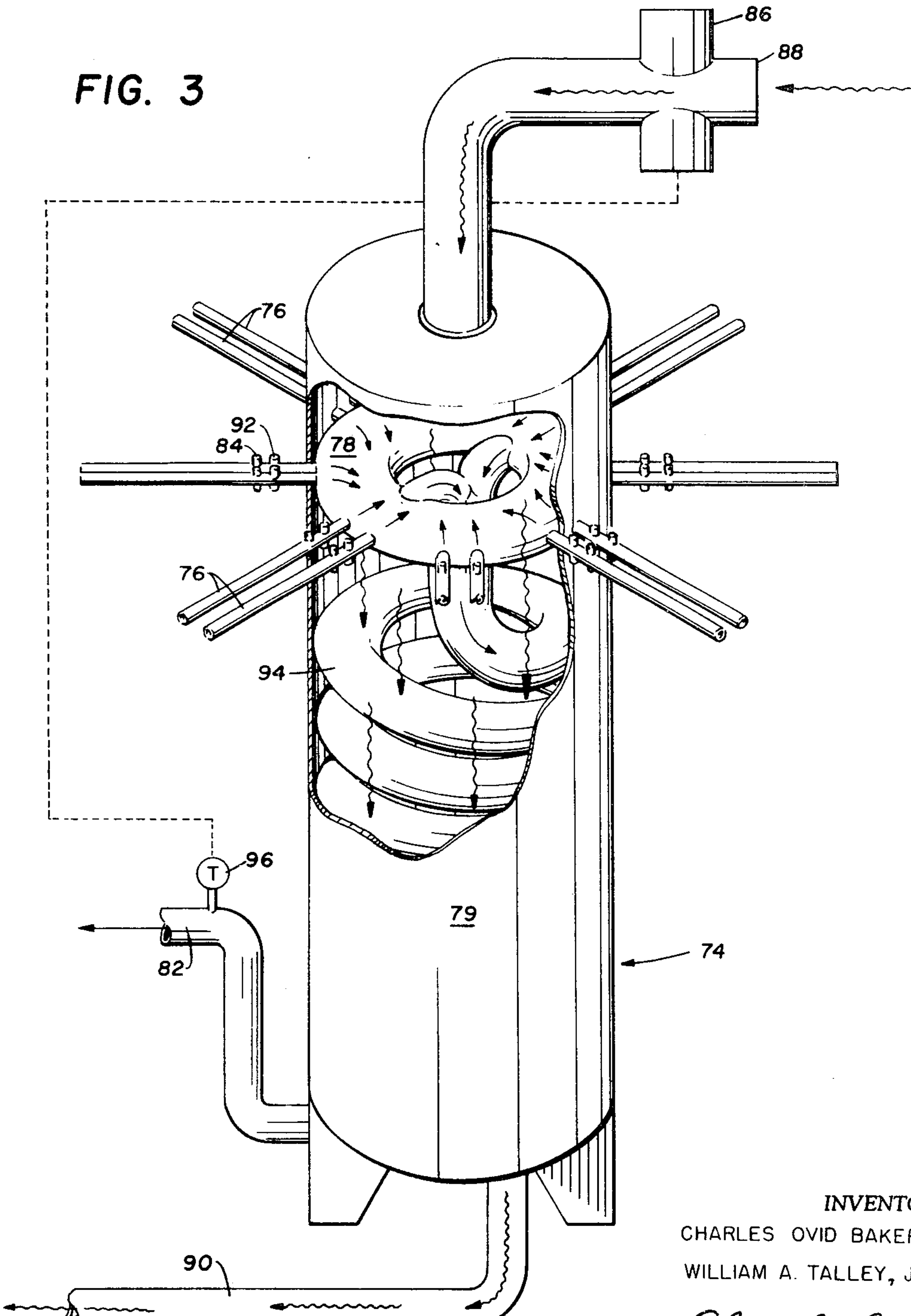
FIG. 3



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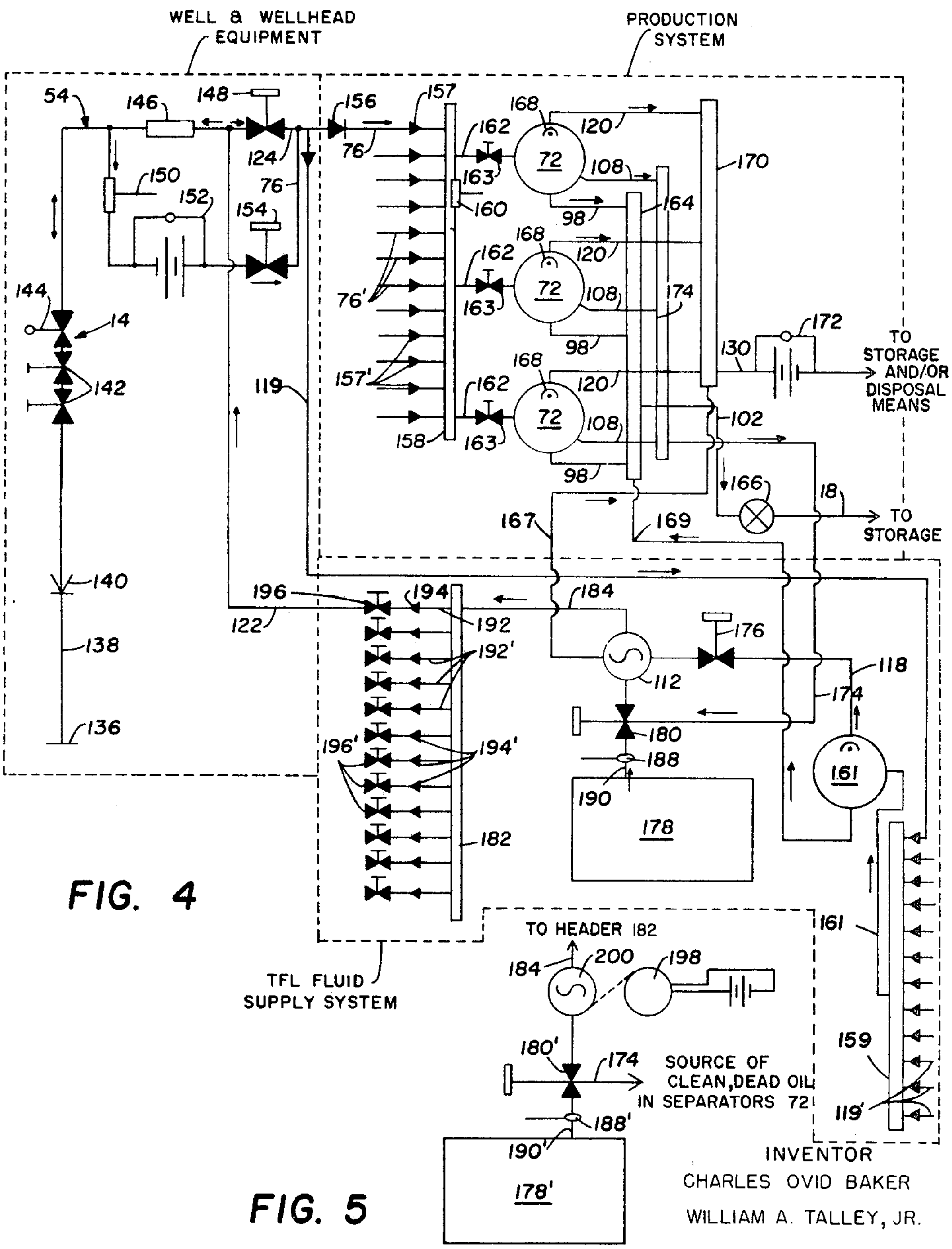

FIG. 4

FIG. 5

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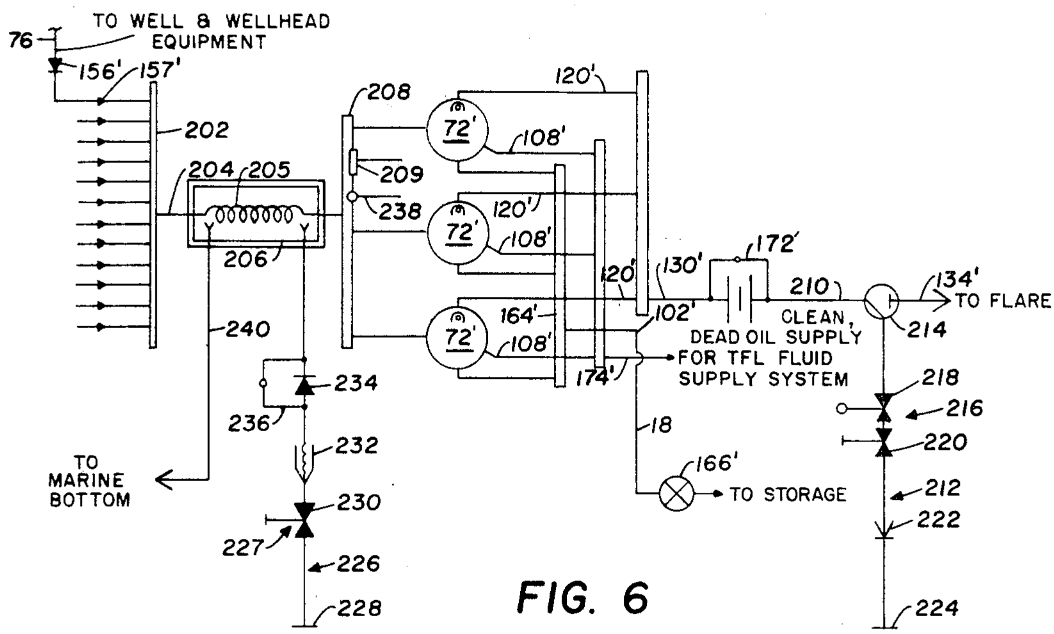

FIG. 6

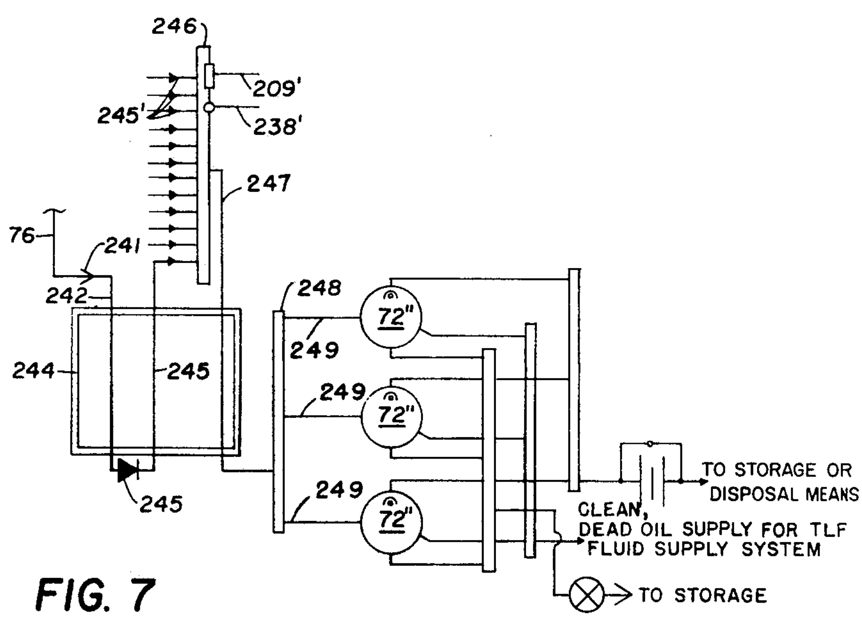

FIG. 7

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UNDERWATER PRODUCTION SATELLITE

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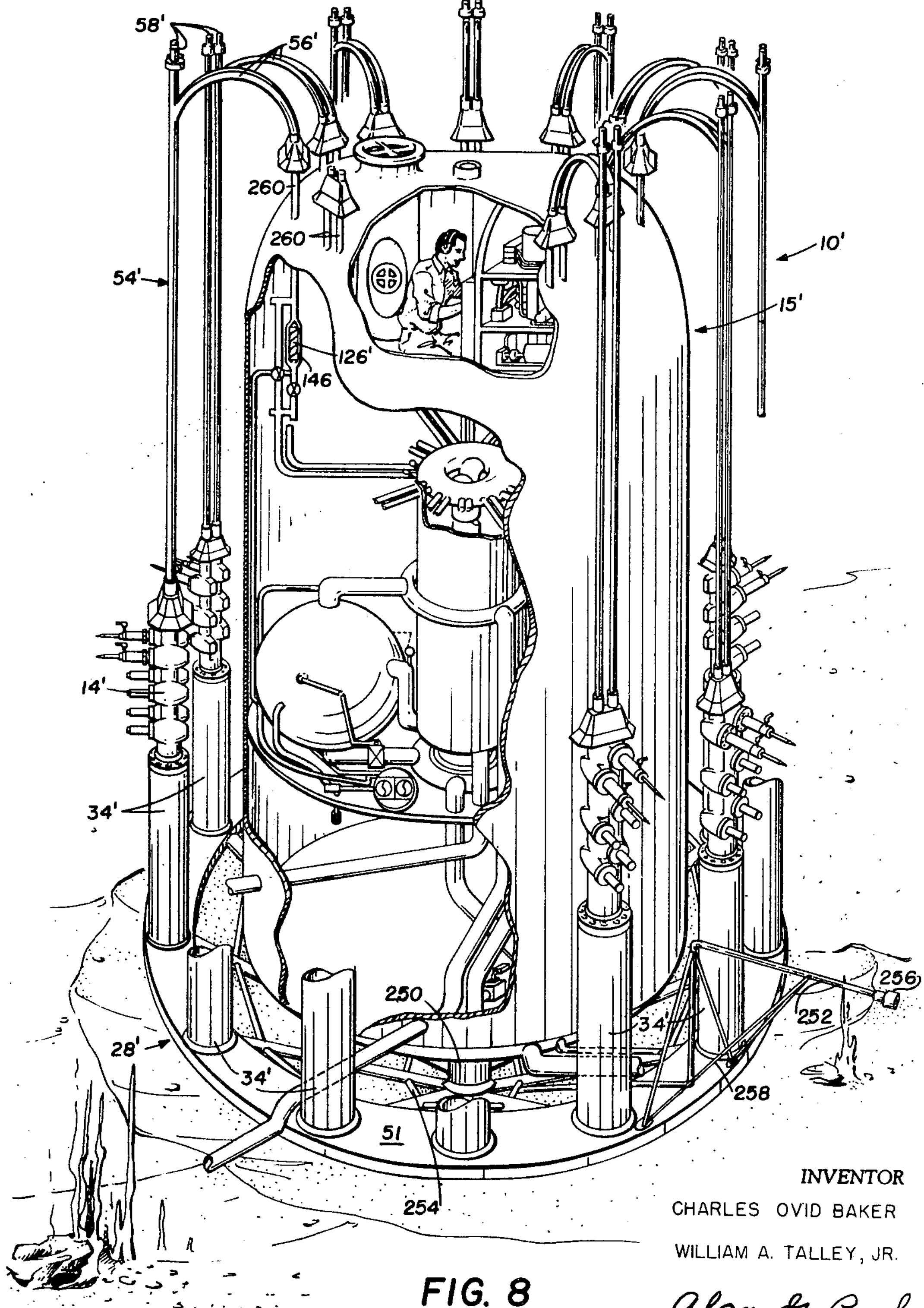

FIG. 8

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United States Patent Office

3,504,741
Patented Apr. 7, 1970

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3,504,741
UNDERWATER PRODUCTION SATELLITE

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Filed June 27, 1968, Ser. No. 740,578
Int. Cl. E21b 33/035, 43/01
U.S. Cl. 166—.5 26 Claims

ABSTRACT OF THE DISCLOSURE

This specification discloses a method and apparatus for the production of subaqueous deposits of fluid minerals through a subsea satellite system. The wells are drilled in a circular pattern through a template on the marine bottom serving also as base upon which the satellite body is installed. The production and control passages of each of the wells are connected to production equipment within the satellite body by separate connector units, independently lowered into place from a surface vessel, to form portions of fluid paths between the passages within the subsea wellheads and the production equipment within the shell of the satellite. Such an installation permits production through the satellite, installed on the template base, after only one of the wells has been drilled and completed. The produced fluids are separated and/or metered within the satellite prior to being transported to storage. Flowline tools are programmed to enter the various subaqueous wells through the connector units. Hydraulic circuitry and controls are provided for pumping the tools and chemicals down through the various wells and for retrieving the tools. Also disclosed is a hot water well utilized as a heat source, in conjunction with a heat exchanger unit within the satellite for warming the produced fluids after a pressure cut is taken to prevent the formation of hydrates, and, if necessary, for warming that portion of the interior of the satellite body where personnel will work.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to a subsea satellite designed to be interconnected with a plurality of subaqueous wells having subsea wellheads so as to control the production therefrom and to provide ordinary maintenance therefor, the fluids from the subaqueous wells being produced through the subsea satellite wherein they are separated and metered and from which they are transported to a storage facility. More particularly, the invention relaates to a means for heating gaseous products within the satellite to hinder the formation of hydrates during the separation operation.

Description of the prior art

Since its inception, the offshore oil and gas industry has used bottom-supported above-surface platforms as the principal mechanism for the installation and support of the equipment and services necessary for the production of the subaqueous mineral deposits. As the industry has developed over the years, it has extended its search for offshore minerals from its birthplace, producing oil and gas in the shallow coastal waters off California and the Gulf of Mexico into areas where, because of excessive water depth and/or other local conditions, the bottom-supported platform is not as economically or technologically feasible.

While theoretically there is no limit to the depth for which a bottom-supported platform can be designed and installed, experience to date indicates that platform costs

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increase almost exponentially with the increase in water depth. Thus, the presently estimated costs of a platform to carry the production facilities for a field in four hundred feet of water or more are so high as to indicate that such an installation cannot be justified economically for any but the most productive fields. Furthermore, the few bottom-supported above-surface platforms that have been designed and built for use in three hundred feet or more of water depth have almost invariably suffered leg failures of one type or another.

A possible solution is to install the production facilities on a floating platform, as is described in the H. D. Cox Patent No. 3,111,692, issued Nov. 26, 1963, which can be maintained in position in a field by either a fixed multipoint mooring system of anchors and anchor lines, or by dynamic positioning system. The above solution involves the expense of continuous maintenance and surveillance of the locating system as well as the associated problems and expense of maintaining the multiple flexible lines connecting well heads on the marine bottom with the continuously moving floating production platform, and the potential hazard, of this system, to the hoses, in the event of a failure of the fixed mooring or dynamic positioning systems.

Another consideration is that, in many areas of the world, local conditions other than water depth impose critical limitations on the use of bottom-supported production platforms. In arctic areas, a bottom-supported platform must be built to withstand the forces imposed by ice that forms on the water surface during the winter months of the year, and in many such areas all year long. Furthermore, any above-water production platform is subject to the mercy of the wind and waves, especially those occurring during hurricanes and other violent storms. In the arctic areas these storms can be exceeded by the forces exerted against the platform by movement of the thick ice layers that freeze on the surface of the water. For example, in Cook Inlet, Alaska the local extremely high tidal movements on the order of thirty feet or more cause very fast tidal currents in the inlet, with velocities of up to eight to ten miles an hour or more. These very rapid currents carry with them the heavy pack ice that forms on the surface of the inlet, so that it bears with tremendous force against any fixed structure, such as a production platform, that should be installed in its path.

In still other areas it is not adverse natural, but man-made, conditions that restrict the use of bottom-supported above-surface production platforms. Among such conditions could be listed official and/or public objection to oil production facilities near public recreational or residential areas, and the presence of heavy marine traffic as in harbors, channels, rivers, or other navigable bodies of water which make it necessarily advantageous to install as much of the production equipment beneath the water surface as possible. For example, the first known use of subsea wellheads is in Lake Erie where gas is produced from subaqueous formations beneath the heavily traveled lake.

Therefore, it would appear that where there is extremely deep water and/or adverse surface conditions, a fully subsea installation would be the most advisable solution. One method, as is shown by the J. A. Haeber Patent No. 3,261,398, issued July 19, 1966, is to locate the individual pieces of production equipment on the marine bottom. Such an installation almost necessitates the use of robots such as shown in the G. D. Johnson Patent No. 3,099,316, issued July 30, 1963. However, such instrumentalities are expensive and not without their own limitations and maintenance problems. Another solution is suggested by the H. L. Shatto, Jr., et al. Patent

No. 3,221,816, issued December 7, 1965, wherein the production equipment for a plurality of wells is grouped within a satellite chamber adapted to be raised to the surface for repair and/or maintenance.

To economically package production equipment used for scheduling, measuring, separating, and otherwise performing the usual manipulations on producing oil and gas wells, it is believed to be necessary to enclose the equipment within a pressure-resistant satellite shell within which can be maintained a breathable atmosphere permitting the equipment inside to be serviced and/or maintained by personnel, not encumbered with diving suits. Single well chambers, most being removable, have been proposed and are exemplified by the J. D. Watts et al. Patent No. 3,202,216, issued Aug. 24, 1965. The most feasible system should include a subsea satellite having therewithin production equipment servicing a number of wells and capable of maintaining life sustaining conditions therewithin.

No feasible system has been presented to date for economical maintaining the several serviced wells in operating condition during production. This would require the periodic passing through of tools for cutting paraffin, setting chokes, removing sand, and other operations normally done with wirelines in a land or platform-supported well. A necessary part of such a maintenance system is means for detecting a malfunction or in simpler installations, for instance where frequent paraffin cutting is necessary, a timed sequence can be used.

One problem that arises, particularly in the production of gas, is that of the formation of hydrates in the cold gas that has been directed through the expansion valve of a separator. Within a satellite it is not easy or economical to dismantle the enclosed separators for frequent cleaning out. A solution to this problem is indicated in the copending application of John R. Leonard, Ser. No. 550,705, filed on May 17, 1966, entitled "Underwater Low Temperature Separation Unit," where a surrounding warm body of water is utilized to heat the cold gas. However, such a system only is effective in areas where the ambient water temperature is rather high. Electrical de-icers have been used in the past but these not only utilize power but require more circuitry in the satellite, complicating the arrangement, and demanding more maintenance.

SUMMARY OF THE INVENTION

In accordance with the present invention, a deep water well is completed in conjunction with a satellite production system for exploiting a gas field, or an oil and gas field having a medium or high GOR (gas-oil ratio). The water well is utilized to provide hot fresh water as a source of heat in an indirect heat exchanger unit to increase the temperature in the fluid stream on a downstream side of a choke to prevent hydrate formation, minimize excessive paraffin deposition in the equipment, and restrict emulsion formation. The chokes are located in conduits connecting each of a plurality of wells with a primary manifold within the satellite station. In the preferred embodiment illustrated, the heat exchanger unit is located between the primary manifold and a secondary manifold where the pressure-reduced fluid is distributed to a plurality of separators. However, the heat exchanger unit could be designed for the transfer of heat to the produced gaseous component at the gas outlets of the separators and/or to the produced liquid components in the sumps of the separators, if a large pressure cut were taken at the separators. Such an arrangement could be most useful where a production or test separator station serves a single subsea well. The water temperature can be controlled in response to a sensor located between the heat exchanger unit and the separators, or downstream of the separators, depending on the configuration of the station. The water well can also be utilized to provide a source of hot water for radiators within the portion of the subsea satellite in which personnel must work. In operation, the water is produced in a normal-type oil well completion and flows through a variable choke that regulates the flow rate and downstream pressure thereof. From the variable choke the warm water enters the body of the heat exchanger unit containing coils through which the cold oil and gas flow in the opposite direction. A temperature sensor employed in the produced fluid downstream of the heat exchanger unit transmits a signal to the mechanism which controls the size of the variable water choke, regulating the water flow to maintain a predetermined heat exchange.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a pictorial view of a subsea production system in accordance with the present invention;

FIGURE 2 is a partially broken away enlarged view of one of the satellite stations shown in FIGURE 1, illustrating the arrangement of the equipment therewithin;

FIGURE 3 is a schematic representation of a heat exchange system to be utilized within the satellite station also, but shown in less detail in FIGURE 2;

FIGURE 4 is a schematic diagram of the basic circuitry required to produce a pluarity of oil and gas wells within a satellite station;

FIGURE 5 is a schematic diagram of a modified TFL Fluid Supply System;

FIGURE 6 is a schematic diagram of a modified Production System for producing a field having a high gas-oil ratio;

FIGURE 7 is a schematic diagram of a modified Production System for producing a field having a medium gas-oil ratio; and

FIGURE 8 is a schematic diagram of a modified satellite station configuration for allowing the satellite body to be installed on a base template of a satellite station prior to the completion of any of the wells through the base template.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now looking to FIGURE 1, a subsea system for producing fluid minerals, in particular gas and oil, from a subaqueous field by a plurality of subsea wellheads is illustrated. A plurality of subsea production satellite stations, generally designated **10**, are spaced across a marine bottom **12**, each satellite station **10** comprising a satellite body **15** centrally positioned within a circular group of closely spaced subsea wellheads **14.** The produced fluids from the subaqueous wells are directed through encircling subsea wellheads **14** into the satellite body **15** of the respective satellite station **10**. The fluids being produced from the subsea wellheads **14** of each circular group are combined within the respective enclosed satellite body **15** and a first stage of separation (gravity) takes place. At least the liquid portion is then directed to a circular manifold **16** atop a central bottom-mounted storage tank **17** through a shipping line **18**, one shipping line **18** extending from each satellite station **10**.

A floating master station **20**, having power generating and final stage separation equipment thereon, as well as being fitted out with offloading apparatus, is in fluid and electrical communication with the bottom-supported storage tank **17** through a tensioned tether pipe **22** extending from the storage tank **17** to a point just beneath the turbulent surface zone of the body of water and fixed at this point to a large subsurface buoy **24**. A flexible conduit **26**, containing a plurality of electrical and fluid flow paths, extends from the upper end of the tensioned tether pipe **22** to the floating master station **20**. The produced liquid, collected in the circular manifold **16**, is directed to the master station through a main shipping line **27** supported along the length of the tether pipe **22**, and a fluid line forming a portion of the flexible conduit **26**. The produced liquid passes through the final stage separation equipment on the master station **20** where the pressure is normalized and dissolved gases are removed. The dead liquid is then transported to storage within the storage tank **17** through a line of the flexible conduit **26** connected to an axial passage in the interior of the tether pipe **22**.

In the upper left-hand corner of FIGURE 1 is illustrated the drilling of a well through a satellite base template, generally designated **28**, which has been previously installed on a marine bottom along with a shipping line **18'** for connecting a satellite station, when completed in conjunction with the template **28**, with the storage tank **17**. A drill string **30** is suspended from above the surface from a semisubmersible drilling vessel **32** and extends through a blowout preventer stack **33** mounted on one of a plurality of upstanding well conductor pipes **34** forming a portion of the template **28**. Illustrated in the lower portion of FIGURE 1 is a manned submersible work vehicle, generally designated **36**, of a type to be employed to assist in the subsea operations and for the dry transfer of personnel to the satellite station **10**. The submersible work vehicle **36** has a pair of articulated arms **38** and **40** carrying a socket wrench **42** and a vice grip tool **44**, respectively. The submersible work vehicle **36** is further equipped with a pivotable positioning motor **46** on each side (one shown) to assist in locating the submersible work vehicle **36** adjacent a satellite station **10** firstly when subsea operations are to be performed during the drilling operations and the installation of the satellite body **15** therewithin, and at later times during maintenance and workover operations. A lower port **48** of the submersible work vehicle **36** is connected with a rear compartment (not shown) within the shell thereof to permit a diver to be released at an installation site if one should be needed. The rear compartment is isolated from the pilot's compartment, seen through the front view plate **50**, so that a diver after exposure to deep water can be kept in compression in the rear compartment while the front compartment is maintained at atmospheric conditions. This general type of submersible work vehicle is well known in the art and specific vehicles of this type are more fully described in the application Ser. No. 649,959, filed June 29, 1967, of Warren B. Brooks, Charles Ovid Baker, and Eugene L. Jones, and the references cited therein.

Now looking at FIGURE 2, the interior of the satellite body **15**, as well as the satellite base template **28**, are illustrated in more detail. The internal equipment comprises that necessary for a high gas-oil ratio, high pressure field. The base template **28** comprises an outer ring **51** to which are rigidly connected the plurality of upstanding vertical well conductor pipes **34** through which subaqueous wells have been drilled. As shown, a dual completion wellhead **14** is mounted on the upper end of each of the well conductor pipes **34** in completing each of the respective subaqueous wells. The satellite body **15** is installed after the completion of all of the wells drilled through the respective base template **28**. The satellite body **15** is shown to be cradled in a plurality of radially extending spaced arms **41** fixed to the base template **28**. Threaded detent rods **43** extend through each of the arms **41** and through the shell of the satellite body **15** into receivers **45** fixed to the inner wall of the shell. The detent rods can be screwed into and out of engagement with the receivers by means of the socket wrench **42** of the submersible work vehicle **36**. A hex nut **53**, terminating in a conical guide, is affixed to the outer end of each detent rod **43**. Support frames **47**, having pillow boxes **49** in which the detent rods **43** are journalled, allow the use of long detent rods **43** extending radially out beyond the well conductor pipes **34**.

A water well **52** is shown as having been drilled through the center of the base template **28** and is necessarily completed prior to the installation of the satellite body **15**. After all of the wells, including the water well **52**, have been completed, the satellite body **15** is lowered into place and is leveled and locked into the base template **28** in any suitable manner. There would be no reason why one water well could not be drilled through one of the well conductor pipes **34** on the ring **51** of the base template **28**, if this should prove more convenient. The only disadvantage would be the elimination of one possible producing well. The W. F. Manning patent applications Ser. Nos. 663,799 and 663,798, entitled Subsea Satellite Foundation Unit and Method for Installing a Satellite Body Within Said Foundation Unit, and Subsea Satellite Foundation Unit and Method for Installing a Satellite Body Therewithin, respectively, disclose alternate leveling and locking means as well as means for registering the installed satellite with respect to encircling wellheads.

The water well **52** is designed to provide a heat source for a heat exchanger unit (to be discussed below) to warm the produced fluids after a pressure cut has been taken. The well water may also be directed through radiators in the portions of the satellite body **15** in which personnel are present to raise the interior temperature of that portion of the satellite body **15** above the ambient temperature at the marine bottom. In deep water the temperature at the marine bottom is in the range of 35° F. to 45° F., too cold for a man to work for long periods unless he is heavily clothed.

Each of the submerged dual completion wellheads **14** has a pair of upstanding tubing nipples (not shown), each being in fluid communication with a producing zone. Each of the pairs of tubing nipples is adapted to telescope into complementary passages of a stab-over connector unit, generally designated **54**, comprising a pair of downwardly curving tubing sections **56** extending radially outward from within the shell of satellite body **15** and terminating in vertical lubricator sections **58**. By means of the stab-over connector units **54**, the production and control passages extending through the subaqueous wells are connected to manifolds within the satellite body **15** for the combining of the produced fluids through the satellite body **15** and/or for the injection of lift gas, or other fluids utilized in secondary recovery procedures, from the satellite body **15**, to all or selected ones of the subaqueous wells. As shown in the embodiment of FIGURE 2, the stab-over connector units **54** are permanently fixed with respect to the satellite body **15**. Therefore, the satellite body **15** must be radially positioned quite precisely so that the stab-over connector units **54** can register with and telescope over the upstanding tubing nipples of the respective wellheads **14**.

An escape hatch **60** is formed within the upper end of the satellite body **15** to permit the entry of an operator **62** from a diving bell or travel chamber, as shown in the Townsend application Ser. No. 521,745, filed Jan. 19, 1966, or a submersible work vehicle **38**. The upper portion of the interior of the satellite body **15**, within which the operator **62** is shown sitting at a panel **64**, comprises a control section, generally designated **66**, from which various operations, not normally programmed, may be controlled and from which stored information can be retrieved. Below the control section **66** is a production section, generally designated **68**, containing the various equipment necessary to separate and meter the produced fluids as well as a pump treating fluids and tools through the various wells.

Beneath the floor of the production section **68** is a treating fluid storage section, generally designated **70**. The treating fluid storage section **70** generally comprises an open-bottomed tank defined by the floor **71** of the production section **68** and the outer, generally cylindrical shell of the satellite body **15**. The storage section **70** can be partitioned to permit the storage of two or more discrete well treating fluids needed in one or more operations. Although some plumbing extends through the storage section **70**, it is substantially uncluttered to permit the storage of a large quantity of well treating fluid.

Centrally located, within the production section 68, is a cylindrical heat exchanger unit 74. Equiangularly spaced around the heat exchanger unit 74 are a plurality of spherical separators 72. The produced fluids normally flow through the shell of the satellite body 15 by way of the tubing section 56 of the connector units 54. From a tubing section 56 the fluid is directed by a branch conduit 76 through an expansion valve (shown in FIGURE 3 and to be discussed with respect thereto) into an upper heat exchanger manifold 78 located within the upper end of an insulated jacket 79 of the heat exchanger unit 74. Fluids, exiting from the manifold 78, flow down through a central pipe 80, leaving the heat exchanger unit 74 near the lower end thereof by means of conduits 82 (one shown) which lead the produced fluids into the individual separators 72.

The separators 72 in the satellite station 10 are of the gravity type to permit the separation of the gas from the oil without a substantial temperature drop in the separators, avoiding hydrate and paraffin deposition problems therewithin. A loss of 7° F. to 8° F. would be normal with such equipment. With a one-minute retention time within the separator, all of the free gas will be removed, only the gas, dissolved in the liquid at the separator pressure, remaining for the secondary, or final, separation stage. While the separators planned for this installation have no water knockout feature, provision for removal of water from the oil could be provided if it was desirable at this stage of production. The pressure at which the separators 72 are designed to function may be governed by the depth at which the satellite station 10 is located since it is desirable to have sufficient pressure to lift the oil from the marine bottom to the master station 20 on the surface. In very deep water the produced oil may have to be lifted, at least in part, by power-driven pumps. Where the satellite is connecting into a truck pipeline, rather than being transported away by tanker, the output pressure of the separators would be governed by the line pressure in the pipeline. Where the wells are producing with a wellhead pressure of, for example, one thousand five hundred p.s.i. and the satellite station 10 is located in two thousand feet of water, a nine hundred-pound pressure drop will be taken, prior to introducing the produced fluid into the separators 72, to obtain a pressure of approximately six hundred p.s.i., which would be that necessary to drive the oil from the marine bottom to the surface. Taking a pressure drop of nine hundred p.s.i. lowers the temperature of the produced fluids by more than 50° F. When considering a ten thousand-foot well in which the produced fluids at the wellhead would be at from 150° F. to 170° F., at 50° F. the resultant temperature would be well within the formation temperature of hydrates and paraffins.

The heat exchanger unit 74, as shown more fully in FIGURE 3, is located in the process fluid circuitry between expansion chokes 84, one located in each of the branch conduits 76, and the separators 72, providing a regulated flow of warm water as a heat source to increase the temperature of the mixed oil and gas on the downstream side of the choke 84 where a pressure cut has been taken, to prevent hydrate formation, minimize excessive paraffin deposition in the equipment, and restrict emulsion formation. The heat exchanger unit 74 depends upon well water obtained from the previously mentioned water well 52 (shown only in FIGURE 2). The water is produced through a normal type of oil well completion and then flows through a variable choke 86 that regulates the flow and downstream pressure. In an example, using a ten thousand-foot water well, the water at the upper end of the heat exchanger will also be in the range of 150° F. to 170° F. The water from the well 52 is directed upward through a conduit 88, entering the insulated cylindrical jacket at 79 of the heat exchanger unit 74, through the upper end thereof. The water travels down through the interior of the heat exchanger jacket 79, emerging from the lower end thereof in outlet line 90 from which the water is dumped into the sea. As the cold produced fluid passes into the manifold 78 within the upper end of the heat exchanger unit 74, after passing through the expansion choke 84 and a one-way valve 92, the fluid comes into indirect contact with the warmer water flowing around the manifold 78. From the manifold 78, the produced fluid flows through a helical coil 94 extending axially through the heat exchanger unit 74 and into a heat exchanger manifold (not shown) in the lower end thereof, and then out of the jacket 79 through conduits 82, each connected between one of the separators 72 and the lower heat exchanger manifold. A temperature sensor 96 is installed in at least one of the outlet lines 82 to act as a flow indicator and monitor mechanism to control the increase or decrease of the water flowing into the heat exchanger unit 74. By increasing or decreasing the size of the choke 80, the water flow is regulated to maintain the required temperature of the produced fluids entering the separators 72 (FIGURE 2). Such a system also acts as a resource conservation in that large use of produced oil and/or gas to fire such heater equipment as would be otherwise needed is not required.

Looking back to FIGURE 2, the liquids leave the separators 72 through respective liquid outlet lines 98, connecting the separators 72 with liquid output manifold 100 centrally positioned around the lower end of the heat exchanger unit 74. The combined produced liquid from the plurality of separators 72 is directed from the manifold 100 through a main oil outlet line 102 which is connected to the input end of a respective shipping line 18.

The liquid is removed, at the lower end of each of the separators 72, by the respective line 98, so as to also drain off all the water, entrained sand, and other impurities with the oil. These impurities might otherwise impede the action of the separator 72 and cause a premature malfunction thereof. A shut-off valve 104 in each of the liquid outlet lines 98 is controlled in conjunction with a float (not shown) within each of the separators 72, to regulate the levels of the liquid within the separators 72. As shown, a mechanical linkage is utilized between the float and the valve 104. One of the electromechanical systems, well known in the art, could be substituted for the mechanical linkage. A clean oil line 108 is connected at a first end thereof into at least one of the separators 72, above the lower end thereof, to pick up oil from above the sediment level and below the low level of the liquid to provide substantially clean oil (with dissolved gas) for pumping a tool into and down through a selected well. Line 108, at the other end thereof, is connected to a first inlet of three-way two-position valve 110, the outlet of which is connected to the inlet of a gas-driven turbine-pump 112 to provide the clean oil under pressure to the TFL system. A second inlet of the three-way two-position valve 110 is also conected to a line 114 having a pickup head 116 in the fluid storage section 70 of the satellite body 15 to provide a source of treating fluid for the turbine-pump 112. Gas under pressure, for driving the turbine portion of the turbine-pump 112, is provided through a turbine gas supply line 118 extending from an auxiliary turbine (not shown in this view) which is supplied with produced fluid tapped off, through lines 119, upstream of the chokes 84. The clean oil under pressure from the pump portion of the turbine-pump 112 is fed into a manifold (not shown in this view). From this last-mentioned manifold, the oil is pumped out, being selectively directed into one or more pressure lines 122, each pressure line 122 being connected into a bypass conduit section 124 just behind a TFL tool 126 stored therein. Each bypass conduit 124 is directly connected to a curved tubing portion 56 of a connecter unit 54 for pumping the TFL too 126 therein into the connecting wellhead 14 and down a passage of the respective well. The separated-out gas, leaving a separator 72 through an upper pipe or gas outlet line 120, is combined with the separated-out gas from the other separators 72 in a ring manifold unit 128 encircling the insulated jacket 79 of the heat exchanger unit 74.

The separated-out gas can be, in various instances, utilized in production procedures, stored for eventual transportation to shore, or disposed of at the site of the offshore production field. A main outlet line 130, from the ring manifold 128, is shown directing the gas out of the satellite station 10 for disposal through one or more distant gas disposal wells (not shown) where the gas will be injected into shallow sands underlying the marine bottom. A safety regulator valve 132 is connected in the main outlet line 130 to allow gas to be bled off through a flare line 134 to the master floating station 20, if the pressure in the main outlet line 130 should rise above a predetermined value. If the gas obtained in the primary stage of separation is to be either disposed of by flaring or is to be stored for future transportation-to-shore facilities, it is conducted to the master station 20 by shipping line (not shown), as described with respect to the produced oil. At the master station 20, the gas obtained from the primary stage of separation is combined with the gas obtained from the secondary or final stage of separation on the master station 20. If the gas is to be flared, a flare stack is erected above the master station 20. If the gas is to be stored, it is first compressed at the master station 20 and then is pumped down to a portion of the storage tank 17 or to a separate storage tank (not shown) nearby. As noted above, the gas from the primary separation stage may also be utilized in production procedures, the most common of these procedures being the utilization of the gas under pressure to provide a lift pressure in the producing formations. A gas injection well for this purpose may be one of the wells drilled through the ring 51 of the template 28, in which case a separated-out gas is fed into the wellhead 14 through a respective one of the curved tubing sections 56 of a stab-over connector unit 54, or the injection well may be located at a distance from the satellite station 10, in which case an interconnecting flowline having a pressure regulator valve and a flare line, as described above with respect to injecting the gas into shallow sand formations, will be utilized.

FIGURE 4 illustrates, in schematic form, a complete system, with the exception of a storage means, for the production of a low gas-oil ratio low pressure field. The fluid is produced in the portion of the system designated as Well and Wellhead Equipment at the TD (total depth) 136 of a representative wall, generally designated 138. In the well 138 is a storm choke 140 placed at approximately a three thousand-foot depth, below the normal lower limit of paraffin deposition, for safety purposes. Quarter-turned manually operated valves 142 are mounted on the wellhead 14 outside the satellite body 15 where they are easily accessible for operation by a man, robot, or a manned craft such as the underwater submersible work vehicle 36 illustrated in FIGURE 1. In some instances, it may be desirable to utilize remotely actuatable valves in place of the manually operated valves 142. A high-low safety valve 144, also mounted on the wellhead 14 outside the satellite body 15, will automatically close should the pressure in the well 138 exceed a specified high pressure or drop below a specified low pressure.

From the upper end of the wellhead 14, the fluid is directed through connector unit 54 to the portion of the wellhead equipment within the satellite body 15 where one or more TFL tools are stored in a storage chamber, designated by block 146. (A TFL storage device and a paraffiin cutting tool, designed to be stored therewithin, are fully described in the patent application Ser. No. 579,571 of James T. Dean, entitled Storage System for TFL Tools,

filed Sept. 15, 1966. In FIGURE 3 of the Dean application, the incorporation of the described storage device in a fluid circuit for automatically maintaining a subsea well is shown.) The TFL storage chamber 146 is located in the previously described bypass conduit section 124, as is a TFL tool control valve 148, which remains closed except during TFL maintenance and/or testing. The branch conduit 76 contains a pressure indicator 150, an orifice meter 152, and a production wing valve 154. The production wing valve 154 is normally open while the well 138 is producing and closed during TFL operations. The branch conduit 76, through which the produced fluid generally flows, provides a path around the TFL storage chamber 146 and the closed control valve 148. When the well 138 is producing, the fluids flow from TD point 136, up through the storm choke 140, and the series of valves 142 and 144, of the wellhead 14, into the branch conduit 76. The pressure and flow rate of the fluid at the wellhead 14 are monitored at all times by the pressure indicator 150 and the orifice meter 152, respectively, and representative signals are transmitted to, and recorded within the control section 66 of the satellite station 10.

The produced fluid flowing through the branch conduit 76, past the interconnection with the bypass conduit section 124, leaves the portion of the system designated in the schematic diagram as Wellhead and Wellhead Equipment and enters the portion designated Production System through a rotary variable choke 156. As the fluid passes through the variable choke 156, the pressure is lowered from that at the wellhead 14 to a pressure just above that necessary to drive the fluid from the marine bottom to the surface. From the rotary choke 156, the produced fluid is directed through a check valve 157 into a collector manifold 158. Branch conduits 76′, each having a check valve 157′, also shown as leading into the collector manifold 158, are connected to the wellhead equipment of the various wells encircling the satellite station 10. A pressure sensor 160 is mounted in the collector manifold 158 to monitor the pressure therewithin, a signal representative of which is transmitted to and recorded within the control portion of the satellite station 10. The rotary variable choke 156 is controlled in response to the pressures indicated by the pressure sensors 150 and 160. Three gravity separators 72 are connected, in parallel, to the collector manifold 158 through inlet lines 162, each having a shut-off valve 163 therewithin. The liquids, including oil and water, exit for the most part through lines 98 which empty into a liquid collector manifold 164. This manifold corresponds to the circular manifold 100 shown in FIGURE 3. From the liquid collector manifold 164, the oil exits through the outlet line 102 and is transferred to storage through shippiing line 18 after passing through a flow meter 166. A clean oil outlet line 108, as previously discussed, extends from a point within each of the separators 72, from where substantially clean pure oil can be obtained, to a manifold 175, which empties in turn into the upstream end of a line 171 connected at its downstream end to an inlet port of a three-way two-position valve 180 in the TFL Fluid Supply System. The gas accumulating in the separators 72 passes out through a high liquid shut-off valve 168 located in the upper end of each of the separators 72, into a gas outlet line 120, which empties into a gas collector manifold 170. The major portion of the gas leaves the manifold 170 through the main gas outlet line 130, passing through an orifice meter 172, and is transferred to storage or disposal means. By disopsal means is meant "flaring' or "shallow sand injecting" as previously discussed. The fluid pressure supply line 119 is connected between the bypass conduit 124, at one end thereof, and a manifold 159 at the other end. Lines 119′ connect the bypass conduits of the other wells, which flow through the satellite station 10, with the manifold 159. The inlet of an auxiliary separator 161, where only a small pressure cut is taken, is in fluid connection with the manifold

159 through a high pressure line 165. The turbine gas supply line 118 is connected between the gas outlet of the auxiliary separator 161 and the inlet of the turbine of the turbine-pump 112 of the TFL Fluid Supply System to supply high pressure gas to the pump portion of the turbine-pump 112. The pressure-reduced gas, from the gas discharge, or outlet, of the pump portion of the turbine-pump 112, is directed through a line 167 into the gas collector manifold 170. The liquids separated out in the auxiliary separator 161 are directed through line 169 into the liquid collector manifold 164. The purpose of the turbine-pump 112 is discussed below. If one of the separators 72 becomes plugged, the liquid will fill that separator and force the respective valve 168 to close. With this possibility in mind, the separators 72 are designed so that any two are all that are required to process the total amount of fluid passing through the satellite station 10. With the same rate of flow of gas through the orifice meter 172, and liquid through the flow meter 166, a signal warning of an increase in pressure will be transmitted to the control portion 66 of the satellite station 10 from the sensor 160 in the manifold 158, indicating that there is a problem. Furthermore, the closing of a valve 168 can be made to actuate an electric switch, which in turn will provide a signal indicating which separator is malfunctioning. The production stream through the plugged separator 72 would then be cut off by closing the respective shut-off valve 163 so that the respective separator 72 can be serviced by personnel within the satellite station 10.

The portion of the schematic diagram designated as the TFL Fluid Supply System contains a fluid storage means 178, which corresponds to the open-bottomed fluid storage section 70 of the satellite station 10 as shown in FIGURE 2. The storage means 178 is connected to a first inlet port of the three-way two-position valve 180 through a line 190 having a salt water sensor 188 therein to provide a signal in the control section of the satellite station 10 indicating that the storage means 178 is empty of treating fluid and now contains only salt water. The other inlet port of the three-way two-position valve 180, as previously discussed, is connected to a source of clean oil through the line 174 extending from the manifold 175 in the Production System portion of the schematic diagram. The outlet of the three-way two-position valve 180 is operatively connected to the inlet of the pump portion of the turbine-pump 112, the outlet of the pump portion of the turbine-pump 112 being connected to an inlet of a manifold 182 through a conduit 184. The power for driving the pump portion of the turbine-pump 112 is provided by gas under pressure obtained through the line 118 from the auxiliary separator 161, which is fed with produced fluid at wellhead pressure from the Well and Wellhead Equipment portion of the system as previously outlined. By opening and closing a valve 176 in the line 118, the operation of the turbine-pump 112 may be controlled. From the manifold 182 the clean oil and/or the treating fluid, under pressure, is pumped through one or more of the outlet lines 192 at a time, each of the outlet lines 192 having a check valve 194 and a selectively actuated cut-off valve 196 therein from which the fluid is directed through the respective line 122 into the Well and Wellhead Equipment portion of the schematic diagram where it is directed into the bypass conduit 124 between the TFL tool storage chamber 146 and the shut-off valve 148. Outlet lines 192′, each having a one-way check valve 194′ and a shut-off valve 196′ therein, are connected to the bypass conduits of the Well and Wellhead Equipment portions of the other wells (not shown) producing through the respective satellite station 10.

To commence a TFL maintenance and/or testing procedure, valves 148 and 154 in the Well and Wellhead Equipment portion would both be closed. The shut-off valve 176, in the TFL Fluid Supply System, connected to the input of the turbine-pump 112 would be open to activate the turbine portion. For paraffin removal, for instance, a paraffin solvent and corrosion inhibitor stored in the storage means 178 would first be drawn into the input of the pump section of the turbine-pump 112 by the proper positioning of the valve 180. After pumping approximately one barrel of treating fluid through the valve 180, the position of the valve would be changed so that the oil from line 174 would then be supplied to the pump portion of the turbine-pump 112. One or more of the valves 196, 196′ would be open to permit the fluid driven by the turbine-pump 112 to exit from the header 182 through a line 122 to apply fluid pressure in the section of the bypass conduit 124, of the Well and Wellhead Equipment portion, between the valve 148 and the storage means 146. With the valve 148 closed, the fluid driven through line 122 into the bypass conduit 124, behind the storage means 146, will cause a paraffin cutting tool 126 positioned within the storage means 146 to be propelled down through the curved tubing section 56 of the connector unit 54 and down through the wellhead 14 of the respective well 138. The piston section of the tool 126 is not completely sealed within the tubing of the well 138 in which it moves so that by the time the tool is down in the well, at the lower end of the paraffin deposition zone, all of the treating fluid is in the well ahead of the tool. When the tool 126 reaches the end of its travel, above the storm choke 140, the valve 176, in the TFL Fluid Supply System portion, controlling the turbine-pump 112, would be shut causing the turbine-pump 112 to cease operation. The shut-off valve 148 in the bypass conduit 124 is then opened causing the TFL tool 126 to be returned up the well 138 by the fluid being produced, which now is directed into the downstream portion of th branch conduit 76 through the bypass conduit 124. When the TFL tool 126 has re-entered the storage chamber 146, an indication of this condition will be given in the control section 66. A switching means for providing this function is shown in the Dean patent application Ser. No. 579,571 discussed above. At this time, the valve 148, in the bypass conduit 124, will be shut and the valve 154, in the branch conduit 76, will be reopened, returning the well to production through the branch conduit 76. All of the previously described steps can be sequentially performed by an operator in the control section 66 of the satellite station 10, by remote control from the floating master station 20, or by a programmed computer, or by a combination of the aforementioned methods.

FIGURE 5 illustrates a modification in which an electric motor 198 is utilized for driving a pump 200. With the substitution of the electric motor 198 and the pump 200 for the turbine-pump 112 (shown in FIGURE 4), the gas line 118 is eliminated and the only exit line from the manifold 170 is the line 130. The remainder of the TFL Fluid Supply System (shown in FIGURE 5) is identical to that shown in FIGURE 4, therefore being a storage means 178′ connected to one inlet of a three-way two-position valve 180′ through a line 190′ having a salt water sensor 188′ therein. The other inlet of the three-way two-position valve 180′ is connected to the line 174 as shown in FIGURE 4 which is connected at the other end thereof to a clean oil source in the separators 72. The outlet of the three-way two-position valve 180′ is operatively connected, to the inlet of the pump 200. The outlet of the pump 200 is in turn connected, through the line 184, to the header 182, as shown in FIGURE 4. The identical procedure would be followed with the exception that electrical power would be used to operate the electric motor 198 to drive the pump 200.

FIGURE 6 shows the modified Production System to be used with the typical high gas-oil ratio high pressure well. This modified Production System is utilized with the Well and Wellhead Equipment portion and TFL Fluid Supply System portion of the schematic diagram of FIGURE 4. As the produced fluid is directed from the branch conduit 76 through a variable choke 156′ and a check valve 147′, it is collected in a primary manifold 202 (generally similar to the manifold 78 shown in FIGURE 2). The produced fluid in the manifold 202, having a high gas content, is now quite cold due to expansion in the choke 156′. This cold fluid passes out of the manifold 202 through a line 204 extending through a heat exchanger unit 206 (corresponding to the heat exchanger unit 74 of FIGURE 2). The fluid, warmed up in the heat exchanger unit 206, enters a secondary manifold 208 from which it is directed into three separators 72′. A pressure sensor 209 and a temperature probe 238 are located in the secondary manifold 208. From the separators 72′ the major part of the produced liquid is collected in the manifold 164′ after which it is removed through a line 102′ having a flow meter 166′ therein, the outlet of the flow meter 166′ being connected to the inlet of a shipping line 18 connecting the satellite station 10 with a distant storage facility. Again, clean oil is picked up by lines 108′ and is directed through line 174′ to the clean oil supply inlet of the three-way two-position valve, as shown in FIGURE 4. The gas exiting from the separators 72′, through lines 120′, is collected in the manifold 170′ from which it is, in the main, transmitted through a line 210 from the orifice meter 172, through a safety pop-off valve 214, to a gas injection well 212, for disposal in shallow sand formations. The gas enters the injection well 212 through the wellhead 216 thereof having a high-low fail-safe valve 218 and a manually operated valve 220. There is also a storm choke 22 beneath the marine bottom in the injection well 212. If the back pressure in the shallow sand formations being used for disposal should rise above a preset limit of the pop-off safety valve 214, the gas will be directed instead through a line 134′ to the surface where it will be flared. To heat the cold fluids within the heat exchanger unit 206, warm water, at 150° F. to 170° F., is obtained from the TD 228 of a water injection well 226 producing through a wellhead 227 comprising a manual valve 230 and an automatic setting valve 232, and a rotary choke 234 having a pressure differential indicating device 236 located thereacross. The warm water flows through the heat exchanger unit 206, past a series of coils 205, in the line 204. From the heat exchanger unit 206, the then cooled water is directed out through line 240 into the surrounding water near the marine bottom. The rotary choke 234 is operated automatically in response to a temperature signal obtained from the temperature probe 238 previously described as located in the primary manifold 208 downstream of the heat exchanger unit 206. As the temperature sensed by the temperature probe 238 decreases, the choke 234 is opened further. If the temperature indicated reaches a specified low level, the satellite station 10 is completely shut in.

FIGURE 7 is a schematic diagram of another modification of the Production System of FIGURE 4, for a typical medium gas-oil ratio, medium pressure well. A well is produced in the same manner as in the previous two examples utilizing the same type of well and wellhead equipment. In this modification the fluid, entering the Production System portion through a branch conduit 76, is directed through a one-way valve 241 into a heat exchanger conduit 242 which traverses a heat exchanger unit 244. The produced fluid having been produced from a TD of ten thousand feet makes its first pass through the heat exchanger unit 244 at a temperature of 150° F. to 170° F. Upon exiting from the heat exchanger unit 244, a pressure cut is taken through a variable choke 245. The now cold fluids are passed back through the heat exchanger unit 244 by the traversing heat exchanger conduit 245 to raise the temperature in the expanded fluid to a prescribed minimum to prevent hydrate formation and wax deposition. From the conduit 245 the fluid passes into a collector manifold 246 containing a pressure sensor 238′ and temperature probe 209′. In collector manifold 246, the fluid from the heat exchanger conduit is combined with the pressure cut fluid from the other wells of the satellite stations through heat exchanger lines 245′. The fluid from each well has previously been directed through the heat exchanger unit 244, had a pressure cut taken and then been passed back through the heat exchanger unit 244 through separate conduits. The combined fluid in the collector manifold 246 is directed out through a conduit 247, making a final pass across the heat exchanger unit 244 into another collector manifold 248. From the manifold 248, the fluid is divided into separate streams and directed into separators 72′ through lines 249. The remainder of the fluid system is identical to that already discussed with respect to FIGURE 4. If the temperature indicated by the temperature probe 209′ decreases below a specified value, all the wells of the satellite station 10 are shut in.

The schematic diagrams of FIGURES 4–7 illustrate examples of systems to be used in specific cases. However, the features of the various figures can be combined in different arrangements to suit various conditions. For instance, the electric-motor-drive-pump 200 of FIGURE 5 could be used with the modifications of FIGURES 6 and 7.

FIGURE 8 illustrates a modified satellite station 10′, similar to the satellite station 10 of FIGURES 1 and 2, having the added advantage of being able to be installed prior to completing any of the production wells through the ring 51′ of the base template 28′. In this embodiment, instead of using cradling arms as illustrated in FIGURE 2, the satellite body is held in the satellite base 28′ by a central sleeve 250 depending from the lower end of the satellite body 15′ and automatic spring-loaded latches (not shown) over the upper end of the well conductor pipe of the water well 52. The latches can be disabled by a hydraulic pressure applied through the conduit 252 extending between a manifold 254, forming a portion of the framing of the base template 28′, at the inner end, and a quick-disconnect coupling section 256, at the outer end. The outer end of the conduit is supported by a skeletal frame 258 to displace the coupling section 256 outward of the well conductor pipes 34′. The arrangement of the equipment within the satellite body 15′ is substantially the same as the arrangement within the satellite body 15 of the earlier discussed embodiment with the exception of the orientation of the TFL tool 126 and the associated hydraulic circuitry. In this instance, the connector units 54′ are not permanently attached to the satellite body 15′ but instead are stabbed-over tubing nipples 260 extending vertically out of the upper end of the satellite body 15′. When a well is to be completed through one of the upstanding well conductor pipes 34′, a wellhead 14′ is first mounted on the respective well conductor pipe 34′. A connector unit 54′ is later lowered from the surface to make the connection between the wellhead 14′ and the satellite body 15′. The connector unit 54′ consists of a curved tubing section 56′ and a vertical lubricator section 58′. The lower end of the lubricator section 58′ is stabbed over the tubing (not shown) extending vertically out of the upper end of the wellhead 14′, while the outer vertical free ends of the curved tubing section 54′ stabs over the respective ones of the upstanding tubing nipples 260 extending out of the upper end of the satellite body 15′. In this manner, with each connector section 54′ being individually engaged between the wellhead 14′ and the respective upstanding tubing nipples 260, greater tolerances can be allowed in installing the satellite body 15′. Furthermore, an individual well can be produced through the satellite station 10′ while the remaining wells are still being drilled and completed. The vertical orientation of the tubing nipples 260 extending vertically into the satellite body 15′ presents no problem, each of the TFL storage chambers 146′ is reoriented into a vertical position so as to be coaxial with the respective tubing nipples 260. The vertical position of the storage chamber **146'** permits the TFL tool **126'** stored therewithin to move easily into respective tubing nipples **260** so that it can be pumped, under fluid pressure, through a full one hundred eighty-degree bend in the tubing sections **56'** of the connector unit **54'**. Such a bend, of one hundred eighty degrees, will not present any insurmountable problems requiring only that the wells be spaced out far enough from the satellite body **15'** to obtain a five-foot radius bend in the conduit. Stab-over connections, as discussed in this application, are more fully described in the Manning application Ser. No. 663,799.

What is claimed is:

1. A satellite station for combining fluids produced from underground fluid mineral-bearing formations through a plurality of spaced-apart wells, and for reducing the pressure of said produced fluid prior to shipping the combined produced fluid from said satellite station comprising: a manifolding arrangement within said satellite station for collecting the produced fluid from said plurality of spaced-apart wells; means for directing said produced fluid from each of said plurality of spaced-apart wells into said manifolding arrangement; means for reducing the pressure of said produced fluid from at least some of said wells in the area of said satellite station whereby the temperature of said pressure-reduced fluid is lowered; at least one water-producing well, in close proximity to said satellite station, extending into an underground water-bearing formation containing water at a substantially higher temperature than said pressure-reduced fluid; and means for directing said substantially higher temperature water from said water-producing well into close proximity with at least a portion of said pressure-reduced produced fluid whereby a heat exchange is effected and the formation of solids within said fluid is hindered.

2. A satellite station, as recited in claim **1**, wherein fluid hydrocarbons are produced from said underground formations and whereby the warming of said pressure-reduced fluid hinders the formation of hydrates and emulsions, and the deposition of paraffin, within production equipment.

3. A satellite station, as recited in claim **2**, wherein said satellite station is provided with an enclosing shell to protect the production equipment therein from a hostile environment therewithout.

4. A separator station for hindering the formation of hydrates while separating hydrocarbons into liquid and gaseous components comprising: means for introducing at least one fluid stream of hydrocarbons under pressure into an expansion chamber forming at least a portion of production equipment within said separator station; means for choking said at least one fluid stream of hydrocarbons as said at least one stream enters said expansion chamber; separate means for removing liquid and gaseous components from said production equipment at lower pressures than that at which said fluid stream enters said expansion chamber thereof; a water well, adjacent said separator station, said water well extending into underground water-bearing formations containing water at a substantially higher temperature than said liquid and gaseous components in said expansion chamber; and means for directing said substantially higher temperature water from said water-producing well into close proximity with said hydrocarbons within said production equipment whereby a heat exchange is effected and the formation of hydrates and emulsions in said hydrocarbons, and the deposition of paraffin within said production equipment, is hindered.

5. A separator station, as recited in claim **4**, wherein said production equipment comprises, in addition to said expansion chamber: a plurality of separators for dividing said fluid hydrocarbon steam into liquid and gaseous components; means for distributing the stream of pressure-reduced hydrocarbons, exiting from said expansion chamber, between said plurality of separators; means for combining the liquid component produced from each of said separators into a single liquid stream; and means for combining the gaseous components produced from each of said separators into a single gaseous stream.

6. A separator station, as recited in claim **5**, wherein there is an indirect heat exchanger for directing said higher temperature water in close proximity with said fluid hydrocarbon stream, said heat exchanger being operatively located between said expansion chamber and said plurality of separators.

7. A separator station, as recited in claim **6**, wherein there are a plurality of fluid hydrocarbon streams under pressure being introduced into said separator station, all of said plurality of hydrocarbon streams being operatively connected with a single expansion chamber; and a choke in each hydrocarbon stream just upstream of said single expansion chamber.

8. A separator station, as recited in claim **6**, wherein there is a means for controlling the flow of water from said water well comprising a variable choke operatively connected between said water well and said indirect heat exchanger; and means for automatically actuating said variable choke in response to a temperature sensor, said temperature sensor being located so as to sense the temperature of said fluid hydrocarbons flowing out of said indirect heat exchanger.

9. A subsea satellite designed to function as a portion of a subsea satellite system having a plurality of wells for prodcing fluid hydrocarbons under pressure, the production wells being completed beneath the surface of a body of water generally surrounding the satellite station which would be fixedly located beneath the surface of the body of water; an auxiliary well to extend from an underground fresh water-bearing formation to a point centrally beneath said satellite station when said satellite station is fixedly located beneath the surface of said body of water; said satellite station comprising an indirect heat exchanger unit centrally located within the shell of said satellite station; means for directing water, produced through said water well, through the lower end of said satellite shell and said heat exchanger unit, said heat exchanger unit having an upper manifold for combining hydrocarbon streams directed into said shell of said satellite station from said plurality of wells; a choke in each hydrocarbon stream upstream of said upper manifold; a lower manifold in said heat exchanger unit for distributing warmed and pressure-reduced hydrocarbons to a pluraltiy of separators equiangularly spaced around said indirect heat exchanger unit; a third manifold encircling a portion of said heat exchanger unit and generally radial conduit means connecting the upper end of each of said plurality of separators with said third manifold to combine the produced gaseous component; a fourth manifold encircling a poriton of said heat exchanger unit and generally radial conduit means connecting the lower end of each of said plurality of separators with said fourth manifold to combine the produced liquid component; and means for connecting shipping lines to said third and fourth manifolds to remove the liquid and gaseous components of said produced hydrocarbons from said satellite station.

10. A method for separating the liquid and gaseous components of hydrocarbons produced from a well under pressure comprising:

(a) directing a restricted stream, of produced hydrocarbons, into an enlarged chamber;

(b) separately drawing off said liquid and gaseous components of said produced hydrocarbons, forming in said enlarged chamber; and

(c) directing water, from an underground water-bearing formation, naturally containing water at a substantially higher temperature than said liquid and gaseous components within said enlarged chamber, into close proximity with said produced hydrocarbons at least adjacent to said enlarged chamber to effect a heat exchange so as to hinder the formation of hydrates and emulsions, and the deposition of paraffin, within said one of said components.

11. A method for separating the liquid and gaseous components of hydrocarbons produced from a well under pressure comprising:

(a) directing a restricted stream, of produced hydrocarbons, into an enlarged chamber;

(b) separately drawing off said liquid and gaseous components of said produced hydrocarbons, forming in said enlarged chamber; and

(c) directing water, from an underground water-bearing formation, naturally containing water at a substantially higher temperature than said liquid and gaseous components within said enlarged chamber, into close proximity with at least one of said components to effect a heat exchange so as to hinder the formation of hydrates and emulsions, and the deposition of paraffin, within said one of said components.

12. A method for separating the liquid and gaseous components of hydrocarbons produced from a well under pressure, as recited in claim **11**, wherein said water, from an underground water-bearing formation, is directed into close proximity with said gaseous component subsequent to said gaseous component being drawn from said enlarged chamber.

13. A method for separating the liquid and gaseous components of hydrocarbons produced from a well under pressure, as recited in claim **11**, wherein said water, from an underground water-bearing formation, is directed into close proximity with said liquid component in the lower portion of said enlarged chamber.

14. A method for separating the liquid and gaseous components of hydrocarbons produced from a well under pressure, as recited in claim **11**, including the following additional step:

(d) separately metering the amounts of said components being drawn out of said enlarged chamber.

15. A method for producing hydrocarbons from a well under pressure, as recited in claim **14**, including the following additional step:

(e) recombining said gaseous component with at least a portion of said liquid component prior to transporting said produced hydrocarbons to a production facility.

16. A method for reducing the pressure of a hydrocarbon stream produced from a well comprising the following steps:

(a) producing fluid hydrocarbons from an underground formation under pressure;

(b) directing a restricted stream, of said produced hydrocarbons, through a coke; and

(c) directing water, from an underground water-bearing formation, naturally containing water at a substantially higher temperature than said fluid stream just downstream of said choke, into close proximity with said hydrocarbon stream, just downstream of said choke, to effect a heat exchange so as to hinder the formation of hydrates and emulsions, and the deposition of paraffin, in said hydrocarbon stream.

17. A method for reducing the pressure of a hydrocarbon stream, as recited in claim **16**, including the following additional step:

(d) controlling the flow of said water, from an underground formation, in close proximity with said hydrocarbon stream, in response to the temperature of said hydrocarbon stream downstream of the portion of said hydrocarbon stream over which said heat exchange is effected.

18. A method for reducing the pressures of a plurality of hydrocarbon streams produced from spaced points in at least one underground formation, through at least one well, including the following steps:

(a) directing each of said hydrocarbon streams through a respective choke to reduce at least a portion of the pressure thereof;

(b) manifolding said plurality of hydrocarbon streams, now at least partially pressure-reduced, into a single hydrocarbon stream; and

(c) directing water, from an underground water-bearing formation, naturally containing water at a substantially higher temperature than said at least partially pressure-reduced single hydrocarbon stream into close proximity with said single hydrocarbon stream, downstream and adjacent to where said plurality of hydrocarbon streams are manifolded into a single hydrocarbon stream, to effect a heat exchange so as to hinder the formation of hydrates and emulsions, and the deposition of paraffin, downstream of said chokes.

19. A method for reducing the pressures of a plurality of hydrocarbon streams produced from space points in at least one underground formation, through at least one well, as recited in claim **18**, including the following additional step:

(d) controlling the flow of said water in close proximity with said single hydrocarbon stream in response to the temperature of said single hydrocarbon stream just downstream of the portion of said hydrocarbon stream over which said water is in close proximity with said hydrocarbon stream.

20. A method of producing fluid hydrocarbons from at least one underground formation under pressure through a plurality of spaced wells including the following steps:

(a) directing a stream of produced fluid hydrocarbons from each of said wells through a respective choke to lessen the pressure thereof;

(b) manifolding said hydrocarbon streams, now at least partially pressure-reduced, into a single hydrocarbon stream;

(c) directing water, from a underground water-bearing formation, naturally containing water at a substantially higher temperature than said at least partially pressure-reduced single hydrocarbon stream, into close proximity with said single hydrocarbon stream, just downstream of where said plurality of hydrocarbon streams are manifolded into a single hydrocarbon stream, to effect a heat exchange so as to hinder the formation of hydrates and emulsions, and the deposition of paraffin, downstream of said chokes; and

(d) separating the single stream of warmed and pressure-reduced fluid hydrocarbons, downstream of said heat exchange, into gaseous and liquid components.

21. The method, as recited in claim **20**, wherein step (d) includes:

(e) distributing said single stream of warmed and pressure-reduced fluid hydrocarbons between a plurality of separators.

22. The method, as recited in claim **20**, including the following additional step:

(f) controlling the flow of said water in close proximity with said single stream of fluid hydrocarbons in response to the temperature of said single hydrocarbon stream downstream of the portion of said hydrocarbon stream over which said water is in close proximity with said hydrocarbon stream.

23. The method, as recited in claim **22**, wherein said controlling of said flow of water is in response to the temperature of said single hydrocarbon stream upstream from where said separating step occurs.

24. The method, as recited in claim **22**, wherein said controlling of said flow of water is in response to the temperature of said single hydrocarbon stream downstream from where said separating step occurs.

25. A method for producing deposits of hydrocarbons, located in formations underlying a body of water, including the following steps:

(a) drilling production wells from a surface station, into the formations containing hydrocarbons to be produced;

(b) completing said production wells beneath the surface of said body of water;

(c) drilling a water well into a hot water-bearing formation;

(d) completing said water well beneath the surface of said body of water;

(e) installing a production satellite beneath the surface of said body of water;

(f) connecting production passages of said production wells with manifolding equipment within said satellite whereby said produced hydrocarbons can be combined; and

(g) directing hot water from said water well through said production satellite and at least at one point in close proximity to said produced hydrocarbons whereby said produced hydrocarbons are warmed to hinder the formation of hydrates and emulsions, and the depsition of paraffin.

26. A method for producing deposits of hydrocarbons located in formations underlying a body of water, as re-

cited in claim **25**, including the following additional step:

(h) reducing the pressure of the produced hydrocarbons at least prior to the transporting of said produced hydrocarbons from said production satellite.

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U.S. Cl. X.R.

166—267

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,504,741 Dated April 7, 1970

Inventor(s) Charles Ovid Baker and William A. Talley, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 52, "relaates" should be --relates--.

Column 4, line 24, "pluarity" should be --plurality--.

Column 6, line 61, "a" should be --to--.

Column 9, line 2, "too" should be --tool--;
line 2, "connecting" should be --connected--;
line 53, "wall" should be --well--.

Column 13, line 2, "147'" should be --157'--;
line 30, "22" should be --222--.

Column 15, claim 5, line 72, "steam" should be --stream--.

Column 16, claim 9, line 29, "prodcing" should be --producing--.

Column 17, claim 16, line 53, "coke" should be --choke--.

Column 18, claim 19, line 18, "space" should be --spaced--.

Column 19, claim 25, line 21, "depsition" should be --deposition--.

SIGNED AND SEALED
AUG 25 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents