Dec. 29, 1970 J. D. LOWD ET AL 3,550,385

METHOD OF AND MEANS FOR FIELD PROCESSING OF SUBSEA OIL WELLS

Filed Nov. 4, 1968 3 Sheets-Sheet 1

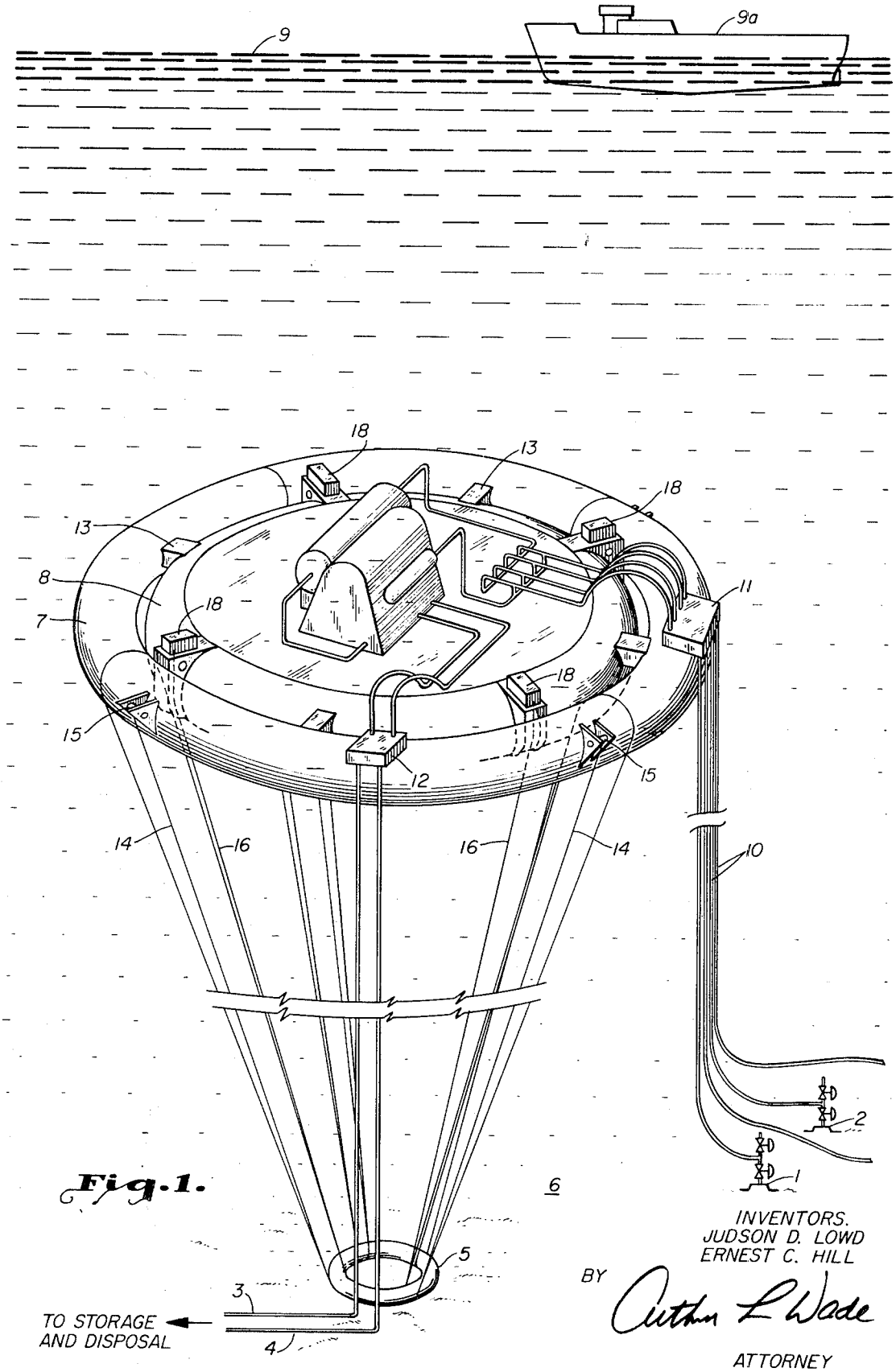


Fig. 1.

6

INVENTORS.
JUDSON D. LOWD
ERNEST C. HILL

BY Arthur L Wade

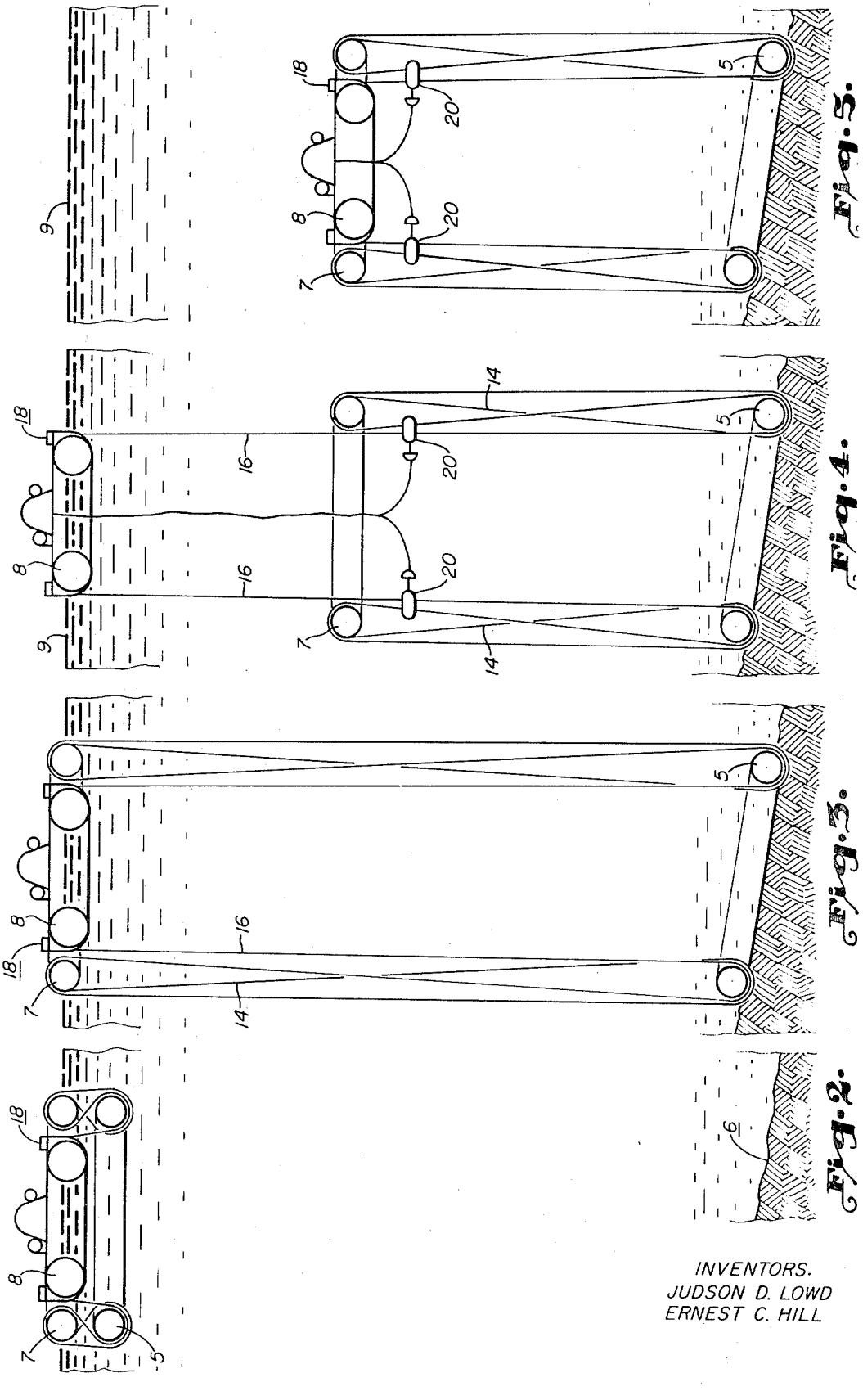
ATTORNEY

Dec. 29, 1970 J. D. LOWD ET AL 3,550,385

METHOD OF AND MEANS FOR FIELD PROCESSING OF SUBSEA OIL WELLS

Filed Nov. 4, 1968

3 Sheets-Sheet 3



INVENTORS.
JUDSON D. LOWD
ERNEST C. HILL

Dec. 29, 1970 J. D. LOWD ET AL 3,550,385

METHOD OF AND MEANS FOR FIELD PROCESSING OF SUBSEA OIL WELLS

Filed Nov. 4, 1968 3 Sheets-Sheet 3

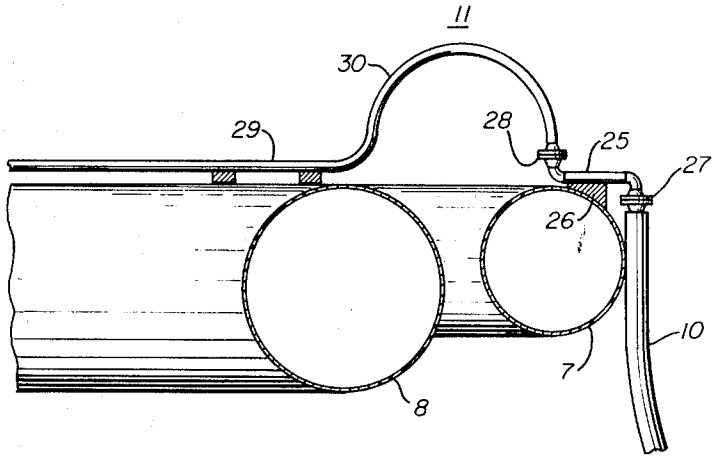


Fig. 6.

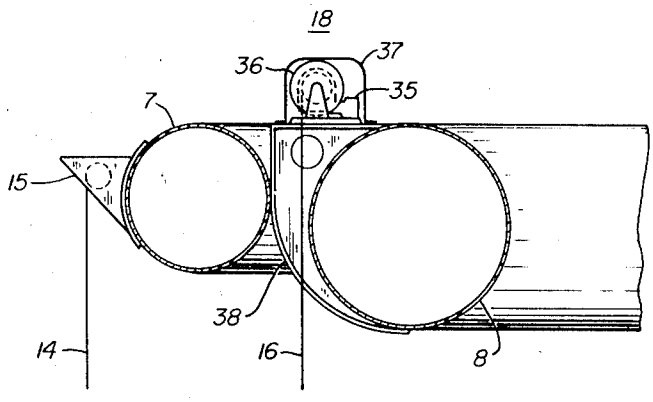


Fig. 7.

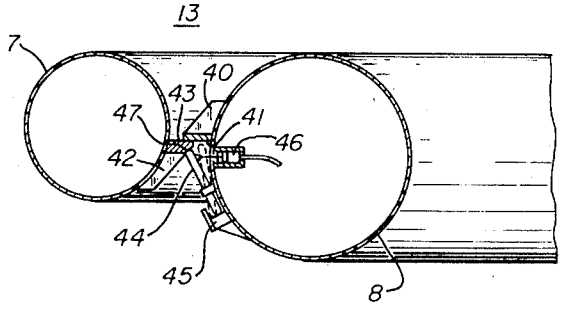


Fig. 8.

INVENTORS.
JUDSON D. LOWD
ERNEST C. HILL

BY Arthur L Wade

ATTORNEY

United States Patent Office 3,550,385 Patented Dec. 29, 1970

3,550,385

METHOD OF AND MEANS FOR FIELD PROCESSING OF SUBSEA OIL WELLS

Judson D. Lowd and Ernest C. Hill, Tulsa, Okla., assignors to Combustion Engineering, Inc., New York, N.Y., a corporation of Delaware

Filed Nov. 4, 1968, Ser. No. 773,121
Int. Cl. B63b 35/44; B63c 11/00
U.S. Cl. 61—46.5 9 Claims

ABSTRACT OF THE DISCLOSURE

A buoyant platform is anchored to float a predetermined distance below the surface. Field processing equipment for subsea oil wells is mounted on the platform. Procedures and equipment for floating the platform to location and setting it at its subsea location are disclosed.

BACKGROUND OF THE INVENTION

(1) Field of the invention

The present invention relates to establishing a stable structural support at a subsea location for equipment required to initially separate and process the fluids of a subsea oil well. More particularly, the invention relates to a buoyant structure tethered a predetermined distance below the surface activity of a large body of water to form the structural support for the wellhead processing equipment of an oil well.

(2) Description of the prior art

As the oil industry has rushed into the sea to reap the harvest of oil discovered beneath the sea bottom, the operating problems have rapidly subdivided. The discovery of oil beneath the sea, drilling under water, producing from subsea wellheads, processing the fluids at the well heads and transporting the products to shore are only some of the subdivisions of the problems. On relatively shallow areas, platforms have been built up from the bottom and the techniques developed on shore have been merely transferred to this more than damp underfooting. At present, fields are being considered which lie 150 to 1,000 feet beneath the surface of the distinctly hostile environment of the sea.

The casual observer concludes it is common practice for a simple run of pipe to be connected to the wellhead to transport the fluids to shore. In many instances, where it is but a short distance to shore, this is the present practice. However, the two-phase flow of gas and oil induces a large pressure drop in a flow line, rapidly limiting the practical distance over which the "blood, guts, feathers and all" produced by a well can be conducted. Also, the cooling of the unseparated phases by the sea, as a heat sink, can form hydrates from the fluids. The solid material induces additional pressure drop in a flow line. With newly drilled wells located many miles from shore their produced fluids must be separated in the so-called field processing near the wellhead.

The equipment to separate oil well fluids includes relatively large vessels with simple controls to regulate pressure and fluid levels within the vessels. A stable base must be provided for this equipment. Obviously, there is a huge range of problems in providing the bases at wellheads in 150 feet or more of water. Still another range of problems arises in controlling the flows into, and out of, the vessels, along with the pressure and levels within the vessels.

In summary, the discovery and drilling of wells at more than 150 foot depths has run far ahead of the development of processing and transporting. The relatively

simple processing by separation and dehydration has yet to be carried out successfully beneath the surface of the sea. All the forces within the industry clamor for solution of these problems on wells which are located at depths of 150 feet and more.

The invention focuses upon the specific problem of establishing a buoyant structure between the surface and sea bottom. Further, the invention solves the problem of providing conduits of oil well production a stable terminal common to processing equipment for the production. There are, of course, many ancillary problems: the equipment must be adjusted in situ and it must be removable to the surface for repair and replacement.

SUMMARY OF THE INVENTION

A principal object of the present invention is to provide a positively buoyant support structure for processing equipment at a subsea location above the bottom.

Another object is to provide a positively buoyant assembly of anchor and support structure for surface transport to a subsea location.

Another object is to provide a method of lowering the anchor structure to the bottom, lowering the buoyant support structure to the desired subsea location beneath the surface above the anchor and lowering the processing equipment down to position on the support structure.

Another object is to provide a buoyant pontoon for processing equipment which can be locked to the support structure and unlocked for surfacing.

The invention contemplates an anchor structure in the form of a torus nested with a support structure also in the form of a torus. Equipment to be mounted at a subsea location is mounted on a solid deck over the center of a pontoon in the form of a torus which is nested with the anchor and support structure. The combination of three torus shapes will float and is towable to where it is installed.

The installation further contemplates the method of first lowering the anchor by eliminating its buoyancy, then pulling the support structure down to a predetermined depth and tethering it securely to the anchor and then pulling the equipment pontoon down to the support structure and locking it into place on the support structure.

Other objects, advantages and features of this invention will become apparent to one skilled in the art upon consideration of the written specification, appended claims, and attached drawings, wherein;

FIG. 1 is an isometric view of a subsea mounting for field processing equipment for oil wells which embodies the invention;

FIGS. 2–5 are diagrammatic plan views of the three basic structures sequentially moved to location and erected;

FIG. 6 is a somewhat diagrammatic plan view of the connections of the flow lines to the equipment;

FIG. 7 is a somewhat diagrammatic plan view of a winch and a guide member for the support structure and pontoon; and

FIG. 8 is a somewhat diagrammatic plan view of a travel stop and lock for the support structure and pontoon.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Subsea oilfield use of the invention

Although the invention is not limited to the type of equipment supported at a subsea location, the invention is disclosed as embodied in a submerged production processing facility receiving the raw production of an oil well. There may be developed other packages of equipment required for subsea exploitation of the tremendous area of the continental shelf. However, the concepts of the invention can be fully illustrated with vessels and controls

for giving basic, field processing of oil well production, mounted in position and connected by relatively short runs of flow lines to the wellheads.

The processing facility should be mounted at a subsea location where it will not interfere with shipping, fishing and other surface activity. Also, the facility should be isolated from the forces of wind, wave and current. It is well known that the natural forces inherent at the interface of sea and air quickly depreciate with depth below the surface. However, it does not necessarily follow that complete submergence of a production processing facility to the very bottom is required. Indeed, it may be highly undesirable in order to function properly.

Fixed supports given consideration

The possibility of placing a tower on the bottom, extending up to the desired elevation, has been studied. However, the economics of constructing a structure tall enough to extend from a thousand foot depth to within two hundred feet of the surface are fantastic. The cost of extending such a support tower to within six hundred feet of the surface is a good deal less, but is still formidable.

Economics favor a buoyant support

The present invention was conceived as embodied in a submerged buoyant support structure held in position at some appropriate depth above the bottom by connection to an anchor system. Within an exhaustive feasibility study, it was established that the total investment for a buoyant support structure and anchor system would be less than one million dollars. Therefore, a tremendous bias is established in favor of the buoyant support in view of the projected investment for a fixed support as at least seven million dollars more than that for the buoyant system.

Additional advantages of buoyant support

In addition to the foregoing economic advantages of the buoyant structure over the fixed structure, there are mechanical advantages. The buoyant support structure can be adjusted in height. The mounting surface of the buoyant support structure can be sized more economically to the space required by the facility supported. Siesmic disturbance is essentially isolated from the facility. Complete removal of the combination and the supported facility is readily carried out for use elsewhere.

General requirements of the buoyant structure

The support structure has the submerged production processing facility mounted on it. This package of equipment includes the gas-liquid separators for bulk and test, with their process and environmental controls. The support structure and package must be considered in combination with an anchor to which they are to be tethered. This combination must meet the following over-all requirements:

(a) *It must float and be towable* to the submerged installation area. Thus it avoids the economic and physical limitations of handling on, and from the deck of a transport ship.

(b) *It must be able to move itself* from the surface of the sea to its submerged operating position without dependence upon a derrick barge as part of the surface support to installation.

(c) *It must be retrievable* with a minimum of surface support, not to include a derrick barge. Retrievability of the process package makes possible the changing of process and equipment occasioned by the varying production characteristics of the field. It also permits repairs which are too extensive to do while submerged. Transfer of the package to another location is thus also possible, if ever required.

Although other specific shapes for the three basic structures of the combination are conceivable, the torus appears to be the most practical to meet the foregoing requirements. The anchor is a torus and is provided with

sufficient compartments to make it buoyant. The supporting structure tethered to the anchor is also a torus. Finally, the production processing facility is mounted on a deck which is connected over the center opening of a torus shaped pontoon which is locked to the support structure in normal use and unlocked for guidance to the surface when repair, replacement or service is required. The torus lends itself well to this application since it is equally stable in seas from any direction and has distinct advantages during emplacement and retrieving operations.

General

FIG. 1 discloses the complete submerged production processing facility receiving the raw production of at least oil wells **1** and **2** which are completed on the marine bottom. Also, the production is taken from the submerged facility by at least conduits **3** and **4**. The terminal equipment for conduits **3** and **4** is not indicated as pertinent to the present invention.

The facility includes at least three basic components. Anchor **5** is on the marine bottom **6**. Support structure **7** tethered to the anchor. Pontoon structure **8** is locked to the support structure. The production equipment is mounted on pontoon **8** from where it serves the oil wells **1**, **2** and delivers to storage and disposal equipment the petroleum fluids of the wells.

The surface of the body of water in which the facility is submerged is indicated at **9**. A surface craft **9***a* is shown, plying the waters in normal commercial trade, the tethered support and pontoon structure being well below such activity near the surface.

The wells are connected to the pontoon equipment by flow lines **10**. These are high pressure conduits which should be given stable support to obviate their failure. Therefore, the lines **10** are shown rising to the upper surface of support structure **7** where they are anchored securely and joined at **11** to the input conduits of the pontoon equipment. The specific anchoring structure is not disclosed in FIG. 1 but will be illustrated in more detail in a subsequent drawing.

The arrangement with which to anchor and support conduits **3** and **4** is similar to that for **10**. The conduits simply lead from their junction at **12** with the output lines from the production equipment. They are led over the side of the support structure **7**.

Support structure **7** and pontoon structure **8** are locked together at positions **13**. Again, details of the locking structure are reserved for subsequent illustration on a larger scale. When the structures are unlocked, pontoon **8** can be raised to the surface **9** as required to repair, service or replace parts of the production equipment mounted at the middle of the pontoon.

The lines tethering the support and pontoon structures **7**, **8** to anchor **5** are indicated at **14**. These lines are fixed by one end to support structure **7** with fixtures **15**. With these lines the support and pontoon structures are winched down to the location shown. Pontoon structure **8**, once it is unlocked from support structure **7**, can be winched between the surface and the location shown by taking up lines **16**. Therefore, production equipment **17** can be brought to the surface for repair, service and replacement. However, it is contemplated that the depth of the equipment from the surface would be small enough to enable diving technicians to reach and service the equipment in situ.

The winches are indicated at **18** as mounted on the edge of the pontoon structure **8**. This is the third structure of FIG. 1 which will be given more detailed disclosure in subsequent drawings. In general, the winches are mounted on a foundation which extends beyond the rim of pontoon **8** to contact support structure **7** and maintain their basic concentricity. The locks **13** then secure them against vertical displacement, relative to each other.

At this point of generalization, it is emphasized that although the three basic components are each illustrated

in the specific form of a torus, this need not be necessary to their functions. The term "torus" is used in its broadest sense. Actually these bodies may be formed of multiple straight sections which are only generally classified as toroidal in the completed form. The general form of the torus was found to have several advantages for this construction, but the practicalities of construction could dictate some modification.

In any event, the broad concept of three buoyant structures arranged as shown in FIG. 1 is developed clearly. The anchor is adjustable in buoyancy so it may be sunk to the marine bottom as shown. The support structure is tethered to the anchor a predetermined distance below the surface. The equipment-bearing pontoon is drawn down to, and locked on, the support structure. The final combination supports oil well production equipment at an accessible depth, with satisfactory stability and at a cost far below that of a tower structure supported from the marine bottom.

Method of erection

In that the three basic components of the submerged production processing facility must be brought to a surface location above their bottom location and positioned as disclosed in FIG. 1, the facility is erected in the same sense that a pile-supported platform is erected. However, the erection requires a procedure, or method, which is unique to this type of support structure. These steps are depicted by FIGS. 2–5 of the drawings.

The first step in erection requires the transport of the basic components to the erection site. Each of the components is buoyant. The anchor **5** is sunk and given sufficient negative buoyancy to restrain the support **7** and pontoon **8** in the FIG. 1 position. However, in the water near the construction site the anchor is kept buoyant and is nested with the other components to comprise a package which can be towed to the surface location. FIG. 2 shows the basic components with the winched lines holding the anchor in a neat package with the support and pontoon. This package can be readily towed to the location for erection.

The method of erection broadly includes:

(a) Floating the assembly to location.
(b) Disconnection of the anchor and emplacing it.
(c) Winching down the support structure.
(d) Pulling the pontoon, with the production equipment, down to its final emplaced position.

FIG. 2 illustrates the first of these method steps. FIGS. 3–5 illustrate the other steps.

To carry out the second of the method steps, means for flooding the compartments of anchor **5** are provided although not specfically shown in these drawings. Some flooding at the surface may give the anchor enough negative buoyancy to sink the anchor positively at the desired position on the marine bottom as shown in FIG. 3. The connecting lines **14** between the anchor and support **7** and pontoon **8** are payed out as the anchor sinks.

The marine bottom may or may not be level. FIGS. 3–5 show the bottom somewhat inclined. However, the winched down support member can be leveled by control of the length of each tether line **14**.

Once the anchor **5** is properly seated on the bottom, its negative buoyancy can be adjusted in several ways. More compartments may be flooded and/or compartments could be filled with solid material. Obviously a tremendous negative buoyancy must be created to anchor the combined positive buoyancy of the support **7** and pontoon **8** when they are winched down into their FIG. 1 positions.

The third of the method steps is completed to bring the structures to the positions disclosed in FIG. 4. Winches at **18** have pulled the support structure **7** down to the desired depth by reeling in lines **14**. Instrumentation not disclosed is available to indicate the attitude of the support structure as it is pulled down. When the support

structure is in position, clamps **20** are then used to lock the anchor lines together so the fourth, and final, method step can be carried out. That portion of the anchor lines designated as **16** are clamped to the anchor lines between the anchor **5** and support sturcture **7**. The winches **18** then reel in lines **16** and pull the pontoon down to the support **7**.

FIG. 5 illustrates the results of the completed fourth step of the method of erection. The equipment-bearing pontoon **8** has been winched down and locked to the support structure **7**. The flow lines can be connected as shown in FIG. 1 and the details needed can be carried out to place the production equipment in operation on this platform at its submerged location.

Well Connections to Process Equipment

In FIG. 1 the connection location **11** indicated where the flow lines **10** from the wells joined the input lines to the process equipment **17** mounted on the platform of pontoon **8**. To reduce the complexity of the disclosure in FIG. 1, both the location **11** and the location **12** were indicated by blocks. FIG. 6 shows one of the upper ends of a flow line **10** connected to an input line to the process equipment.

In the general sense, a relatively short conduit system **25** is mounted with great stability on a platform fitting **26** which is attached to the upper external surface of the support structure **7**. This conduit section has flange **27** and flange **28** vertically oriented. Flange **27** mates with the flange of flow lines **10** extended up from below. Flange **28** mates with the flange of input conduit **29** going into equipment **17**.

Input conduit **29** is formed with a long unsupported bend **30** for at least the reason that some movement is thereby provided the mating flanges to take care of minor misalignment. The specific construction of these flanges for subsea service is not disclosed. Obviously every detail of this nature must be carefully considered for the demands of subsea environment. Finally, the FIG. 6 disclosure generally represents both junction at **11** and those at **12**.

Winches and guides

At least four winches are contemplated for the equipment as disclosed in FIG. 1. They are indicated in FIG. 1 at **18**. FIG. 7 discloses this equipment in further detail.

The winches are used for pulling the pontoon structure **8** down to its operating emplacement point under the sea. They are also used for controlling its ascent to the surface as well as for mooring to the subsea support during surface operations. They should be equally spaced around the perimeter of the torus pontoon and externally mounted.

A winch for this use could be electrically powered by reversible electric motor **35**. It is contemplated that the motor **35** will be directly geared to the shaft of the winch **36** with no clutch. Braking would then be done on the shaft of the motor. The gear box motor, brake and other components which will not stand exposure to sea water would be enclosed in cases filled with oil.

Winches are heavy and thus more easily installed if not located in a small interior compartment. They must be located as far from the center of the pontoon **8** as possible for maximum stability during the time they are controlling the attitude of the pontoon and equipment **17** mounted on it. Also, the mounting must permit the taut vertical cable to pass from the winch drum near deck level past the outside of the pontoon without touching it.

A removable cover **37** is disclosed. The cover is close fitting and gas filled to minimize exposure of the equipment and cable to sea water.

A guide **38** is provided as a framework to position the pontoon accurately relative to the outer support structure **7**. This guide frame is more easily provided near the winch supports since both must be heavy and securely attached where extra hull reinforcing is provided. As the pontoon structure moves downward into the center

of the support structure, the guide members **38** will accurately center it.

Travel stops and locks

In FIG. 1, locking structure at positions **13** was indicated in block form. FIG. 8 is established to more specifically disclose a form for the structure at positions **13**.

First, a stop must be provided to limit the vertical travel of pontoon **8** as it moves into place through the opening in the submerged support structure **7**. This stop, as well as the guiding and orienting structure, must function accurately so the piping between the two units will mate. The stop comprises, essentially, projection **40** on pontoon **8** with downwardly facing surface **41** and projection **42** on support **7** with upwardly facing surface **43**. In FIG. 8, the surfaces are shown as they engage.

After the pontoon **8** is accurately positioned, it must be securely locked at that position to provide stability as a platform for the equipment mounted on pontoon **8**. A hold-down bar **44** is pivoted in socket structure **45** on pontoon **8**. The pivoting is controlled through an actuator **46**, and with this structure bar **44** is pivoted counterclockwise, as shown in FIG. 8, to engage seat **47** which is shown on projection **42**. Thus projection **42** can be said to be captured between bar **44** and surface **41** to link support **7** and pontoon **8** solidly together against their vertical separation. Of course, a number of these locking structures are shown about the circle of the hiatus between support **7** and pontoon **8** to complete the link in a very solid fashion.

CONCLUSION

It is a bizarre concept to tether a buoyant platform between a marine bottom and surface and mount heavy oil field equipment on the platform. The imagination of the casual observer reels with the impact of his inhibitions that the currents of the sea are so powerful and unstable as to render the subsea buoyant installation vulnerable to every caprice of the hostile environment. However, serious, systematic and continuing study of the conditions at depths below 200 feet has stimulated us to conceive the disclosure of this applicationt on a practical rationale.

The rates of currents below 200 feet are not too great. The environment is surprisingly stable. Oil field production equipment floating hundreds of feet above its wellheads on the marine bottom may be a strange sight, but the arrangement is practical under our concepts.

Further, the method of emplacing the various sections of the subsea complex is distinctive. They can be floated to location as a unit and lowered individually to the position shown in the drawings. The method and structure are novel and embody practical concepts.

There are many details of this embodiment which have been carefully worked out to implement the broad concepts. The orienting structure to keep the two rings of the buoyant structure properly spaced and the arrangements to lock them together are among these features. Altogether, the package evidences a spectacular breakthrough in the subsea thinking of today.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the method and apparatus.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. A subsea structure, including,
an anchor member structured and arranged to be adjustable in buoyancy,
a buoyant support structure adapted to be tethered from the anchor member a predetermined distance below the surface,
means operatively connected between the buoyant support structure and anchor for drawing the buoyant support structure down toward the anchor member and tethering the support structure to the anchor,
a buoyant pontoon structure,
means operatively connected between the buoyant pontoon structure and support structure for drawing the pontoon down to the support structure and locking them together, and
equipment mounted on the pontoon structure and adapted to perform a work function in the hostile environment of the sea.

2. The structure of claim **1**, wherein, the anchor member is in the form of a torus.

3. The structure of claim **2**, wherein, the support structure is in the form of a torus.

4. The structure of claim **1**, wherein, the anchor member and the support structure and the pontoon structure are each in the form of a torus.

5. The structure of claim **1**, wherein, the equipment is an oil well production processing facility adapted and arranged to perform at least primary separation of the fluids of the production for subsequent transportation of the fluids.

6. A method of erecting the three basic structures of a subsea platform, the basic structures each having the general shape of a torus and sized to nest together in a unitary, floatable package, including,
towing the floating package to a marine surface location above which erection is desired on the marine bottom,
reducing the buoyancy of the anchor structure to a negative value and guiding it to its desired position on the marine bottom,
winching down the second of the basic structures a predetermined distance below the surface, and tethering it securely to the anchor structure,
winching down the third and last of the basic structures to a position where it is concentrically arranged within the second structure,
and locking the second and third structures together, equipment being mounted on the third structure and adapted to perform a work function in the hostile environment of the sea.

7. The method of claim **6**, including,
connecting the end of a flow line conducting production from a subsea oil well to the second of the basic structures tethered to the anchor structure, and
coupling the equipment mounted on the third structure to the end of the flow line connected to the second of the basic structures tethered to the anchor structure to flow production to the equipment for primary processing.

8. A subsea support system for production equipment for an oil well, including,
an anchor member sunk to the marine bottom a predetermined distance from an oil well,
a buoyant support structure tethered to the anchor structure a predetermined distance below the surface,
a buoyant pontoon structure positioned at the support structure,
a lock structure rigidly fixing the buoyant support structure to the buoyant pontoon structure so that both are tethered to the anchor as a unit,
a flow line extending from the oil well to a mount on the support structure from where the flow line is coupled to production equipment on the pontoon structure, and

a winch operatively connecting the pontoon and support structures with tethering lines, the winch and lines being arranged to reciprocate the pontoon with the production equipment mounted thereupon between its locked position at the support structure and the surface where the equipment is inspected and serviced and replaced in whole or in part.

9. The lock structure of claim **8**, including,

a first projection structure on the support structure with a face directed upward,

a second projection structure on the pontoon structure with a face directed downward to engage the upward face, and

a pivoted bar member mounted on one of the buoyant

structures so it can be pivoted into engagement with the other of the buoyant structures and lock the projection surfaces together.

References Cited

UNITED STATES PATENTS

2,908,141	10/1959	Marsh, Jr.	61—46.5X
3,111,692	11/1963	Cox	61—46.5

JACOB SHAPIRO, Primary Examiner

U.S. Cl. X.R.

9—8; 61—69; 114—.5; 175—7