Jan. 23, 1962 A. D. RHODES ET AL 3,017,934

CASING SUPPORT

Filed Sept. 30, 1955 6 Sheets-Sheet 1

FIG. 1.

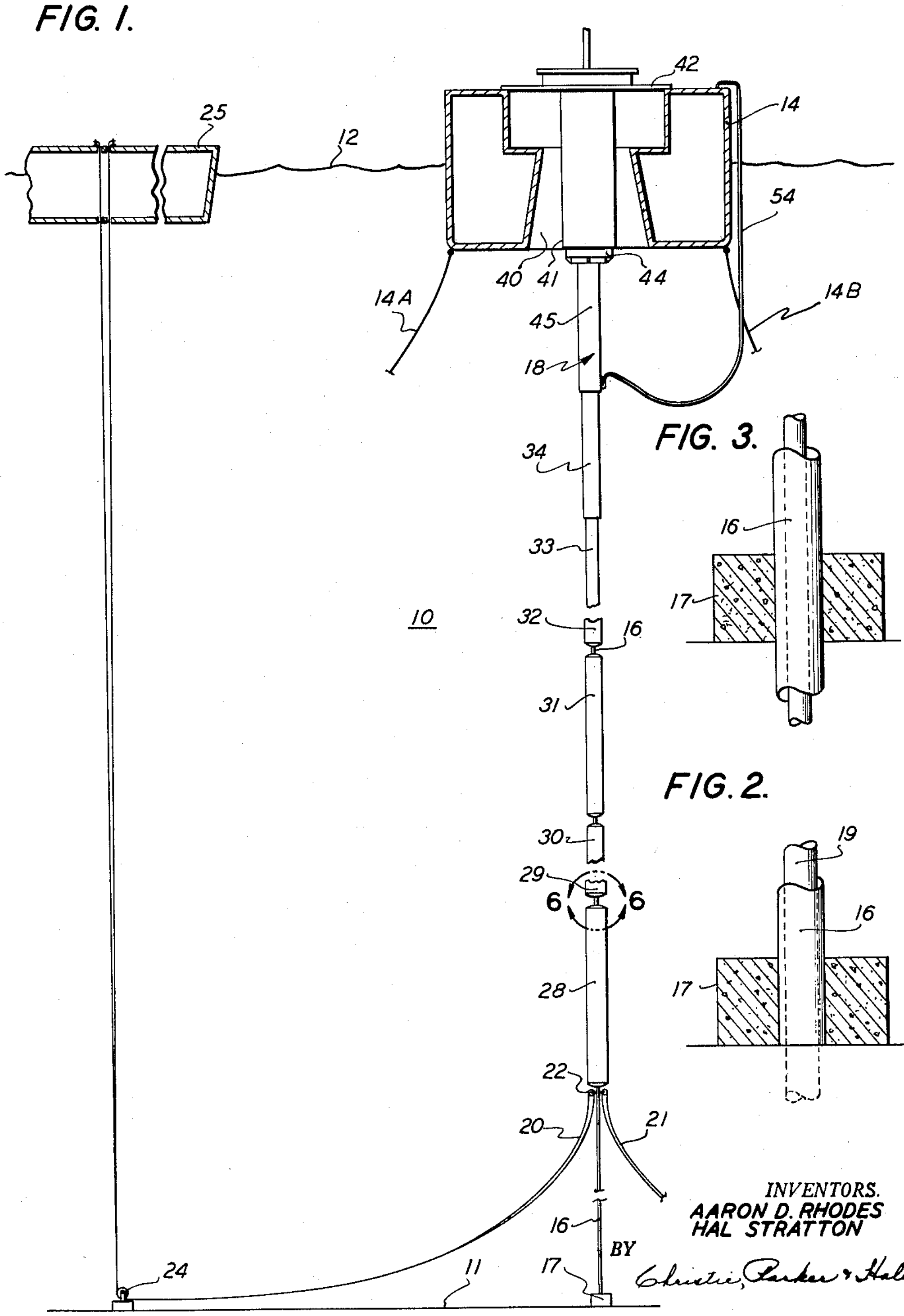

FIG. 3.

FIG. 2.

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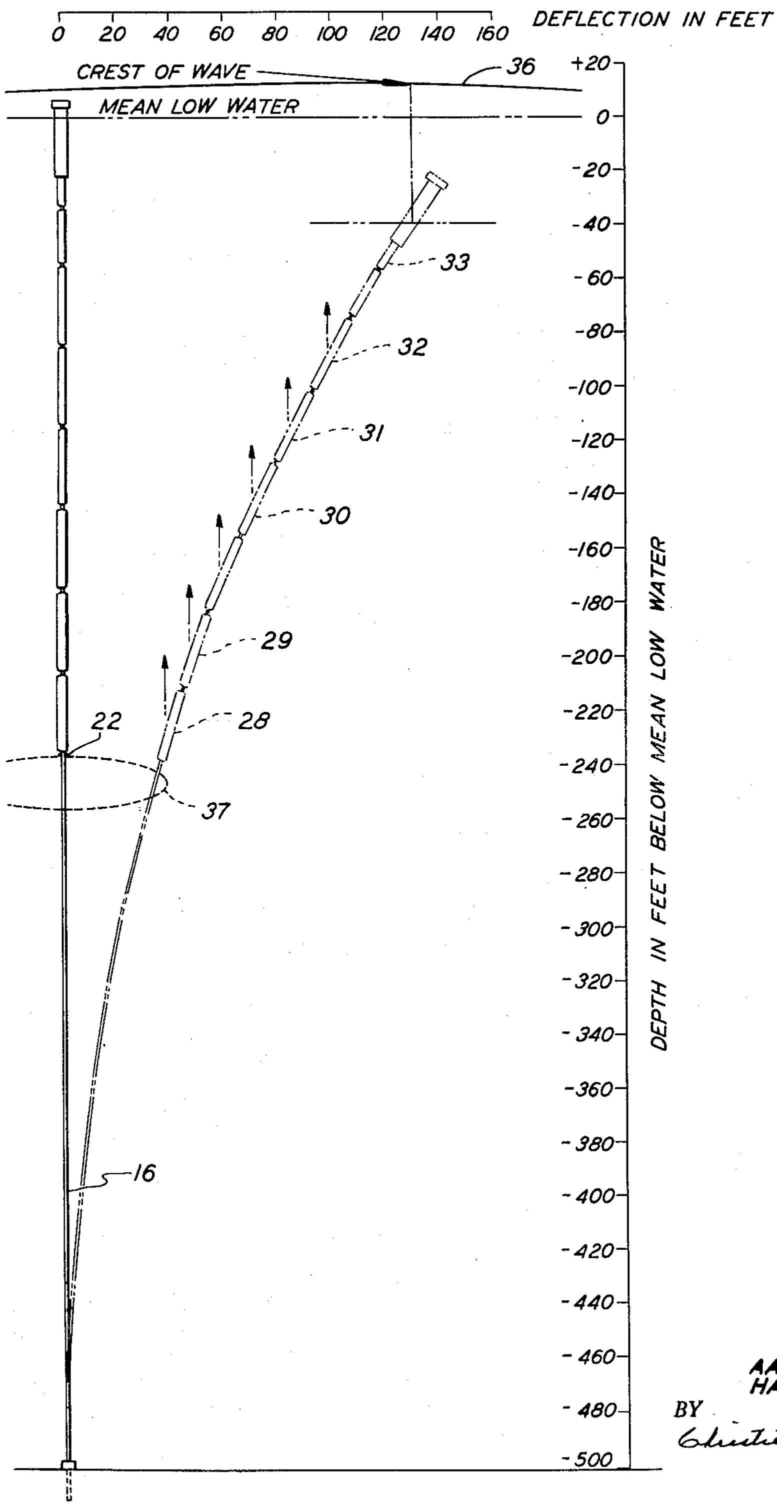
Jan. 23, 1962 A. D. RHODES ET AL 3,017,934

CASING SUPPORT

Filed Sept. 30, 1955 6 Sheets-Sheet 2

FIG. 4.



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Filed Sept. 30, 1955 6 Sheets-Sheet 3

FIG. 5.

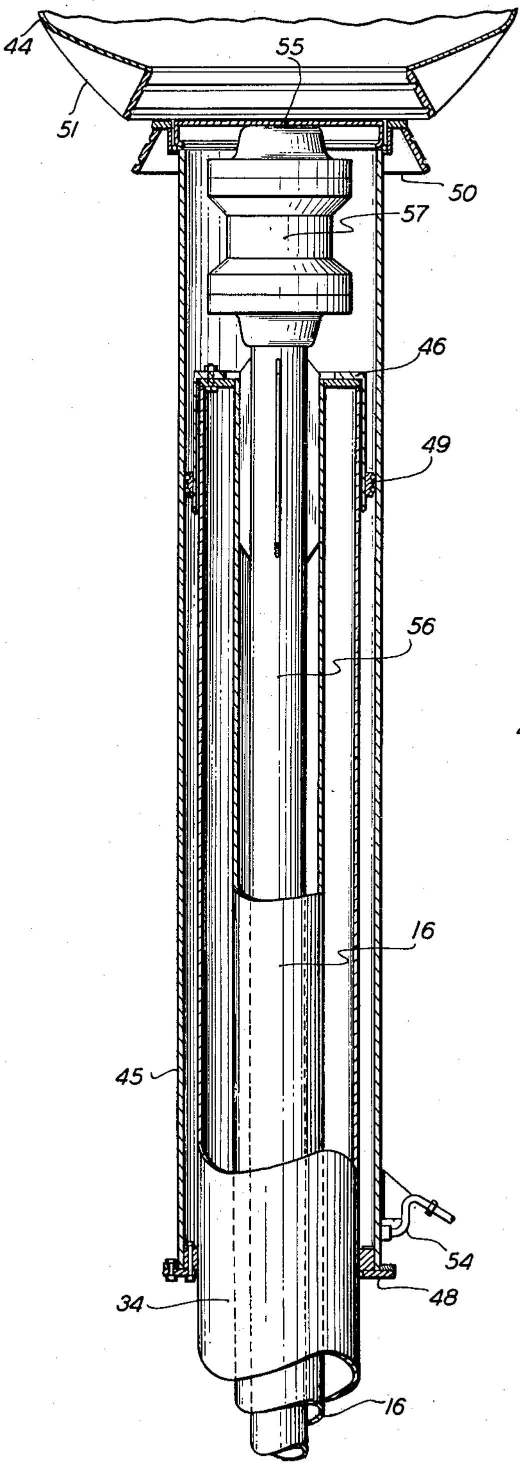

FIG. 6.

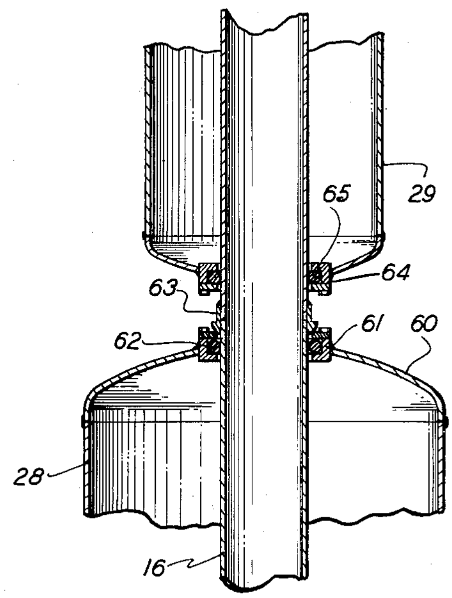

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FIG. 7.

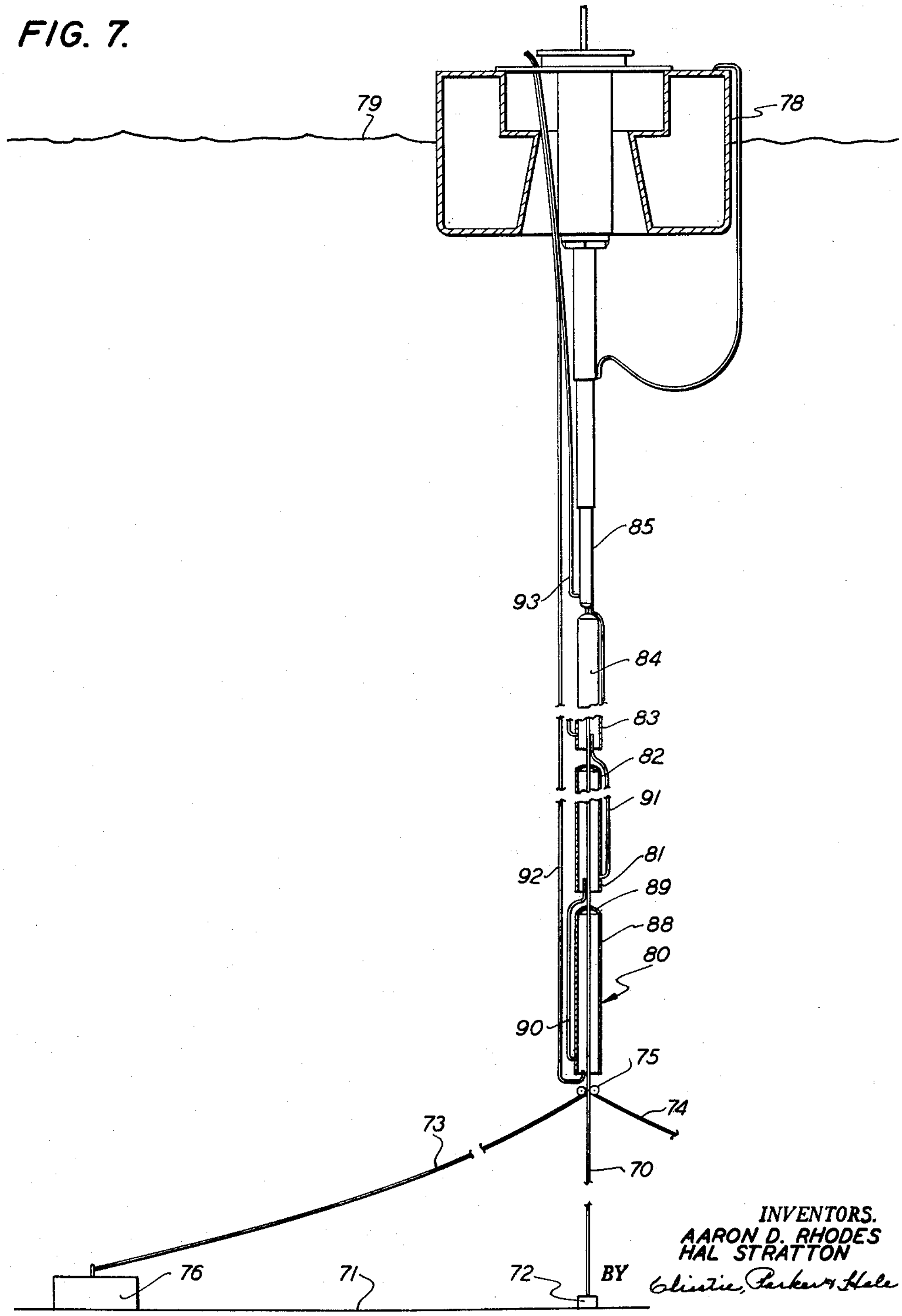

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FIG. 9.

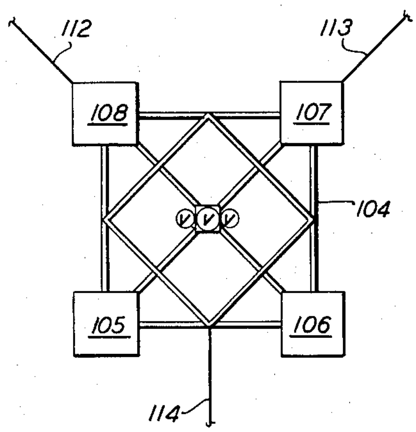


FIG. 10.

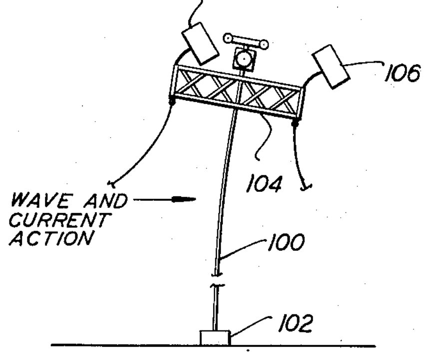
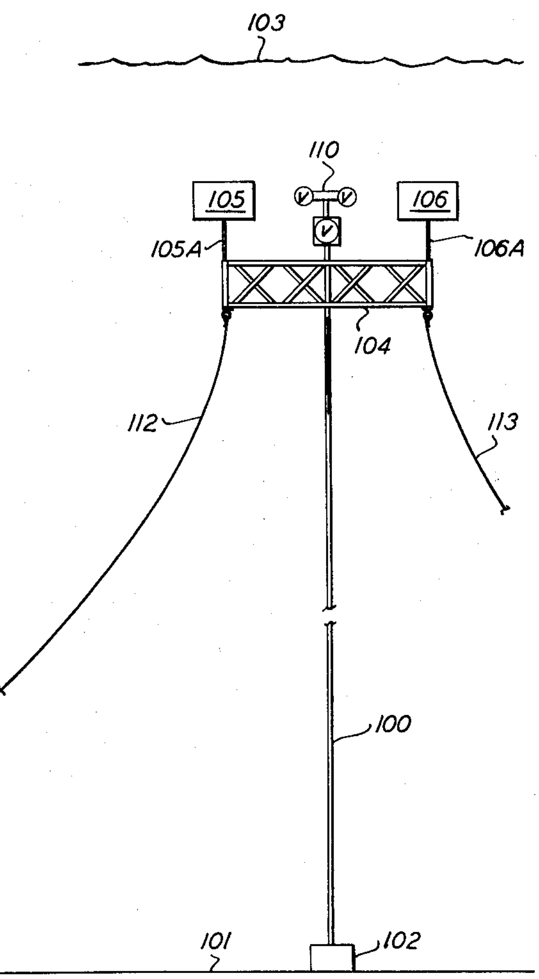


FIG. 8.



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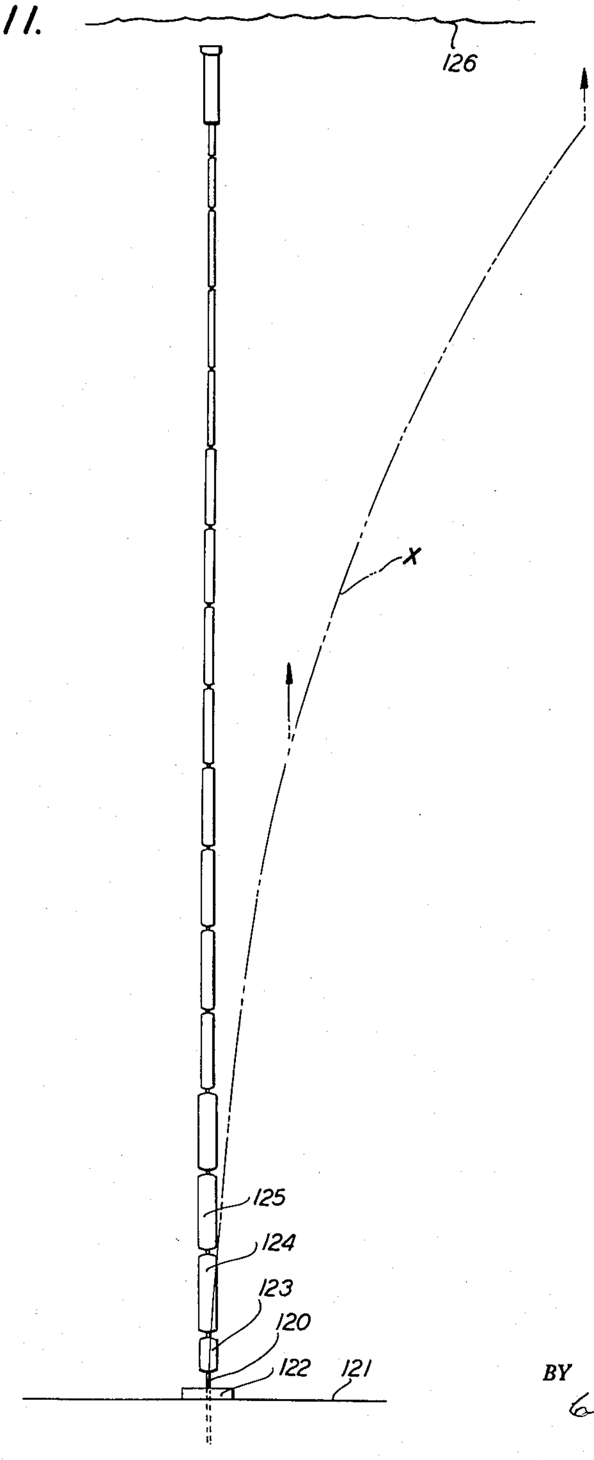
Filed Sept. 30, 1955 6 Sheets-Sheet 6

FIG. 11.



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United States Patent Office

3,017,934

Patented Jan. 23, 1962

1

3,017,934
CASING SUPPORT

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Filed Sept. 30, 1955, Ser. No. 537,738
3 Claims. (Cl. 175—7)

This invention relates to the problems of drilling and producing wells under water and particularly to means for supporting a well casing extending upwardly from the bottom of a body of water. The invention will be described with relation to application to the exploration for and production of hydrocarbon in submarine formations, although applicable to any materials susceptible to thus being discovered or produced and whether beneath marine or fresh bodies of water.

There is presently a great deal of activity in so-called offshore exploration for and production of hydrocarbons with a promise of appreciable future increase. This activity is taking place in ocean locations as in the Gulf of Mexico and off the coast of California as well as on inland water bodies. There are many exploration, development and production problems uniquely associated with the search for and the acquisition of hydrocarbons which may be located several hundreds or thousands of feet below the bottom of a water body, which itself may be several hundreds or thousands of feet deep. It has been demonstrated that well bores may be sunk in the ocean bottom from a floating vessel suitably anchored to prevent excessive displacement of the vessel with respect to a given point on the bottom but otherwise unconnected with the bottom. To drill a well bore from a floating vessel involves the unique requirement that means be provided for relocating the bore hole from time to time as tools are removed therefrom, as for example when the floating vessel is moved and returned on account of storms or other factors. In addition, drilling well bores from a floating vessel in a marine bottom presents unusual problems in provision of blow-out preventers, mud circulation, capping, and production of a well thus drilled.

It has been proposed to drill such a well with a conventional drill string unsupported between the floating vessel and the marine bottom. In such event a conductor pipe is initially set by spudding or by stripping over the drill string. Return mud circulation and blow-out prevention are achieved by connection of circulating head and blow-out preventers to such a conductor immediately above the marine bottom.

It has also been proposed to drill submarine formations through an articulated casing anchored at one end to the marine bottom and affixed at its opposite end to the floating vessel. This latter expedient requires that the casing be removed in the event that the vessel is removed, since in any appreciable water depths such a casing is unable to support itself. Such a system has been described in United States Patent Re. 24,083, issued on November 1, 1955 to James M. McNeill. This last described technique has been modified slightly in according with at least one teaching by the provision of a single large buoyancy chamber affixed to an upper end of a casing extending from a marine bottom toward the water surface whereby

2

the floating vessel can be detached and moved, leaving the casing thus buoyantly supported for later reuse. The buoyant chamber is of such size as to hold the casing in tension. See U.S. Patent No. 2,476,309, issued July 19, 1949 to Walter B. Lang.

There are situations in which it is advantageous to provide a casing extending upwardly from a marine bottom and through which a drill string may be advanced to drill a submarine well from a floating vessel, or through which a successfully completed well may be produced. The lower end of the casing may be so anchored to the marine bottom and sealed to the well bore that blow-out preventers, circulating heads, Christmas treees and other necessary apparatus required by good exploration and production technology can be supported at the upper end of the casing closely adjacent the surface of the water body. This is an important advantage in water depths of one to several hundred feet since all maintenance of such blow-out preventers, circulating heads and the like can be carried out in a relatively few feet of water at the upper end of such a casing. In addition, if hydrocarbons are produced from a well thus drilled, production control such as the conventional Christmas tree may be affixed to the upper end of this casing, again permitting ready access for installation and maintenance. Once such a marine casing is set and sealed to the initial section of conductor pipe in the well bore the depth of the water body becomes relatively unimportant and all problems of drilling and production are keyed to the water depth at the upper end of the casing. Conveniently the casing is terminated at a sufficient depth below mean low tide to clear the bottoms of any ocean-going vessels.

We have now discovered a critical factor in the provision of a marine casing of the type described which has a decided effect on the practicality of such a casing. We having found that to satisfactorily support the casing of this type it is necessary to distribute the required buoyancy, and to do this a plurality of separate buoyant means are provided of such aggregate capacity as to maintain the casing under tension, or approximately so, at all times.

The invention therefore contemplates a buoyantly supported casing extending upwardly from the bottom of a water body and comprising an elongated tubular member, means anchoring the tubular member adjacent one of its ends to the bottom and a plurality of separate buoyancy chambers spaced from each other and connected to the tubular member to maintain the member in tension under the influence of the distributed buoyancy.

Distribution of the total buoyancy required to support the casing between numerous spaced buoyancy means is of considerable importance in achieving the necessary stability of the casing and to minimize what may otherwise prove to be prohibitive response to forcible current and wave forces.

One of the major problems associated with the provision of a marine casing of the type described is the effect thereon of wave and current forces in an ocean location. It is necessary to restrain such a casing from bending at any point under the influence of any expectable deforming influences in excess of the elastic limit of the casing. We have found that this requires the imposition by one means or another of a restraint on the deflection of the casing, which may be induced by predictable current and wave forces. We have provided two forms of such restraint which may be used independently or in conjunction with one another.

One means of restraining the casing against undue deflection is by distributing the supporting buoyancy throughout a substantial length of the casing so that the vertical component of buoyant force is distributed along the casing and acts against any predictable horizontal component of current or wave forces so as to maintain the deflection of the casing at all times within its elastic limit.

A second means of restraining such a casing against excessive deflection which may be induced by natural forces is by a plurality of guying anchors so tensioned that the casing is flexible within its elastic limit and within a suitable margin of safety but is absolutely restrained from excess deflection.

As mentioned above, these two restraining techniques may be combined so that a lower portion of the casing is restrained by suitable guying means and distributed buoyancy is applied to an upper portion of the casing above the restraining means so as to prevent excessive deflection of this upper portion of the casing.

For purposes of drilling submarine wells, means may be provided whereby a floating vessel may engage and disengage the upper end of the casing at will. Once a well is completed and is producing through the casing, such operative engagement by a floating vessel is in general no longer necessary.

The invention will be clearly understood from the accompanying detailed description of several embodiments thereof taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a partial schematic elevation of a casing structure in accordance with the invention, showing the cooperating application of the two types of restraint previously mentioned, and further illustrating a means of attaching the upper end of the casing to a floating vessel;

FIG. 2 is an enlarged view of one form of anchor for anchoring the casing of FIG. 1 to the marine bottom;

FIG. 3 is an enlarged view of a second form of anchor for the same purpose;

FIG. 4 is a graph showing the deflection of the casing of FIG. 1 when it is not attached to the floating vessel and under assumed conditions of wave force;

FIG. 5 is an enlarged sectional elevation of one means of attaching the casing of FIG. 1 to a floating vessel, which means is illustrated in elevation in FIG. 1;

FIG. 6 is an enlarged sectional elevation of a portion of the casing taken on the line **6—6** of FIG. 1 and showing one means of affixing buoyancy chambers directly to the casing;

FIG. 7 is a schematic elevation of an alternative embodiment of the casing of the invention;

FIG. 8 is an elevation of a still further embodiment of the invention;

FIG. 9 is a plan view of the embodiment of FIG. 8;

FIG. 10 is a reduced scale elevation of the system of FIG. 8 illustrating the effect thereon of wave and current forces; and

FIG. 11 is an elevation view of another embodiment of the invention including a plot of the deflection thereof under the wave forces assumed in the graph of FIG. 4.

In FIG. 1 a body of water **10** overlies a marine bottom **11** to a depth indicated by water surface **12**. A floating vessel **14** is shown in transverse section and in this instance would normally be held in a substantially fixed position by a plurality of separate anchors represented in the drawing by anchor cables **14A**, **14B**. Additional anchors may be employed, although not shown in the drawing. A casing **16** in anchored adjacent one of its ends to the bottom **11** by an anchor means **17**. The casing extends upwardly and in the illustration is ultimately connected to the floating vessel **14** by means of a telescopic union **18**, which is illustrated in FIG. 5 and described relative to that figure.

As shown in FIG. 2, the casing **16** may be anchored solely by means of the anchor **17**, which is a concrete block formed on the lower end of the casing. The block **17** serves to hold the casing on the bottom, lateral displacement being prevented for example by a conductor pipe **19** set in the underlying formation and packed off in the casing by conventional means (not shown) to seal the casing with the well bore. In this instance the casing may be initially lowered to the marine bottom conveniently by making it up in sections as it is lowered from an overlying floating vessel. Alternatively, the entire casing may be floated to the desired location and up-ended in position. In either case a well may be spudded in by lowering a drill string through the casing to commence drilling in the marine bottom. A conductor pipe may then be stripped over the drill string into the well bore, cemented in place and packed off with the casing to complete the construction partially illustrated in FIG. 2.

Alternatively, and as shown in FIG. 3, casing **16** may extend through a concrete block anchor **17** to project into the underlying formation and thereby provide its own anchor against lateral displacement. In a soft bottom the extending end of casing **16** may penetrate the formation without assistance. In some cases it may be necessary to artificially spud in the casing hydraulically or otherwise. Once the casing is located, conductor pipe may be set, cemented and sealed to the casing as described above.

The anchoring means shown in FIG. 3 is preferred where soft bottoms are encountered, and the anchoring means shown in FIG. 2 is preferable with hard bottoms, it being unnecessary in this case to in any way force the casing **16** into such a hard bottom. Other means for anchoring the lower end of the casing to the marine bottom may be employed, practice of the invention being in no way limited to the two anchoring means which are illustrated by way of example only.

At a point above the anchor **17** a plurality of guy lines, usually at least three in number, are provided, two of which, lines **20** and **21**, are shown in the figure. The guy lines **20** and **21** and any others employed are suitably fastened to the casing **16** as by sheaves **22** and, as illustrated for line **20**, may be carried through an anchored sheave **24** to a buoyant float **25**. By means of the float and anchor sheave arrangement the correct tension can be applied to the guy line **20** and by similar expedient correct tension can be applied to the other guy lines employed so as to result in any predetermined desirable limitation on the deflection of the conductor **16** through the region extending from the anchor **17** to the sheave **22**.

Above the sheave **22**, casing **16** is provided with a plurality of separate longitudinally spaced buoyancy pods **28**, **29**, **30**, **31**, **32**, **33**. These buoyancy pods are provided in sufficient number and total buoyant volume to support the entire weight of the casing, which is determinable by the type of casing employed and the heighth of the casing column. In this manner the total buoyancy requirements are distributed over an appreciable length of the casing from the shackle **22** to a point adjacent the surface and as a consequence the vertical component of buoyant force is similarly distributed. Preferably the buoyancy chambers are larger at the lower extremity of the buoyed section of the casing and are progressively reduced in diameter and buoyant volume as the surface **12** of the water body is apporached. Thus the lowest buoyancy pod **28** is larger in diameter than the succeeding pods **29**, **30**, **31**, etc. and the pod **29** is similarly larger than the succeeding pods **30**, **31**, etc.

There are several reasons for so constructing the buoyancy pods. As previously mentioned, the distribution of the total buoyancy requirements among several buoyancy chambers is advantageous in that they may be so distributed as to minimize the deflecting load of ocean current and wave forces. This is particularly true where the separate buoyancy chambers become progressively smaller as the surface of the ocean is approached since the magnitude of wave action is an inverse function of the ocean depth. In the illustrated system the wave action is considerably less on a given surface area of the buoyancy pod 28 than on the buoyancy pod 33. For this reason it is entirely practical and desirable to make the pod 28 of larger size than the pod 33.

Furthermore, as the casing is deflected under the influence of wave and current actions, and particularly when it is a free column unattached at its upper end to a floating vessel, a greater vertical component of buoyancy is necessary at the greater depths to resist the bending moment of any given section of the casing. This effect can be appreciated from a consideration of FIG. 4 which is a graphic illustration of the action of the casing of FIG. 1 when that casing is not connected to a floating vessel and under wave forces represented by a wave having a crest indicated by line 36. The lower end of the casing 16 below shackle 22 is free to move within a given orbit illustrated at 37, the radius of the orbit 37 being determined by the tension applied to the guy lines 20, 21, etc. Under the illustrated applied wave force and in the water depths as shown, the upper end of the casing will deflect as shown. By virtue of the vertical component of buoyancy provided by each of the pods 28, 29, 30, 31, 32, 33, etc. the deflection at any point along the casing will be within the elastic limit thereof.

One means of interconnecting the self-supporting casing in a floating vessel whereby drilling operations may be carried on from the vessel through the casing as a conductor to the ocean bottom is shown in sectional elevation in FIG. 5. It is important to note than no means need be provided on the vessel to support the casing since it is self-supporting by virtue of the multiplicity of buoyant chambers attached thereto. For this reason the casing remains in location once a well is started or when a well is under production independent of any surface vessel. Preferably the casing proper terminates below the draft line of the largest ocean vessel, say approximately 35 to 40 feet below mean low tide. A suitable non-destructive buoy may be used to indicate the location of the thus submerged casing and when it is desired to make use thereof, a floating vessel can be provided with means for locating and attaching to the upper end thereof. One such means is shown in elevation in FIG. 1 and in sectional elevation in FIG. 5.

Vessel 14 (FIG. 1) has a central well 40 through which a tubular column 41 may be suspended from a working structure 42. The superstructure of the vessel together with the conventionally required drilling equipment such as rotary table, derrick, pipe stacks, draw works, etc. form no part of the invention and are not illustrated. A cylindrical union 44 is telescopically supported in the lower end of the column 41 and provides means for attachment to a longitudinally adjustable sleeve 45 mounted on the upper end of casing 16. The uppermost buoyancy chamber 34 is sealed off at the upper end of the casing 16 as by the sealing cap 46 and the sleeve 45 is mounted concentrically around this chamber 34. The lower end of the sleeve carries a seal 48 slidable on the buoyancy chamber 34 and this chamber carries a seal 49 adjacent its upper end and upon which the sleeve 45 may slide. The two seals not only provide an intervening annular air space but serve the additional function of positioning the sleeve concentrically around the chamber 34.

The upper end of sleeve 45 is provided with a frustoconical flange 50 for attachment to a mating flange 51 formed on the lower end of the union 44.

A line 54 is connected to the lower end of sleeve 45 and, as illustrated in FIG. 1, may be connected to a source (not shown) of compressed air or hydraulic fluid on the vessel. When the vessel is moved away from the casing the line may conveniently be supported by a marker buoy (not shown) left to mark the location of the submerged casing.

Sleeve 45 is illustrated in FIG. 5 in the retracted or submerged position in which condition it is normally provided with a watertight cap 55. An inner tubing string 56 terminating in a blow-out preventer 57 is shown disposed in casing 16 and extending upwardly to a point adjacent the upper end of the submerged sleeve.

When it is desired to engage the submerged system from an overlying floating vessel it is the practice to initially pick up the buoyed air hose. By introducing fluid under pressure into the hose, sleeve 45 is forced to a position of maximum submersion and the vessel is floated and anchored in position over the casing. The pressure is then relieved from the annulus formed between sleeve 45, chamber 34 and the two seals 48, 49, whereby the buoyant effect of the air trapped in the upper portion of the sleeve, if air is the fluid employed, raises it until contact is made with the union 44. If the sleeve is submerged by hydraulic means it can be separately buoyed to bring it into engageable position. When it is desired to cast off, the connection with union 44 is released and sleeve 45 is retracted from the vessel bottom by again introducing compressed fluid into the sleeve annulus to force the sleeve into position of maximum submersion.

Other means may be provided and developed for making necessary connection between the buoyantly supported casing and a floating vessel. It must be remembered that on occasion such as in the event of sudden storms, quick disconnection with a minimum of danger to personnel and equipment is important. The system illustrated in FIG. 5 meets this requirement.

To avoid bending any portion of the casing 16 beyond its elastic limit, it is important that all portions of its buoyant length be free to flex so as to avoid localized application of an exaggerated deflecting force. To permit free flexure of the casing 16 throughout that portion of its length provided with longitudinally spaced concentric buoyancy pods, these pods are slidably supported thereon. One means for so doing is illustrated in the enlarged sectional elevation of FIG. 6 taken on the line 6—6 of FIG. 1.

This figure shows the upper portion of pod 28 and the lower portion of pod 29 as affixed to the casing 16. Pod 28 is provided with a bell cap 60 which carries a concentric stuffing box 61 having an O ring 62 sealed therein and bearing against the circumference of the casing 16. An annular lock ring 63 is affixed to the casing and provides means against which the stuffing box 61 of the pod 28 bears and through which the buoyancy afforded by the pod 28 is transmitted to the casing 16. Pod 29 immediately above pod 28 is provided at its lower end with a similar annular stuffing box 64 housing a sealing ring 65. The upper and lower ends of the successive pods may be constructed respectively as the upper end of pod 28 and the lower end of pod 29.

An alternative embodiment of the invention is shown schematically in elevation in FIG. 7. In this figure a casing 70 is anchored to a marine bottom 71 as by anchoring means 72 and guyed intermediate its lower and upper ends by guy lines 73, 74 and additional guy lines if desired connected to the casing 70 at a shackle 75. The guy line 73 is shown anchored simply by a fixed anchoring means 76 which is a satisfactory alternative to the guy anchoring means shown in FIG. 1. The upper end of the casing 70 is connected to a vessel 78 floating on the marine surface 79, as for example in the manner shown in FIG. 5.

The casing is provided above the shackle 75 with a plurality of buoyancy pods 80, 81, 82, 83, 84, 85 which progressively diminish in buoyant volume and circumference upwardly from the lower pod 80. The embodiment shown in FIG. 7 is substantially the same as that shown in FIG. 1 in principle, differing therefrom in the specific nature of the buoyancy pods.

Pod 80 consists of a cylinder 88 open at its lower end and provided at its upper end with a bell cap 89 affixed around the casing 70. The cap 89 may be rigidly affixed to the casing or may be attached thereto by means of a sealing arrangement of the type used with pod 28 in FIG. 6. The succeeding pods 81, 82, 83, etc. are similarly constructed. In this embodiment conduit means are provided connecting the lower end of each pod with the lower end of the succeeding overlying pod. Thus, conduit 90 communicates between a lower portion of pod 80 and the lower portion of the succeeding overlying pod 81, and conduit 91 communicates between a lower portion of pod 81 and a lower portion of the immediately adjacent overlying pod 28 and so on up the casing.

A source of compressed air (not shown) located on the floating vessel 78 is connected through a conduit 92 to supply air under pressure to the lower end of the lowermost pod 80 and a return line 93 connects the uppermost pod 85 back to the compressed air source. By means of this compressed air source the buoyancy of the pods may be maintained with continual or periodic introduction of air to compensate for solution thereof in the ocean water. The conduits interconnecting the several pods are so arranged with respect to the position of inlets and outlets that a given pod is substantially filled with air to the level of its side outlet before any appreciable volume of air flows through such side outlet.

This arrangement has the advantage that there is no possibility of or concern with leakage of ocean water into sealed pods.

A different embodiment of the invention particularly adapted for water several hundred feet deep is shown in FIGS. 8, 9 and 10. In this embodiment a casing 100 is again anchored to a marine bottom 101 by suitable anchor means 102 shown schematically in the drawing. At the upper end of the casing 100 and at a safe distance below surface 103 of the water body, an enlarged truss 104 is secured to and extends laterally outwardly from the casing. Truss 104 is preferably an open framework offering very little resistance to current or wave action and to which a plurality of buoyancy chambers 105, 106, 107, 108 are mounted. The truss serves the purpose of supporting the buoyancy chambers outwardly from the casing 100 sufficiently to permit operations through the casing without interference from these chambers. Such operations may take the form of oil production as through a Christmas tree 110 schematically illustrated, or drilling operations as from a floating vessel (not shown) in the manner described with relation to FIGS. 1 and 7.

The buoyancy chambers 105, 106, 107 and 108 are preferably flexibly attached to the truss 104 as by means of cables 105A, 106A etc. so that their response to ocean currents and wave action is not transmitted in its entirety to the truss. Again to limit deflection of the casing 100 within its elastic limit, guy means are provided in the form of at least three guy lines 112, 113, 114. As illustrated, guy line 112 may be carried through a sheave 116 supported at the marine bottom by an anchor means 117 and up to a surface float (not shown) in the manner of the guying arrangement shown in FIG. 1.

The response of the system shown in FIGS. 8 and 9 to wave and current action is shown in the reduced scale view of FIG. 10. The first result of such water force is primarily the displacement of the buoyancy chambers, of which chambers 105 and 106 are shown, under the latitude of the flexible connection of these chambers to the truss 104, and secondarily, displacement of the truss itself due to water action on the casing and on the truss independent of the surface area of the buoyant chamber. Additional thrust results primarily in further displacement of the truss as illustrated provided only that such displacement will not exceed the limitations placed thereon by the guy lines 112, 113 and 114.

The arrangement shown in FIGS. 8, 9 and 10 is particularly advantageous from a maintenance standpoint where very deep water is encountered. The buoyancy chambers as well as the means supporting the buoyancy chambers are all within ready access of a diver, as for example approximately 35 feet below mean low water level. Moreover, the truss 104 can serve as a convenient stage upon which a diver may carry out the maintenance of the Christmas tree 110 or of blow-out preventers, circulating head and the like in case drilling operations are being conducted.

A still further embodiment of the invention is shown in FIG. 11. This embodiment has the advantage of avoiding the need for any guy lines whatsoever. A casing 120 is again anchored to a marine bottom 121 by an anchoring means 122. In this embodiment the casing 120 is provided with a continuous series of closely spaced buoyancy pods 123, 124, 125, etc. extending from adjacent the anchoring means 122 to the upper end of the casing, terminating just below the water surface 126. In this instance the buoyancy pod 123 is of relatively large diameter and small longitudinal extension with succeeding pods being of progressively decreasing diameter and increasing longitudinal extension. In this manner the vertical component of buoyancy, which acts to resist to a certain extent the horizontal component of deflecting action of waves and current, is distributed along the casing so that a maximum deflection thereof takes the form of the dotted line X, which in no case exceeds the elastic limit of the casing material. This is true even in the absence of any limiting guying means anywhere along the extension of the casing. The buoyancy pods 123, 124 etc. may be of the type shown in FIGS. 1 and 6 or, alternatively, of the type shown in FIG. 7.

For all practical purposes the invention brings the bottom of the ocean up close to the surface for oil exploration and drilling operations. Deep water maintenance and associated problems are greatly minimized and in fact in certain embodiments substantially eliminated. At the same time, these results are made possible by reason of the fact that the elongated casing is supported by distributed buoyancy means. As a result, wave and current action attendant in operations in large bodies of water are effectively tolerated.

We claim:

1. A buoyantly supported casing extending upwardly from the bottom of an open water body comprising a generally upright, elongated and laterally flexible tubular member, means anchoring the lower end of the tubular member to the bottom, a plurality of separate buoyancy chambers disposed a substantial distance below the water surface, and means for connecting the buoyancy chambers to the tubular member at longitudinally spaced points, the separate buoyancy chambers being of progressively greater buoyancy per unit length in a direction along the longitudinal axis of the member with increasing water depth.

2. A buoyantly supported casing extending upwardly from the bottom of an open water body comprising a generally upright, elongated and laterally flexible tubular member, means anchoring the lower end of the tubular member to the bottom, a plurality of annular and separate buoyancy chambers longitudinally disposed along and concentrically around the tubular member a substantial distance below the water surface, and means for connecting the buoyancy chambers to the tubular members at longitudinally spaced points, the separate buoyancy chambers being of progressively greater buoyancy per unit length in a direection along the longitudinal axis of the tubular member with increasing water depth.

3. A buoyantly supported casing extending upwardly from the bottom of an open water body comprising a generally upright, elongated and laterally flexible tubular member, means anchoring the lower end of the tubular member to the bottom, a plurality of separate buoyancy chambers disposed a substantial distance below the water surface, and means for connecting the buoyancy cham-

bers to the tubular member at longitudinally spaced points, the separate buoyancy chambers being progressively of greater buoyancy per unit length in a direction along the longitudinal axis of the tubular member with increasing water depth, and being progressively greater in dimension in the direction of the longitudinal axis of the tubular member from the bottom to the top chamber.

References Cited in the file of this patent

UNITED STATES PATENTS

1,332,384	Dray	Mar. 2, 1920
1,636,447	Standish	July 19, 1927
1,660,714	Lincoln	Feb. 28, 1928
1,712,803	Wood	May 14, 1929
1,746,132	Stokes	Feb. 4, 1930
1,764,488	Zublin	June 17, 1930
1,957,622	Visnyei	May 8, 1934
2,019,059	Sherman	Oct. 29, 1935
2,171,672	Plummer	Sept. 5, 1939
2,187,871	Voorhees	Jan. 30, 1940
2,383,840	Benckert	Aug. 28, 1945
2,399,656	Armstrong	May 7, 1946
2,419,053	Bennett	Apr. 15, 1947
2,476,309	Lang	July 19, 1949
2,512,783	Tucker	June 27, 1950
2,606,003	McNeill	Aug. 5, 1952
2,610,028	Smith	Sept. 9, 1952
2,783,027	Gilbert	Feb. 26, 1957

OTHER REFERENCES

Oil Weekly of August 2, 1946, pages 60 to 66.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,017,934 January 23, 1962

Aaron D. Rhodes et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 61, for "according" read -- accordance --; column 2, line 13, for "treees" read -- trees --; column 3, line 72, for "in" read -- is --; column 4, line 66, for "apporached" read -- approached --; column 5, line 41, for "to" read -- or --; column 8, line 11, for "Thlis" read -- This --; line 67, for "direection" read -- direction --.

Signed and sealed this 26th day of June 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,017,934 January 23, 1962

Aaron D. Rhodes et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 61, for "according" read -- accordance --; column 2, line 13, for "treees" read -- trees --; column 3, line 72, for "in" read -- is --; column 4, line 66, for "apporached" read -- approached --; column 5, line 41, for "to" read -- or --; column 8, line 11, for "Thlis" read -- This --; line 67, for "direection" read -- direction --.

Signed and sealed this 26th day of June 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
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