Nov. 8, 1966 N. POTTORF 3,283,515

MARINE STRUCTURE

Filed April 15, 1964 2 Sheets-Sheet 1

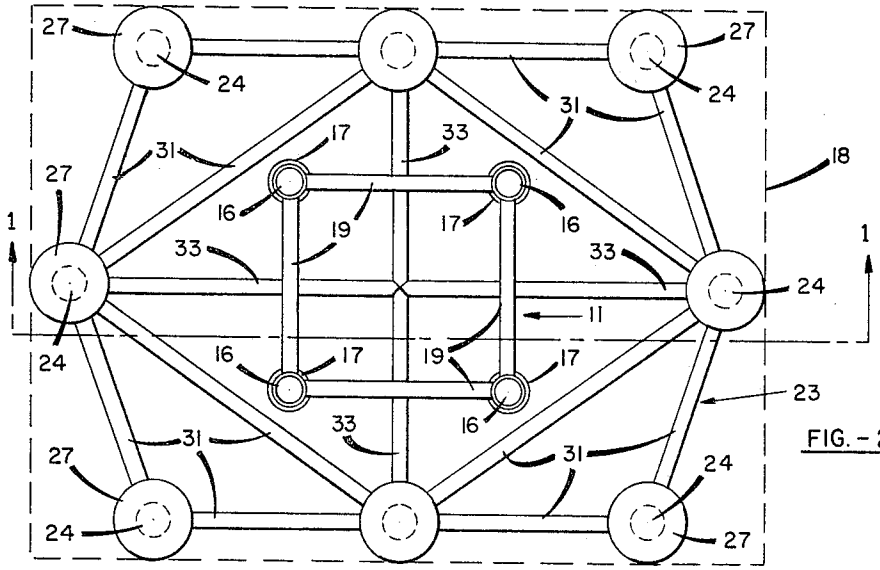


FIG. - 2

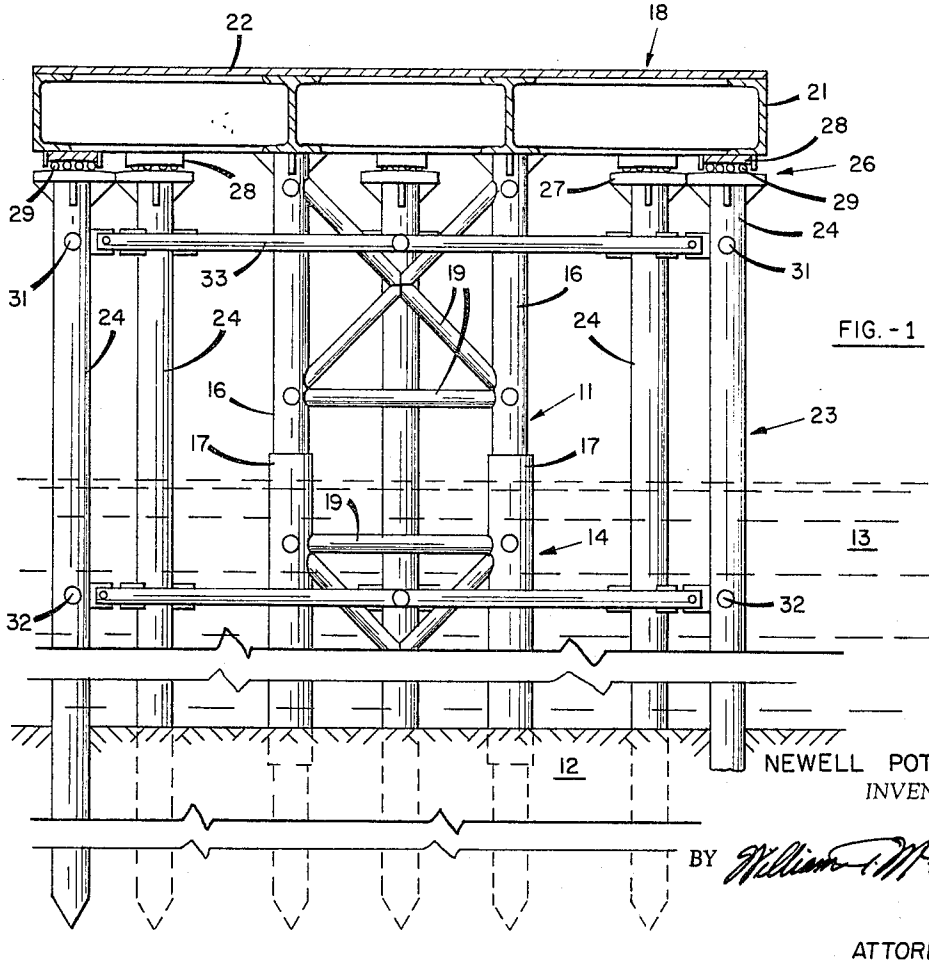


FIG. - 1

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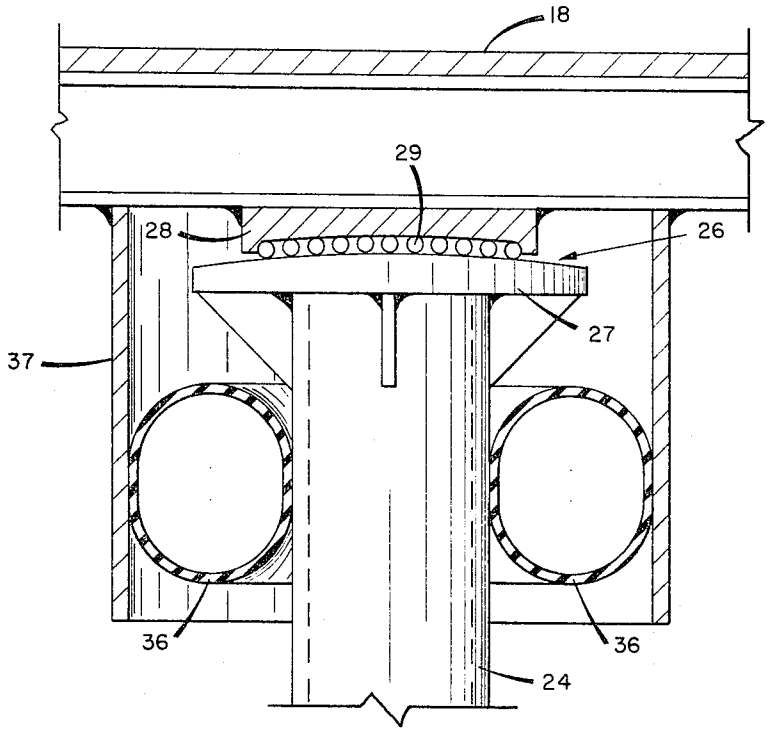


FIG. -3

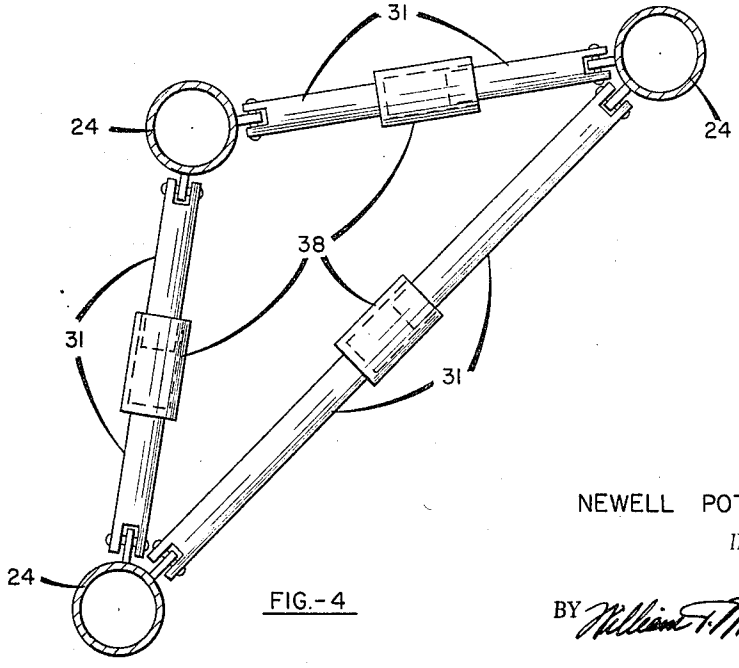


FIG. -4

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MARINE STRUCTURE

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6 Claims. (Cl. 61—46)

This invention relates to offshore structures, and more particularly it relates to offshore platforms such as those employed in the drilling and producing of oil and gas wells. More specifically, the invention is concerned with a marine structure for withstanding forces imposed upon the structure by large floating objects, such as moving sheets or masses of ice.

With the advent of offshore petroleum operations a multitude of problems and expensive necessities has arisen in connection with marine equipment employed in the drilling and producing of offshore wells. One of the main equipment items involved is the structure which supports the equipment employed in these operations. In many instances it is desirable to employ a fixed structure supported by the formation underlying the body of water in which operations are conducted. Heretofore, various fixed drilling and production platforms have been designed and constructed. Such platforms generally are designed to support the gravity loads normally to be expected to be imposed on them, as well as the lateral loads resulting from currents, waves and wind. The design of such structures is quite complex and involves rigorous engineering analyses and calculations. The marine platforms built for such use have generally proven satisfactory for use in areas where only gravity loads and water and wind affect the structure.

In certain areas of the world, however, oil and gas operations are being carried out in waters where, at least in certain seasons, large masses of moving ice must be contended with. Typically, large sheets of ice, as much as one-half mile or so wide and several feet thick, are carried by currents at considerable velocities. In addition thicker, more compact pieces weighing several hundred tons move with the current. Such moving ice imposes upon a marine structure not only static loads but also impact loads which may cause serious permanent damage to a marine structure. Generally speaking, it is feasible to design for such static loading of a marine structure, but a satisfactory design including impact loading has not heretofore been proposed. Regarding the impact loading, one criterion which has been proposed is that the structure be capable of withstanding approximately 1,000 tons of ice moving at a speed of six knots, without failure of the structure. During normal operations, personnel and equipment on a platform are exposed to the hazards of vibrations resulting from the force of moving ice pushing against the platform. For example, such vibrations may make it practically impossible for the personnel to move about on the platform without being thrown overboard, or where equipment such as a wellhead conducting high pressure hydrocarbon fluids is connected to the platform, these vibrations may cause damage to such equipment with the resultant failure and exposure to serious hazards.

A typical marine structure of the above type may comprise three principal components: (1) a jacket or template, (2) piling for supporting the structure, and (3) the deck section. The template may be fabricated ashore from vertical tubular sections spaced on a convenient module and tied together by trusses. Typically, the prefabricated template is lowered from a barge to the ocean bottom and extends from the mud line to a point just above the water level. Steel pilings having a diameter

slightly smaller than the legs of the template may be driven down through the legs into the ocean bottom to a depth adequate to carry the load imposed upon the entire structure. The piling normally extends some distance above the high water level and serves to support the deck member above the highest water level expected.

If a rigid marine structure were designed to resist the steady force of moving sheets of ice, as well as impacts from heavy ice masses, the cost of such a structure would be prohibitively high, and it is quite likely that it would not be feasible to design such a structure which would be free from excessive vibrations.

The general object of the present invention is a marine structure which is capable of withstanding the forces and impacts of large floating objects, especially moving sheets or pieces of ice. A more specific object of the invention is a marine structure capable of withstanding the loading of extensive ice sheets without excessive motion or vibrations, while also withstanding the impact of thick, massive pieces of ice. A further object is such a structure in which vibrations caused by such floating objects are minimized. Still, a further object of the invention is a marine platform for supporting well equipment and personnel with a minimum hazard when exposed to flowing ice. Still another object of the invention is such a marine structure which is of practical and economical construction. Other objects of the invention will become apparent by reference to the following description of the invention.

Briefly, the present invention comprises a deck member supported by a relatively rigid inner support member having its lower end affixed to a formation underlying a body of water, and an outer flexible support member affixed to the underwater formation and having an upper end movably connected to the deck member to provide vertical support therefor while permitting lateral movement at its upper end. Typically, the inner support member comprises a plurality of piles driven through the legs of a template into the formation to provide a supporting member for the deck capable of withsanding the forces of the water, wind and relatively small pieces of floating ice with no significant movement. The outer support member typically comprises a ring of spaced-apart, flexible vertical support members encircling the inner support member and each affixed at its lower end to the underlying formation. The upper end contacts the deck through a bearing member which permits lateral movement of the upper end of each of the members so that lateral vibrations of these members are not transmitted to the inner support member and the deck member. Advantageously, means are provided for limiting the lateral movement of the outer vertical members with respect to the deck member.

In one embodiment, means are provided for damping the vibrations of the outer vertical members, and in another embodiment, the outer vertical members are structurally interconnected to provide additional strength and stiffness over that obtainable from the independent members.

The present invention will be better understood by reference to the following description of a preferred embodiment thereof, taken in connection with the accompanying drawings wherein:

FIGURE 1 is illustrative of an elevational view, in partial cross section, of a marine structure according to the invention,

FIGURE 2 illustrates a plan view of the structure of FIGURE 1 with the deck removed,

FIGURE 3 illustrates one embodiment of apparatus for connecting the outer support members to a deck member, and

FIGURE 4 illustrates one arrangement for resiliently interconnecting the guard pilings.

Referring to FIGURES 1 and 2, the inner support member **11** is positioned vertically with its lower end securely affixed to the formation **12** underlying the body of water **13** in which the platform is located. Typically, the inner support member comprises a template **14** which is lowered through the water to rest on the bottom, with piles driven through the legs of the template into the formation. The template may be a relatively simple structure (as shown) or may comprise a relatively large number of modules providing the desired structural stability and covering a desired area. Typically, piles **16** are driven through the template legs **17** and through the sediment and rock on the bottom to a depth sufficient to provide satisfactory vertical and lateral stability. The piles extend upwardly above the template to a height above the water level sufficient to elevate the deck **18** above the highest expected level of the water. The beams of the deck member preferably are rigidly connected to the uppermost end of the inner piles, as by welding, and the inner support member is centrally located in respect of the deck. The inner support member typically is designated to withstand the forces of waves and currents, as well as wind and relatively small floating objects. The inner support member provides the main vertical support for the deck. However, it is not necessary that this structure be designed to withstand the impacts of thick, massive pieces of floating ice. If desired, the template legs and/or pilings of the inner support member are structurally interconnected by braces or trusses **19** to provide the desired strength and stability for this member. It is to be understood that, as used herein, the term "inner support member" refers to the above-described template-piling structure or pilings alone may be employed; and the inner support member may comprise any suitable number of pilings or template modules providing a relatively rigid supporting structure for the deck.

Typically, the deck **18** is constructed of heavy structural members **21**, such as H or I beams forming supporting joists and covered by continuous panels of decking **22** forming the desired working area of the platform. The platform may be of any design suitable for the intended purpose. For example, it may be desired that the platform support a derrick and other associated drilling equipment, in which case the platform will be relatively large and capable of supporting very heavy loads. On the other hand, the platform may be employed as a production platform, in which case it may be much smaller and lighter in weight.

Surrounding the inner support member **14** is an outer support member **23**, preferably comprising a group of spaced protective members such as guard piles **24** forming a protective ring around the inner support member. Typically, the spaced protective members are guard piles driven into the formation underlying the body of water and extending above the level of the water. The design and spacing of the guard pilings may vary considerably, depending upon the particular installation, and the spacing is such as to prevent thick, massive pieces of floating ice from passing between the guard piles and striking the inner support member. A typical arrangement might comprise 36-inch diameter x 2-inch guard piles on approximately 15-foot centers. Sheet ice loading is not as exacting as that imposed by thick massive pieces. The 15-foot spacing mentioned will prevent masses of excessive size from impacting upon the inner support member. As an added benefit, spacing as above will provide some reduction in the force exerted on the inner support by the portions of extensive sheets passing between the guard piles. Observations indicate that the force on the inner support will be reduced if the open space between guard piles is less than eight times, and preferably less than six times, the width of the inner support structure. Each guard pile is provided adjacent its upper end with a bearing member **26** in contact with the underside of the deck to provide additional vertical support for the deck. These bearing members advantageously include a heavy bearing plate **27** securely attached to the upper end of the guard pile and a similar plate **28** on the bottom side of the deck. Roller bearings **29**, such as ball bearings, are retained in a race between the two bearing plates to permit lateral movement of the upper end of the guard piles with respect to the deck, while at the same time providing vertical support for the outer extremities of the deck. While roller bearings are preferred, in some instances it may be found satisfactory to merely provide lubrication between the bearing plates. The bearing plates may be provided with a slight curvature, of a radius approximately equal to the distance between the bearing plate and the pivot point of the flexible piling, e.g., the mud line or other fixed point about which the guard piling may bend when struck by thick massive pieces of ice.

The guard pilings preferably are designed to permit bending and flexure when struck by a large heavy mass of floating ice, and they need not be designed to withstand the impact of such masses of ice without vibrating. When a large mass of floating ice strikes one or more of the guard piles, the guard pile flexes with the impact and bends to a limited degree about a fixed point below the water level. At the same time the floating sheet of ice generally will be sheared and broken into smaller pieces, depending upon the spacing of the guard pilings, and these smaller pieces may move on through the structure without damage to the inner support member. The amplitude and frequency of vibration of the guard pilings will depend upon the velocity and characteristics of the moving ice, as well as the structural characteristics of the piling. Advantageously, the guard piles are designed to provide as small a diameter as possible, consistent with the necessary bending strength, since the smaller the diameter of the guard piles, the more readily a large mass of ice is cleaved and broken up upon striking the guard pilings.

As shown in the drawings, it may be found advantageous to structurally interconnect the resilient guard piles by linking members. For example, one set of interconnecting horizontal members **31** may be located above the level of the water and ice, with a lower set of similar members **32** located beneath the level of the water at a point not subjected to the ice forces. In this manner, when one pile is struck by a moving ice sheet the other piles help it to withstand the impact of the ice. Preferably, the horizontal interconnecting members are affixed to groups of three or more guard pilings as shown, to bear mainly compressional loads resulting from impact with the ice. Advantageously, the piles at the extreme ends of the structure are interconnected by horizontal tension members **33** to provide additional strength to the groups of interconnected guard piles. Thus, when one or a few of the guard piles in the protective ring are struck by a large mass of ice, the protective ring flexes as a unit, but the combined strength of the pilings forming the ring will be much greater than the strength of any one piling standing alone.

As shown in the drawings, the guard piles preferably are provided with a means for damping the vibrations resulting from impact with the floating ice. One means of accomplishing such damping is to provide, near the upper end of each of the guard pilings, a resilient member, such as an inflated rubber donut or tire or a pneumatic shock absorber arrangement to absorb and cushion the major horizontal shock forces, while still providing some lateral support for the pile. Typically, as shown in FIGURE 3, an inflated rubber donut **36** encircles the upper end of a guard piling **24** and is positioned between the piling and a circular skirt **37** depending from the lower side of the deck **18**. Alternatively, the guard pile may be positioned inside of an enclosed caisson affixed to the ocean bottom and extending upwardly to a point below the water level, with hydraulic or pneumatic fluid maintained between the piling and the caisson to provide a dash-pot action to dampen the vibration of the piling. In such an arrange-

ment perforated vanes may be employed to increase damping. Alternatively, loosely packed particles of gravel or the like may be employed to achieve the damping effect.

It may be found advantageous to resiliently interconnect all or a portion of the guard pilings rather than rigidly connecting the pilings. In such an instance a resilient unit **38** such as a pneumatic or hydraulic piston and cylinder, or a suitable spring device may be employed in either or both of the upper or lower horizontal linking members, between the guard pilings, to provide the desired interconnection of the guard pilings so that at least a portion of the shock loading resulting from impact is absorbed in such a unit when a piling is struck by moving ice.

From the foregoing description of preferred apparatus according to the present invention, various alternative details of construction will become apparent to the artisan without departing from the spirit and scope of the present invention. For example, a structure of the type described may be employed as an anchorage for large vessels in rough water. Also, in view of the low probability of impact with large massive pieces of ice, the guard pilings may be designed to be expendable upon being struck by such ice, and damaged pilings may be replaced if severely damaged.

I claim:

1. A marine structure comprising

a vertical inner support member having its lower end affixed to a formation underlying a body of water and an upper end extending above the level of said water;

a horizontal deck member positioned above the level of said water and affixedly attached to said inner member adjacent the upper end thereof;

a vertical outer protective means encircling said inner support member, the lower end of said protective means being affixed to said formation and the upper end thereof extending above the level of said water;

vertical load transfer connecting means movably connecting said deck member to said outer protective means to provide vertical support for said deck member while permitting lateral movement of said outer protective means relative to said deck member.

2. The structure of claim **1** wherein said protective means includes a plurality of vertical protective members and wherein said vertical load transfer connecting means includes a plurality of bearing members connecting said protective members to said deck member, said bearing members permitting lateral movement of the upper ends of said protective members with respect to said deck member.

3. The apparatus of claim **2** wherein said bearing members comprise roller bearings.

4. The apparatus of claim **2** including a skirt member depending from said deck adjacent each of said protective members and spaced therefrom, and resilient means positioned between said skirt member and said protective member to dampen vibrations occurring in said protective member.

5. The apparatus of claim **2** including a plurality of horizontal linking members interconnecting at least a portion of said protective members.

6. The structure of claim **5** further including resilient means in said horizontal linking members resiliently connecting said protective members.

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