United States Patent

Blurton et al.

[15] **3,693,729**

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[54] AIR CUSHION DRILLING VEHICLE

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[52] **U.S. Cl.**.....**173/23,** 61/46.5, 114/0.5 D, 180/119, 180/127

[51] **Int. Cl.** **E21b 7/12**

[58] **Field of Search** .....173/23; 180/116, 119, 127; 114/0.5 D; 175/5–10; 61/46.5

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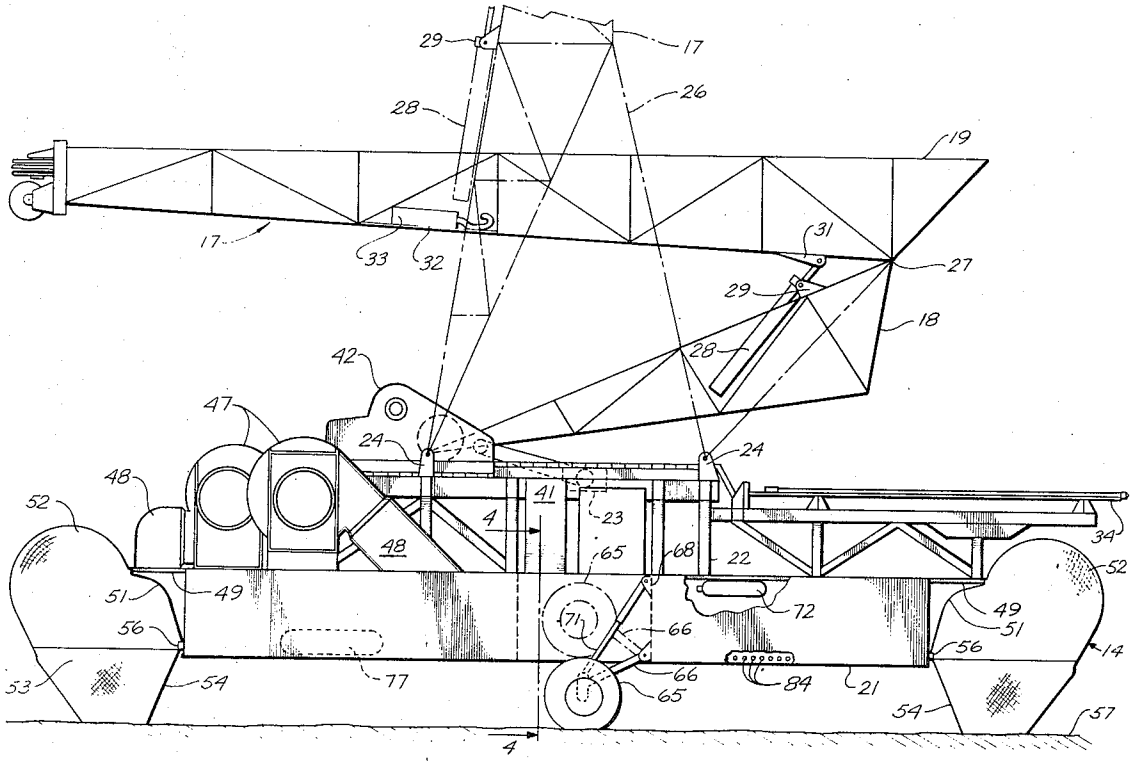
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[57] **ABSTRACT**

An air cushion vehicle particularly useful for a drilling rig for oil wells and the like employed in arctic environments having open water, muskeg, ice, snow, and tundra is described. The vehicle includes a watertight compartmented chassis or platform about which is provided a flexible skirt for cooperation with a surface for minimizing air leakage therebetween. Means are provided on the platform for supplying a volume of air under pressure to the region within the skirt for raising the pressure thereunder and thereby lifting the principal portion of the weight of the platform. Wheels are also provided for resiliently applying a force to the surface on which the vehicle rides to provide sufficient contact with the surface to provide control of the vehicle as it is towed. The means for supplying air comprises blowers selectively connected to prime movers, such as diesel engines, which are also selectively connectable to the draw works of the drill rig. The drill rig also includes a tower foldable between an erect drilling position and a lowered transporting position with the mode of folding such that the transverse center of gravity of the tower is not significantly shifted between these two positions. Means are also described for launching the air cushion vehicle from a ship and for preparing an arctic drilling site for the air cushion supported drilling rig.

12 Claims, 11 Drawing Figures



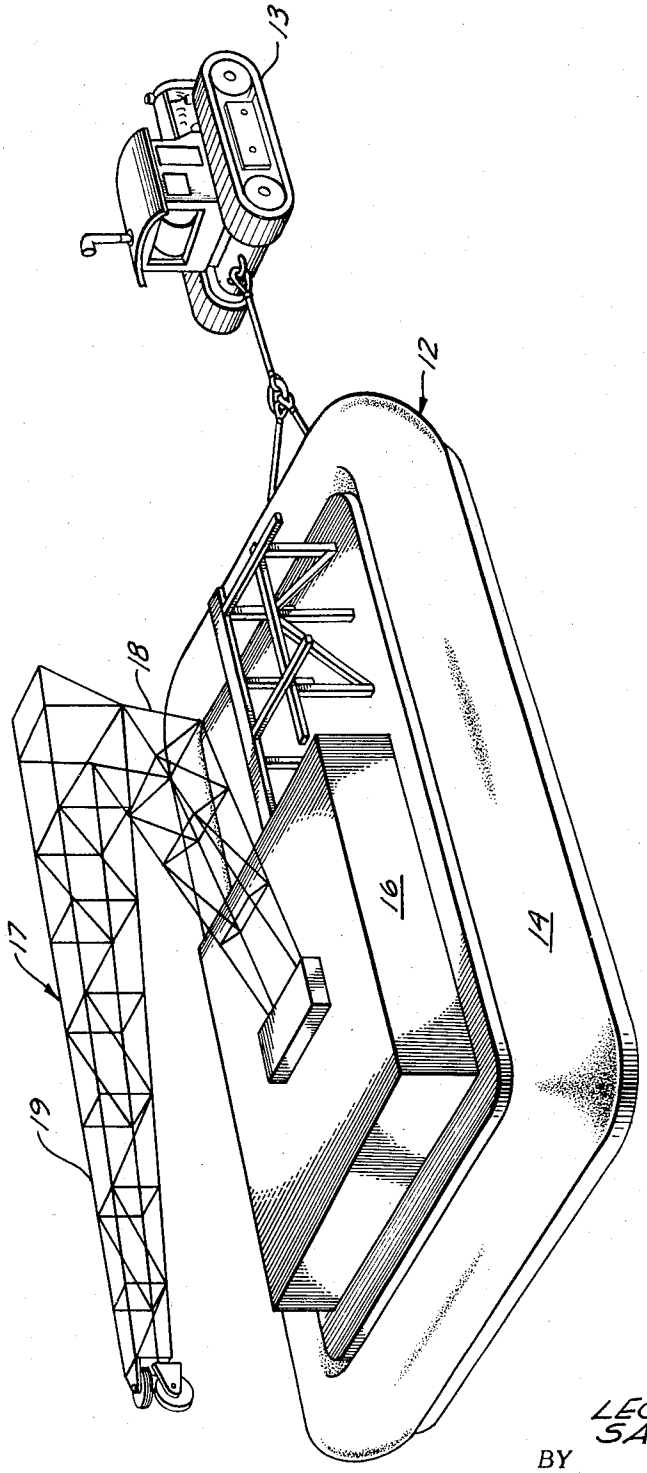


FIG. 1

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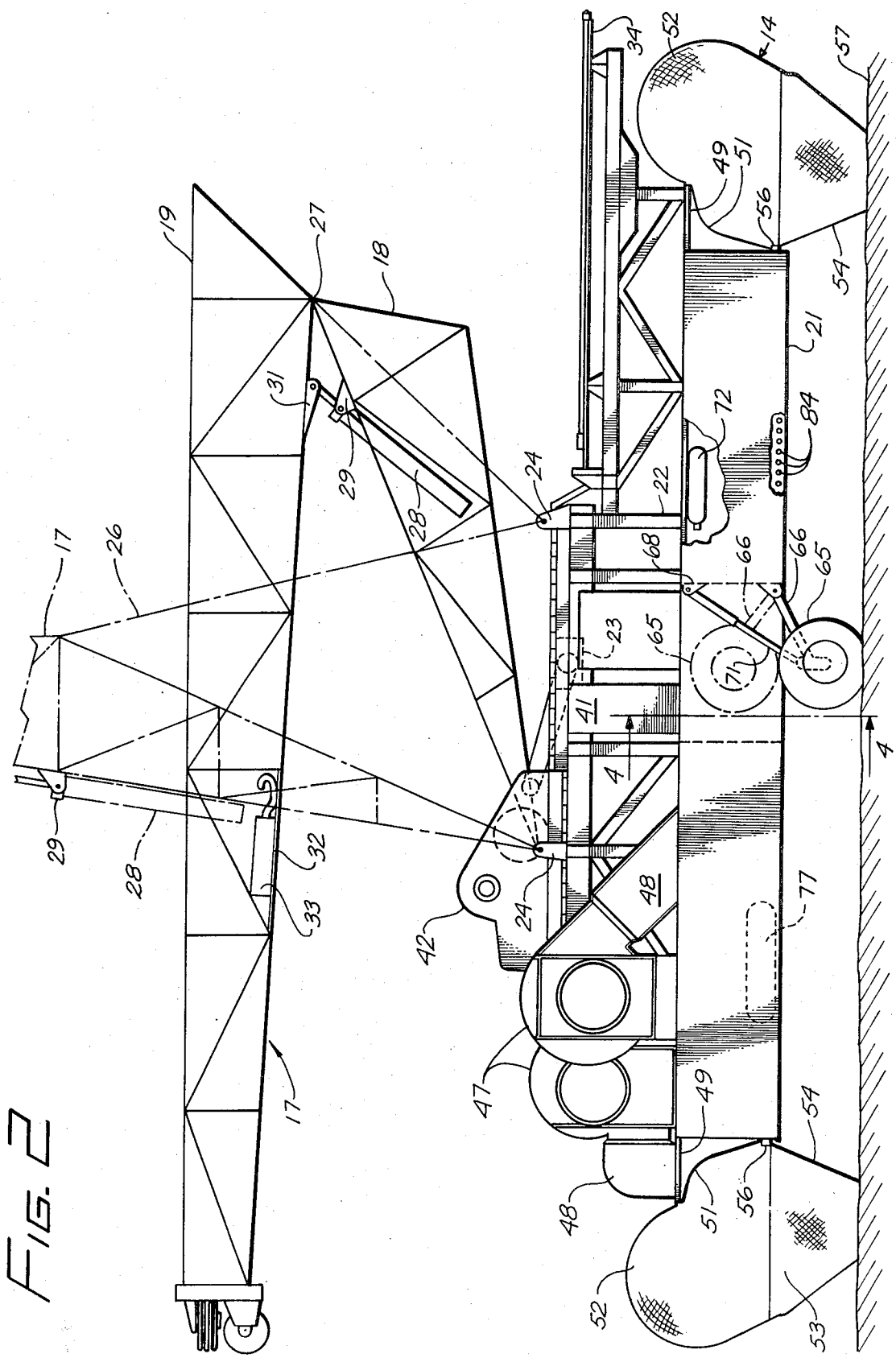

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FIG. 2

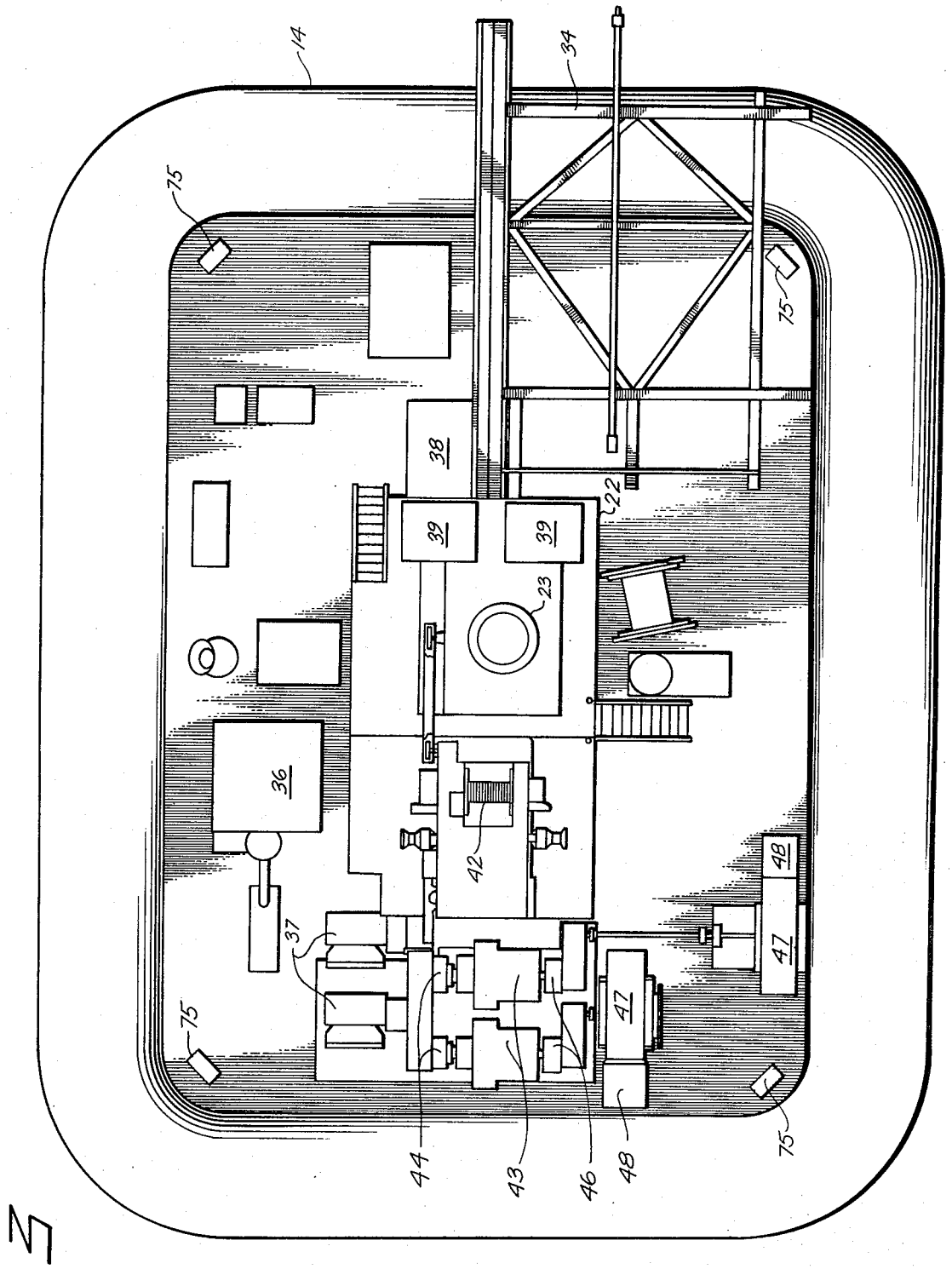


FIG. 3

FIG. 4

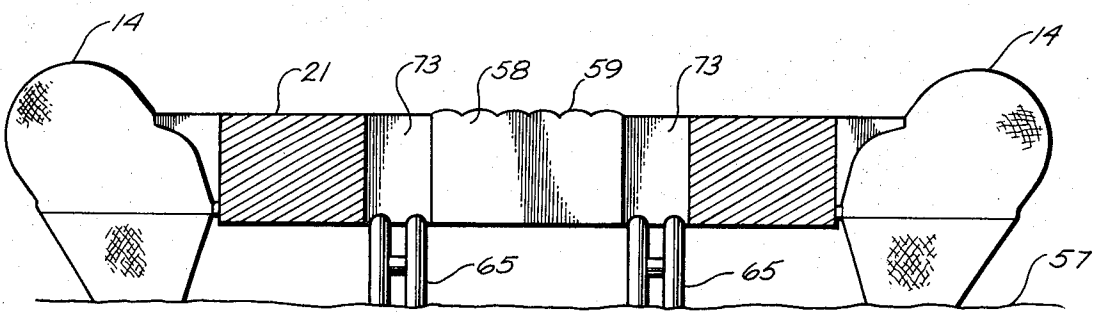


FIG. 5

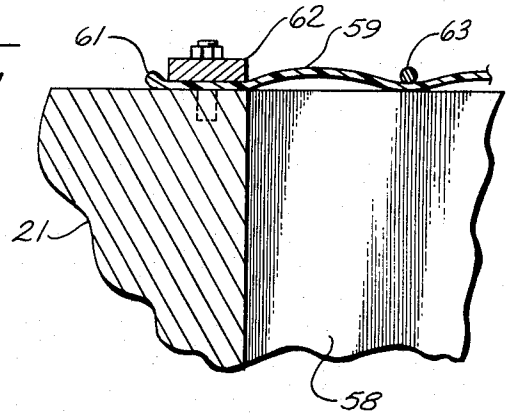
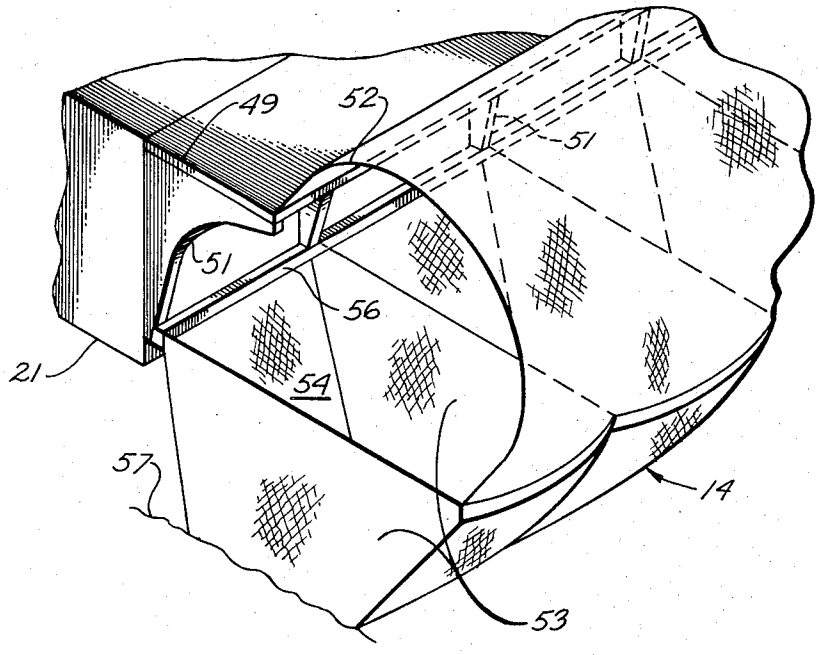


FIG. 7



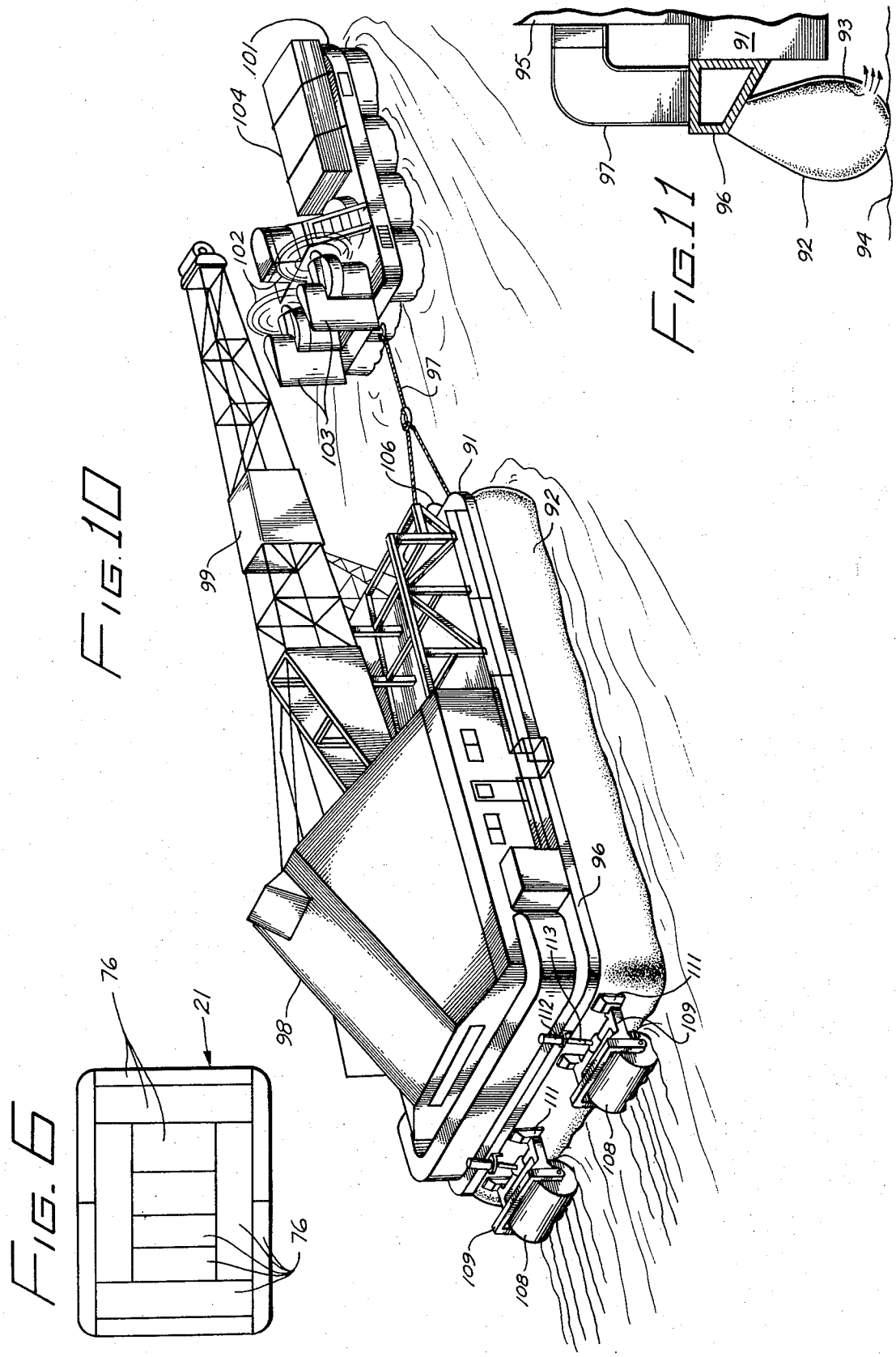


FIG. 10

FIG. 11

FIG. 6

FIG. 8

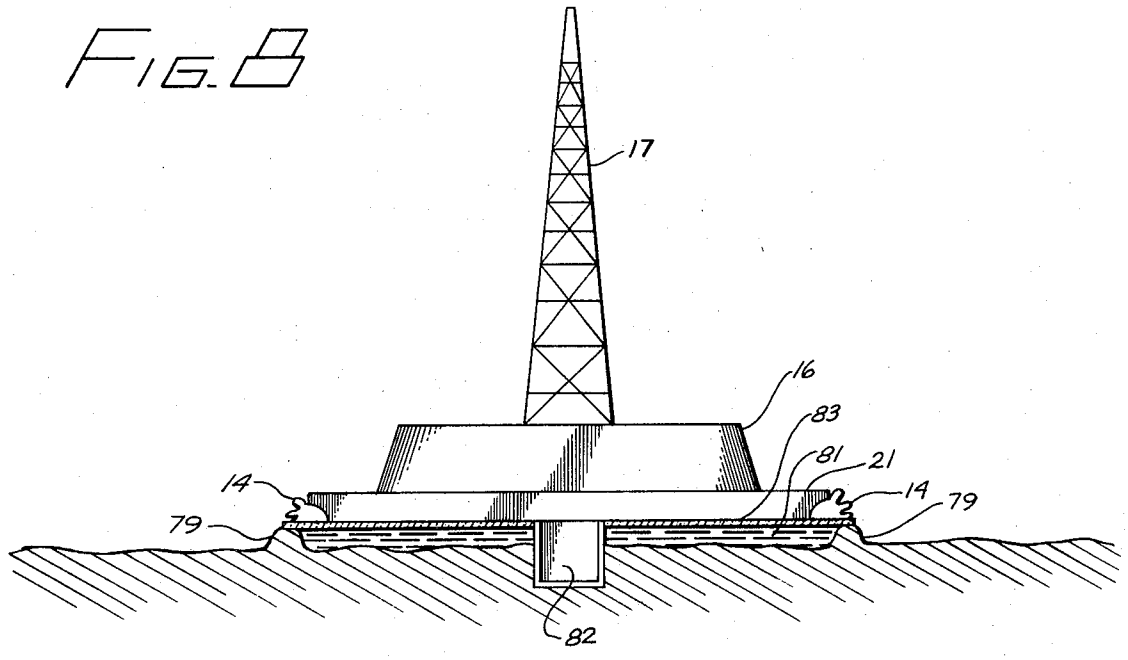
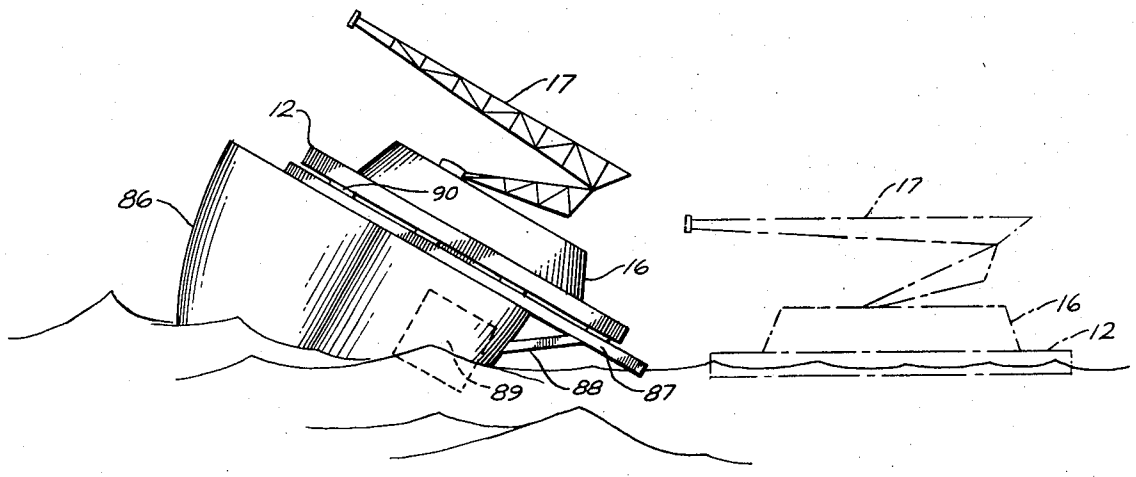


FIG. 9



AIR CUSHION DRILLING VEHICLE

BACKGROUND

In recent years there has been considerable interest and exploration for oil and gas reserves in arctic regions, particularly in Alaska and northern Canada. In order to exploit these established oil and gas reserves, wells must be drilled under quite adverse conditions associated with the low temperatures of the arctic environment. Some of the areas of interest are in water in areas protected from the open sea, and these areas may be open in part of the year and frozen over in other parts of the year. In other regions, a substantially permanent layer of ice is encountered. Snow is found in some regions; and still others are what is known in the arctic as muskeg, which is a boggy marsh unable to support ordinary land vehicles. Other areas of the arctic are tundra, which are open, treeless plains, having a blanket or organic material overlying a permafrost wherein a subsurface portion is permanently frozen and the surface portion is annually thawed to produce a mucky surface soil. Cutting roads through the insulating tundra exposes frozen soil beneath and destructive thawing may occur during the summer season.

Year round transportation over such surfaces is extremely difficult, particularly when the items being transported are heavy and bulky as is the equipment required for drilling oil wells. The techniques that have been employed to date in the arctic have, in the main, used aircraft and helicopters for transporting equipment which must therefore be in relatively small units and assembled at the drilling site. Clearly, weather conditions have a serious adverse effect on such airborne operations, and such transport is quite expensive. As one simple example, an on-site cost for diesel fuel in the arctic may be as much as $2.00 per gallon.

In order to minimize the cost of arctic operations, it is desirable to move a completely assembled drilling unit from drilling site to drilling site. The length of time that a drilling rig is on a site is normally in the order of from about 10 days to about 6 months, with the most usual time being in the range of 2 or 3 months. Clearly, if it is necessary to disassemble and reassemble the drilling unit for transport to a new site with such frequency, a very large item of expense is involved.

One of the principal problems in moving a completely assembled drilling unit in the arctic involves the "-footprint" pressure of the vehicle moving the unit, particularly in areas involving a layer of ice over water, or tundra, or muskeg during the summer months. Because of the very high footprint pressures of an assembled drilling rig, it is completely impractical to move such a rig on wheels, tracks or skies.

An air cushion approach for supporting a heavy mass, such as a drilling unit, with a low footprint pressure has been investigated in the past and discarded due to certain technical objections. Thus, for example, the efficiency of the power plant required for both lifting and propelling a large air cushion vehicle has been so low as to disuade acceptance by industry. Conventionally, the air cushion vehicle is driven by aircraft-type propellers which are noticeably inefficient, and, with the high cost of fuel, use of large vehicles in the arctic may be prohibitive.

The conventional air cushion vehicle is very difficult to maneuver since the air bubble on which it rests is nearly frictionless and directional control of the vehicle is difficult at low speeds. Thus, for example, when the vehicle is on a slope there is little, if anything, to prevent the vehicle from sliding down the slope. Similarly, in a high wind, such as is quite common in the arctic, the vehicle may be blown off its intended path. In order to obtain control of conventional air cushion vehicles, relatively high ground speed has been employed so that a substantial volume of air moves over control surfaces and the vehicle is essentially flown like an airplane and control may be lost at low speed when the velocity of airflow over control surfaces drops off. Travel at sufficient speed to maintain control over the unpredictable terrain of the arctic is dangerous since passage over rough ground or water, or open leads in the ice or the like, may cause loss of the air cushion, quickly resulting in a crash of the vehicle. Such crashes of conventional vehicles have resulted in loss of life of the operator and passengers.

It is, therefore, desirable to provide a relatively low cost assembled drilling rig on an air cushioned vehicle capable of being controlled at low speeds in an arctic environment.

BRIEF SUMMARY OF THE INVENTION

Therefore, there is provided in practice of this invention according to a preferred embodiment an air cushion vehicle including a chassis or platform for carrying a load such as a conventional assembled drilling rig and having a flexible skirt around the periphery of the platform for cooperation with a surface over which the vehicle is moved for minimizing airflow therebetween. Means are provided for supplying pressurized air within the skirt for maintaining sufficient pressure to support the weight of the vehicle, and means are provided for resiliently engaging the surface with sufficient force and friction for maintaining control

DRAWINGS

These and many other features and advantages of this invention will be appreciated as the same becomes better understood by reference to the following detailed description of a presently preferred embodiment when considered in connection with the accompanying drawings wherein:

FIG. 1 illustrates in perspective a drilling rig being transported on an air cushion vehicle constructed according to principles of this invention;

FIG. 2 is a side partial cross section of the apparatus of FIG. 1;

FIG. 3 is a top view of the apparatus of FIG. 1;

FIG. 4 is a schematic transverse cross section of the apparatus of FIG. 1;

FIG. 5 is a detail of a seal on the drill well of the apparatus of FIG. 1;

FIG. 6 shows schematically the modular construction of the apparatus of FIG. 1;

FIG. 10 is a perspective view of a second embodiment of a combined drilling rig and air cushion vehicle; and

FIG. 7 is a detail of the skirt region of the vehicle of FIG. 1;

FIG. 8 is a schematic view of a combined drilling rig and air cushion vehicle on a prepared drilling site;

FIG. 9 illustrates schematically means for launching an air cushion vehicle from a transporting ship;

FIG. 11 is a detail of the skirt of the vehicle of FIG. 10.

Throughout the drawings like reference numerals refer to like parts.

DESCRIPTION

FIG. 1 illustrates in perspective a combined drilling rig and air cushion vehicle constructed according to principles of this invention. As illustrated in this embodiment, a vehicle **12** is being towed by a conventional tractor **13** across an ice field or other arctic terrain. Surrounding the vehicle **12** is a flexible skirt **14** described in greater detail hereinafter within which a large volume of air at increased pressure is pumped in order to lift the vehicle on a cushion of air trapped within the skirt. A shelter **16** on the main deck of the vehicle provides a habitable environment for workmen on the drill rig and protects drilling equipment from the severe arctic environment. A drilling tower **17** is mounted on the vehicle for handling the lengths of drill pipe employed in the conventional drilling and completion of an oil well or the like. The tower **17** in its drilling position (not shown in FIG. 1) is erect above the vehicle in the familiar posture of oil wells. During transport, however, in order to maintain the overall center of gravity of the vehicle as low as possible, and to lower the center of pressure of wind forces on the the vehicle, the tower is folded to a lowered position, as pointed out hereinafter. In a preferred arrangement, the tower has a lower section **18** and an upper section **19** which fold relative to each other as the lower section **18** folds down so that the transverse center of gravity of the tower is not greatly shifted between the raised and lowered positions.

FIGS. 2 and 3 illustrate in longitudinal cross section and top views, respectively, many of the construction details of the apparatus illustrated in perspective in FIG. 1. In both of these views the shelter **16**, illustrated in FIG. 1, is removed to show elements of the equipment which would otherwise be protected and hidden by the shelter. The main body of the vehicle comprises a platform or chassis **21** described in greater detail hereinafter. In a typical embodiment, the platform is about 64 feet long and about 46 wide, which provides sufficient room for the equipment required for drilling and completing an oil well.

In a typical arctic situation, a second somewhat similar vehicle would be stationed nearby for providing transport and storage of drill mud, cement, drill pipe, and the like. A third habitat vehicle having structures for housing crew members would also be stationed nearby. In most situations the transport and storage vehicle and the habitat vehicle would be located contiguous to the illustrated vehicle having the drill rig; however, on ice over water the other vehicles may be stationed as far away as 200 yards in order to permit the stresses induced by the weight of vehicles at the drilling location to be distributed through the layer of ice.

The total weight of the vehicle, including the drill rig and various expendables when set up for drilling, applies a weight of about 275 per square foot which can safely be supported on a layer of ice about 5 feet thick. As pointed out hereinafter, when the vehicle is traveling the footprint pressure is appreciably less due to decreased total weight because of the absence of expendables and a larger footprint area so that the traveling footprint pressure is about 110 per square foot (0.8 psi), which is approximately twice the footprint pressure of the usual air cushion vehicles presently employed at relatively high velocities.

Mounted on the platform or chassis **21** is a so-called sub-base **22**, which provides a raised deck for workmen during drilling operations and which supports a portion of the equipment required for drilling operations, such as, for example, the approximately centrally located rotary table **23** conventionally employed in drilling operations. Mounted on the sub-base **22** are foundations **24** on which the lower segment **18** of the tower **17** is supported (the tower **17** is omitted from FIG. 3 for clarity).

The tower **17** is a substantially conventional folding tower such as available from the Lee C. Moore Company. Such a tower has a lower segment **18** pivotally mounted on a pair of foundations **24** so as to be pivotable between a lowered traveling position as seen in solid in FIG. 2, and a raised operational position as seen in phantom in FIG. 2. When the tower is in its raised position, legs **26** connected to a pair of the foundations **24**, support the lower segment **18** in its raised position. The legs **26** are disconnected and pivoted out of the way or removed when the tower is folded down for transporting as in the position illustrated in solid in FIG. 2.

When the tower is folded down the upper segment **19** pivots about a pivot **27** so as to fold back across the lower segment **18** as controlled by a hydraulic actuator **28**. The cylinder of the actuator **28** is connected to the lower segment **18** of the tower by a trunnion **29** and a piston is pivotally connected to the upper segment **19** by a bracket **31**.

The otherwise conventional tower **17** is modified only by providing a plate **32** on one side of the upper tower section **19** so that the heavy pulley block and hook **33** can be snubbed over and lashed in place on the plate for transporting the tower in a lowered position. When the block **33** is in the lashed position as shown in FIG. 2 and the tower is folded, as illustrated in solid in FIG. 2, its overall transverse center of gravity is substantially directly below the center of gravity of the elevated tower. In this manner, the overall center of gravity of the vehicle is not greatly shifted whether the tower is in a raised or lowered position. This enables the footprint weight distribution to be predicted and controlled when the tower is raised so that the weight distribution on the surface beneath the platform is fairly uniform to prevent tilting. Likewise, the center of gravity remains substantially centrally located with the tower lowered so that the vehicle remains balanced when traveling on a cushion of air.

It is desirable in an air cushion vehicle to maintain the center of gravity as low as possible during travel to enhance the stability of the vehicle. The tower, which may be over 120 feet tall, is a relatively heavy apparatus and lowering is highly desirable for improving the traveling stability of the vehicle. Similarly, when the tower is raised, the overturning effect of wind pressure on the tower is much greater than when the tower is

lowered and, therefore, traveling with the tower lowered is much safer in the winds so common in the arctic.

A conventional pipe rack **34** is provided on the platform **21** for accepting lengths of drill pipe employed in drilling operations. A tank **36** for drilling mud is also provided on the platform, and in a position approximately opposite the center of gravity from the pipe rack **34**, so that substantial amounts of pipe and mud in their respective receptacles do not grossly change the over all center of gravity of the platform. Other conventional well drilling equipment, such as, for example, pumps **37**, an active mud tank **38**, pipe set backs **39**, and blow-out preventer control equipment **41** is also positioned on the main deck of the platform in a distribution that assures a vehicle center of gravity near its geometrical center.

A conventional drill rig draw works **42** is positioned on the sub-base **22** for handling the cables commonly employed in oil well drilling. The draw works **42** are powered by a pair of prime movers **43** which are preferably diesel engines which power not only the draw works but also the pumps **37** and most other equipment commonly employed in drilling operations. The engines **43** are connected to the draw works and other equipment by way of a pair of clutches **44** so that they can be selectively connected and disconnected as desired. A second pair of clutches **46** are also connected to the diesel engines **43** so that the engines can be selectively connected to a pair of high volume low-pressure blowers **47**. Each of the blowers **47** is connected to an air duct **48** which leads the air through the edge of the platform which is in the form of an outwardly extending flange **49** having intermittent braces **51** for weight support.

Air from the ducts **48** enters an upper plenum **52** of the skirt **14**. As may be seen more clearly in the perspective view of FIG. **7**, the plenum **52** having an edge connected to the flange **49** continues as an open passage entirely around the platform so that air entering from the two ducts **48** is conveyed within the skirt entirely around the vehicle. The lower portion of the skirt **14** includes a plurality of webs **53** lying in a substantially vertical plane and connected in one corner to the platform **21**. The outer edge of each web **53** is connected to the outer exposed portion of the skirt and the inner edge is connected to an inner skirt **54** which extends entirely around the platform and is fastened thereto at its upper edge by a bar **56**. The bottom portion of the skirt **14** is completely open adjacent the ground **57**, for example, so that air can leave the skirt through the open bottom portion.

The skirt **14** is fabricated of a flexible material, and because of the low temperature environment encountered in the arctic, care must be taken in selecting a flexible material that will not harden or become brittle at low temperatures. Polyurethane impregnated fabric materials, which remain flexible at arctic temperatures, are suitable for use in the skirt.

In operation, air is injected into the plenum **52** through the ducts **48** and the upper portion of the skirt is caused to billow outwardly as illustrated in FIGS. **2** and **7** under the urging of the increased air pressure. The webs **53** constrain the lower portion of the skirt and maintain it in the general configuration illustrated. Air passes downwardly from the plenum **52** through the spaces between the webs **53** which may, for example, be one or two feet apart, and escapes between the lower edges of the skirt and the ground **57**. A portion of the air passes under the inner skirt **54** to increase the air pressure underneath the platform **21**, and the principal portion of the air escapes beneath the outer skirt **14** into the environment. The air pressure built up within the inner skirt **54** and under the platform is substantially the same as the air pressure within the plenum **52**, and as this builds up it applies a force against the bottom of the platform which serves to raise the platform to a position as illustrated in FIG. When so raised, the bottom of the platform is about 5 feet above the ground in the illustrative embodiment, and it is found that obstacles about 2 ½ feet high can readily be cleared with such an arrangement.

As air is applied within the skirt **14**, it does not continue indefinitely to increase pressure and further raise the platform above the ground, since as the platform raises the outer edge of the skirt will clear the ground and air will "leak" out around the skirt. An equilibrium clearance above the ground is quickly established with the leakage around the skirt equalling the volume of air inserted into the plenum by the blowers **47**. With a vehicle of the size and weight herein described and illustrated in a preferred embodiment, the outer edge of the skirt may be as much as 3 inches from the ground surface when a full volume of air is escaping therefrom.

As the vehicle moves and encounters obstacles, a portion of the skirt is pushed aside and raised to pass over the object, and some added leakage of air may occur as the object is passed. Because of the inner skirt **54** and the large cross section of the plenum **52**, there is no large change in air pressure beneath the platform and the platform is not lowered appreciably. When the skirt is lifted on one side of the platform, or for some other reason additional air leaks from one side, a very slight pressure gradient occurs under the platform and a slight degree of tilt results, which brings the skirt on that side in closer proximity to the surface and pressure and position equilibrium are very quickly restored.

For the same reason, substantial displacement in the center of gravity of the platform and its contents from the geometric center while it is supported on the air cushion can be readily tolerated. This merely brings the "heavy" side of the platform slightly closer to the ground and hence somewhat closes the gap between the skirt and the ground on that side as compared with the opposite "light" side of the platform and the platform travels smoothly at a slight tilt normally only a few inches in many feet. It is found with a platform of the size herein involved that a displacement of the center of gravity of as much as 5 feet from the geometric center can be tolerated; however, it is preferred to maintain the center of gravity much closer to the geometric center in order to provide a tolerance to accommodate other disturbing influences, such as roughness of the terrain, ground slope, and wind loading.

Located directly beneath the drill tower **17** is a drill well **58** which is a rectangular hole extending through the platform **21** to provide clearance for the equipment employed for well drilling. In order to move the vehicle on a cushion of air, a seal must be provided over the

drill well. Such a seal is illustrated in FIG. 4 and in FIG. 5 which comprises a fragmentary view of an edge of the well 58, wherein the upper surface of the drill well is covered by a sheet 59 of flexible plastic impregnated fabric similar to that employed in the skirt. An enlarged welt 61 around the edge of the sheet 59 prevents the sheet from sliding from under a metal bar 62 bolted to the deck of the platform 21. Air pressure beneath the plastic sheet 59 billows it upwardly and in order to minimize stress on the edges of the sheet, a network of cables 63 are lashed over the sheet. If desired, a rigid cover could be employed in lieu of the flexible sheet 59; however, the problems of handling a heavy rigid cover and storage during drilling operations when the cover is not needed make the flexible sheet arrangement preferred.

As mentioned hereinabove, a vehicle supported solely on a cushion of air is essentially frictionless and quite difficult to control at low speeds since it will drift from position under wind pressure or down a relatively gradual slope. Therefore, means are provided for resiliently engaging the surface below the platform to provide frictional contact and prevent side slipping. In a way, the effect is analogous to that of a centerboard on a sailboat which provides substantial resistance to lateral slipping of the sailboat by engagement with the water. A sailboat without a centerboard is readily subject to side slippage under wind pressure.

In the preferred embodiment, the means for engaging the ground, ice or other surface beneath the vehicle comprises a pair of sets of wheels 65 mounted on support bars 66 independently pivotally connected to the platform at pivots 67. The cylinder 68 of a hydraulic actuator is pivotally connected to the platform at a pivot 69, and the piston 71 of the actuator is connected to the support bar 66 adjacent the wheel 65 in each set. The hydraulic actuator is connected to a conventional pneumatic accumulator 72 for resiliently applying pressure to the hydraulic actuator. Thus, the wheels 65 can be extended to the position shown in solid in FIG. 2, or can be retracted to the position shown in phantom by varying the pressure in the pneumatic accumulator 72.

During travel, the wheels 65 are normally in the extended position so as to contact the surface and provide stabilization and control of the vehicle. While on the drilling site, the wheels are not needed and are retracted. By applying pressure to the hydraulic actuator 68 by way of a pneumatic accumulator 72, a substantially constant pressure can be provided between the wheels 65 and the ground 57, and substantial independent vertical articulation of the wheels can be accommodated as obstructions are encountered by one set of wheels or the other, or even by both sets.

The pressure that the wheels apply to the ground or other surface beneath the vehicle is within the control of the operator who need set only the pneumatic pressure in the accumulator in order to maintain a contact of constant force despite surface irregularities. Normally, the force applied to the ground by each of the two sets of wheels employed in a preferred embodiment is in the order of 20,000 pounds, although less may be employed under favorable conditions of wind and terrain and more may be required in adverse winds and on side slopes. When traversing muskeg or tundra in thawed condition, the wheel pressures can be reduced as necessary for avoiding damage to the terrain. In any event, the proportion of the weight of the vehicle and drill rig supported by the wheels is a minor fraction of the total, normally less than about 10 percent, and the major portion of the vehicle weight is supported by the air cushion. The wheels are principally for control of the vehicle in the prevention of side slippage, and would apply too high a footprint pressure for most arctic applications if they supported a substantial fraction of the total vehicle weight.

As more clearly seen in the schematic view of FIG. 4, the two sets of wheels 65 are arranged in wells 73 on either side of the drill well 58. They are so located as a convenience in fabrication, and they are actually slightly forward of the center of gravity of the vehicle. The line between the sets of wheels 65 should be approximately under the center of gravity, however, some tolerance in position is acceptable since they do not support a substantial fraction of the vehicle weight and have little effect on the attitude of the vehicle. Two sets of wheels on the same axis under the vehicle are preferred since this permits turning on a very short radius without any requirement for castering the wheels. If more than two sets of wheels on different axes were employed, the same short radius of turning could not be provided without the additional complexity of providing castered wheels. This is of interest since the air cushion vehicle provided in practice of this invention is towed by another vehicle and a short turn radium is desirable to avoid any towing problems.

Although wheels are greatly preferred as the surface engaging means since large diameter pneumatic or metal tires can be provided for low footprint pressure, other arrangements can be employed, such as, for example, skis or track laying arrangements. Wheels are, however, preferred since they do not require any attitude adjustments to be made as the wheels are raised and lowered as would be the case if skis or some track laying arrangements were employed. Wheels are also simple, inexpensive and reliable. When the vehicle is employed over water, the wheels may not provide sufficient engagement with the surface and may be supplemented by centerboard arrangements to minimize side slippage due to wind forces, although it is preferred to avoid travel over water in high winds.

As illustrated in FIG. 1, the air cushion vehicle would normally be towed by a tractor; towing can also be by a second air cushion vehicle or a helicopter, if desired. Either of these latter two modes may be preferable when the vehicle is towed over water, or ice over water, since they also have low footprint pressure as compared with a tractor. In particularly steep terrain, winches 75 mounted on the deck of the platform can be employed to manipulate cables connected to objects solidly affixed to the terrain, such as trees, piling or the like. Such cables can be employed independently to move the air cushion vehicle at a slow rate or can be used to supplement the towing power of a tractor or the like. They are also useful on steep side slopes to supplement the wheels in preventing side slippage.

As mentioned briefly hereinabove, the air cushion vehicle is made sufficiently buoyant to float stably in water. In order to provide flotation and for airborne shipping, if desired, the platform is preferably constructed in a plurality of watertight modules 76 as illus-

trated in the top schematic of FIG. 6. This view shows schematically an arrangement of individual modular elements for the platform 21 in which each module 76 is a hollow box welded up from sheet steel with reinforcing ribs as required. The individual modules are merely bolted together to form the desired platform. It will be noted that in the illustrated embodiment only four module shapes or sizes are required to assemble the entire platform. These module sizes and shapes are conveniently selected to permit the assembly of platforms of other sizes using the same basic modules. The individual modules 76 are watertight and may be separately internally compartmented in order to provide damage control and safety in case of accidental rupture of one of the compartments of the module.

In a preferred embodiment, the buoyancy of the modules is selected so that the entire platform will safely float even when completely loaded with expendables for drilling operations so that there is no substantial safety problem in case the vehicle and drilling rig should break through ice while conducting drilling operations. It is apparent that if the vehicle will float safely under these conditions it will also float readily when in its traveling mode with approximately half the weight of the drilling mode. The importance of a center of gravity low and over the geometric center is apparent in a floating vehicle.

The interior of the modules 76 provides a convenient place for storing fuel for drilling operations, and toward this end fuel bags 77 may be positioned within one or more of the modules for containing diesel fuel and the like. Fuel bags are flexible rubber or plastic containers within which fuels are conventionally stored so as to collapse when fuel is withdrawn therefrom. These are desirable since they are convenient and lightweight for such application. The fuel bags in the modules may also be employed during transportation of the vehicle to provide some ballasting for shifting the center of gravity if desired.

Air cushion vehicles have been employed in the arctic using an air cushion of about 58 pounds per square foot (0.4 psi) and are propeller driven at speeds of up to about 60 miles per hour. As mentioned hereinabove, reasonable speed must be maintained in conventional air cushion vehicles in order to provide control. The heavy masses involved in drilling equipment effectively precludes speeds of this nature and a somewhat higher air cushion pressure must be maintained to keep the area of the air cushion within reasonable proportions. It has been found that air cushion pressures for vehicles such as those herein described having drill rigs thereon can be as high as about 110 pounds per square foot (0.8 psi). Such pressures can be employed in fine sediments and in water under a slowly moving vehicle without severe scouring effects. With a pressure of this magnitude supporting a vehicle having a drill rig thereon, the surface of water is depressed about 18 inches beneath the air cushion and the volume of air escaping around the periphery of the skirt causes considerable spray. A similar effect may be observed in powdered snow or dry tundra; however, it has not been observed that such a slow moving vehicle scours the surface to the point that it "digs itself into a hole" so that it cannot be towed along. This is at least partly due to the large size of the vehicle and its substantial clearance above the surface permitting it to clear and readily pass over rather large obstructions.

Operation of a conventional air cushion vehicle is difficult since it is on a substantially frictionless support and traveling at low speeds is not readily accomplished. With a vehicle the size of the drill rig, a ground speed in the order of 2 to 10 miles per hour is employed which is too low for reliable control if the vehicle were solely on an air cushion. The wheels, however, prevent side slippage and forward progress is fully within the control of the tractor operator. The only control required on the air cushion vehicle itself is setting of the pressure in the pneumatic accumulator powering the hydraulic actuator which sets

means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling means; the contact pressure between the wheels and the surface, and setting of the blowers to maintain a predetermined pressure within the skirt. There is very little criticality in either of these settings since the former merely varies the footprint pressure locally and the latter merely causes the vehicle to ride higher or lower depending on whether the blowers are set at a higher than optimum or lower than optimum speed, and no great change is made for substantial variations in blower pressure.

Just as in other drilling rigs a reasonable foundation for the platform must be prepared at the drilling site. If the drilling site is in open water, the vehicle is merely moored and floats at the site. Similarly, if the drilling site is in a muskeg bog, the platform is merely set on the surface of the bog and may sink some distance into the marshy ground without any problem whatsoever. On tundra, bulldozers may be employed for leveling and smoothing a site for the drilling platform, or if it is during the winter months, a technique similar to that suitable for smoothing and leveling an ice surface is preferred.

Such a technique is illustrated schematically in FIG. 8 wherein uneven ground is smoothed by erecting a cofferdam 79 surrounding the drilling site. The area within the cofferdam is then flooded with water to a sufficient depth to cover any objectionable irregularities, and the water is then frozen to form a smooth level layer of ice 81. If a production well is to be maintained on the site, it may be desired to leave a subsurface cellar 82 in the region immediately below the tower 17. This provides a location for the blow-out preventer and other production equipment which may be installed on the well prior to departure of the drilling rig. This equipment is preferably installed in the cellar 82 so that the air cushion vehicle clears the equipment when it leaves the site. The cellar can be temporarily covered so that the air cushion is not lost as the skirt traverses the cellar. If the technique is employed on ice, the blow-out preventer is normally installed on the bed of the body of water beneath the ice. Also, in employing the technique on ice, the extent of the body of ice formed within the cofferdam 79 may extend a considerable distance beyond the drilling platform in order to raise the thickness of the ice at least 5 feet for a sufficient distance to accommodate the stresses of the heavy drilling platform without breaking through the ice.

When the drilling platform is installed on ice, whether in its original condition or made by freezing a pond as illustrated in FIG. **8**, care must be taken to avoid melting the ice due to the heat generated by the drilling rig. If the ice is melted, a problem may be encountered wherein the drilling rig freezes to the ice surface so that it cannot be readily moved to a new site. In order to avoid melting of the ice beneath the platform an insulating layer **83** is first laid over the ice prior to installing the platform in position. A suitable insulating material having low thermal conductivity and sufficient strength to bear footprint pressures of the order herein involved is readily available commercially in large slabs, which can be laid directly on the ice and cemented together with hot asphalt or the like in order to form a continuous layer. Such arrangements are also employed in arctic airfields. Another suitable insulation involves a layer of styrofoam overlaid with 2 or 3 feet of gravel.

Rather than employing insulation over the ice there are also situations where it is desirable to provide artificial cooling to maintain the ice beneath the vehicle. Thus, as seen in the cutaway portion of FIG. **2** conventional refrigeration coils **84** are laid in good thermal contact with the bottom of the chassis **21** for cooling that surface. The coils **21** can be used for maintaining ice frozen beneath the platform and are also useful for initially forming a pad of ice to support the loaded weight of the platform when the ambient temperature is not sufficiently low to quickly freeze a sufficient layer of ice. The coils **21** can also be used for heating and deliberately thawing ice beneath the platform to prevent sticking when it is desired to move the platform to a new location.

In order to move the air cushion supported drill rig from one drilling site to another, any remaining expendables are removed from the platform in order to minimize the weight, and the drill tower is lowered as hereinabove described and illustrated. The diesel engines are disconnected from the draw works and connected to the blowers, and pneumatic pressure is applied to the hydraulic actuators of the surface engaging wheels. As the blowers inflate the skirt and increase the air pressure beneath the platform, a pressure is soon reached where the platform is lifted off of the surface so as to ride on a cushion of air. The wheels, under the resilient urging of the hydraulic actuator, remain in contact with the surface at the selected force. As soon as the vehicle is stabilized, towing to a new site can commence.

In much of the arctic, such as over open ice or water, through most muskeg, and over most tundra, very little trail preparation is required. If needed, however, bulldozers can be employed to scrape major obstructions from the path and provide a reasonable grade for travel of the platform from one site to another. This is conveniently done while the drill rig is employed in drilling operations, and the bulldozer employed for trail preparation can also be employed for towing the vehicle to the new site. It should be recalled that the air cushion vehicle hereinabove described and illustrated has a terrain clearance of about 5 feet and obstructions as much as 2 ½ feet high can readily be cleared during travel so that careful trail preparation is not mandatory.

As mentioned hereinabove, the individual modules **76** of the platform **21** are of such a size that they fit within existing aircraft or can be carried by large helicopters so that the platform can be transported by air an assembled at a remote location if desired. The other equipment on the platform is clearly air transportable also. This is, however, not the most economical way of transporting a heavy, bulky item of this nature, and it is preferred to completely assemble the vehicle and drilling rig at a convenient location and transport the completely assembled apparatus to the site by ship. It will be noted that the 65-foot-long vehicle described in a preferred embodiment has a length about equal to the beam of a ship suitable for transporting such equipment.

A convenient and economical transporting arrangement is illustrated in FIG. **9**, which comprises a schematic view of a conventional ship **86** on the deck of which a vehicle **12** substantially as hereinabove described is carried. Such a vehicle when completely assembled is too heavy for off-loading by conventional ship's cranes and, therefore, special means are provided for off-loading the vehicle. It might be noted that if the vehicle is transported in modules and assembled in the arctic, the modules can be off-loaded from the ship with conventional cranes and assembly can be at shipside.

Ship launching ways **87** are built onto the deck of the ship **86** and the vehicle **12** is transported on these ways. If desired, conventional skids or rollers **90** can be provided between the vehicle and the ways for launching. A portion of the ways **87** extend beyond the side of the ship with suitable reinforcing braces **88** as may be required to the frame of the ship. When the ship reaches the location where it is desired to launch the platform and drill rig, ballast is pumped into tanks **89** within the ship to roll the ship until the ends of the ways **87** are in the water. The drilling vehicle **12** is then released and permitted to slide down the ways or is urged along the ways by winches until it reaches the water and floats away as illustrated in phantom in FIG. **9**. Such a technique for launching the vehicle from the deck of the ship is analogous to side launching of ships from ship building ways on land.

After the vehicle is in the water, its inherent buoyancy keeps it afloat and erect until the blowers are started to provide an air cushion for raising the vehicle above the water for ready towing to a drilling site or onto ice or the beach for towing across land to a drilling site. If desired, the vehicle can be towed to shallow water without operating the air cushion. It might be noted that the technique for launching the vehicle and drill rig are suitable for delivering the vehicle to a drilling location, but are not readily reversible and it is not contemplated that the vehicle be reloaded on the ship by the same technique.

FIG. **10** illustrates another embodiment of drill rig and air cushion vehicle constructed according to principles of this invention. As illustrated in this embodiment, a platform or chassis **91** is surrounded by a flexible skirt **92** in the same general manner as in the preferred embodiment hereinabove described. A cross section of the skirt and an edge of the platform **91** is illustrated semi-schematically in FIG. **11**. As seen therein the skirt in this embodiment comprises a long plenum like section extending along the edges of the vehicle and may be one member or may be subdivided

into compartments intermittently as desired. Vent holes **93** on the inward side **92** pass air from the interior of the skirt to the region beneath the vehicle chassis **91**. Air flows from this region between the skirt **92** and the ground **94** or the surface over which the vehicle is riding. Since there is a substantial air flow between the skirt and the ground the skirt seldom contacts the ground directly and there is no substantial problem of wear of the skirt.

Air is provided to the skirt from one or more blowers **95** from which it is lead to a plenum **96** extending completely around the vehicle by a duct **97**.

Referring again to FIG. **10**, a shelter **98** mounted on the vehicle provides a habitable environment for men and equipment operating the drill rig. A conventional drilling tower **89** is mounted on the platform so as to be pivotable between a lowered position illustrated in FIG. **10** for transport and an erected position (not shown) for drilling operations. It might be noted that the drilling tower illustrated in FIG. **10** which merely pivots down to a substantially horizontal position, rather than folding as in the preferred embodiment, is a somewhat smaller tower for handling shorter lengths of drill pipe and for drilling wells to shallower depths than the folding tower.

As in the previously described embodiment the drill rig on the air cushioned vehicle is towed from site to site rather than being self-propelled. In this instance, the towing is provided by an additional air cushion vehicle **101**, which includes a pair of propellers **102** for providing forward propulsion, and movable control surfaces or rudders **103** for directional control and steering of the air cushion vehicle. In addition to providing towing for the vehicle supporting the drill rig, the air cushion vehicle **101** may also provide a bed for transporting cargo **104**.

In order to provide stability for the air cushioned vehicle supporting the drill rig, means are provided for engaging the ground or other surface over which the vehicle travels. In this embodiment a fraction of the vehicle load is applied to the ground outside the skirt by means of large pneumatic rollers. A single central rollers **106** is provided at the forward end of the vehicle between arms of the tow bar **107**. A pair of similar rollers **108** are provided at the back end of the vehicle for contacting the ground with a preselected pressure. Each of the rollers **108** is supported on a rigid frame **109** having arms extending through the flexible skirt **92** and pivotally mounted on the chassis of the vehicle so that it is free to translate vertically. Flexible bellows **111** are provided between the frame **109** and the skirt **92** for preventing substantial air leakage and also accommodating motion of the frame **109**. A hydraulic actuator **112** has its piston **113** connected to frame **109** for applying a selected downward force as controlled by a pneumatic accumulator so that the rollers contact the ground with a selected pressure.

By providing rollers outside the skirt in this embodiment there is some sacrifice in the turning radius available, however, in some situations this is acceptable for the slightly lower footprint pressure available in such an arrangement. Rather large size rollers can be accommodated outside the skirt, whereas when wheels are employed beneath the skirt they must be somewhat smaller so that they can be readily retracted when not in use without substantially reducing the buoyancy of the overall vehicle.

Although only two embodiments of drill rig supported on an air cushioned vehicle have been described and illustrated herein many modifications and variations will be apparent to one skilled in the art. It is therefore to be understood that the invention may be practiced otherwise than as specifically described, limited only as is indicated in the appended claims.

What is claimed is:

1. A portable unitized drilling station comprising:
- a platform;
- a drill tower mounted on the platform for drilling oil wells and the like, said drill tower being foldable between an erect drilling position and a lowered transporting position, and wherein the center of gravity of the drill tower is substantially on a common vertical line in both the erect and lowered positions;
- a drill well aperture through the platform beneath the drill tower;
- means for temporarily sealing the drill well aperture;
- flexible skirt means around the periphery of the platform for cooperation with a surface for minimizing air flow therebetween; and
- means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling tower.

2. A portable drilling station as defined in claim **1** further comprising:
- a plurality of wheels within the skirt means and beneath the vehicle; and
- means for resiliently biasing the wheels downwardly from the vehicle with a selected force equal to a uniform minor portion of the weight of the platform and drilling tower.

3. A portable drilling station as defined in claim **2** wherein the plurality of wheels comprises:
- a first wheel;
- means for biasing the first wheel downwardly from the station;
- a second wheel substantially coaxial with the first wheel, the center of gravity of the portable drilling station being approximately over a line between the first and second wheels; and
- means for biasing the second wheel downwardly from the station for motion independent of motion of the first wheel.

4. A portable drilling station as defined in claim **1** further comprising:
- a mounting frame movably connected to the platform and extending through the flexible skirt means;
- sealing means for preventing air leakage between the skirt means and the mounting frame;
- a fluid actuator for moving the mounting frame; and
- a wheel rotatably mounted on the outer end of the mounting frame for selectively contacting a supporting surface.

5. A portable unitized drilling station comprising:
- a platform;
- drilling means mounted on the platform for drilling oil wells and the like;
- a drill well aperture through the platform beneath the drill means;

means for temporarily sealing the drill well aperture;
flexible skirt means around the periphery of the platform for cooperation with a surface for minimizing air flow therebetween;
means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling means;
a plurality of wheels for contacting a supporting surface; and
means for selectively moving the surface engaging means into and out of contact with the surface and for resiliently biasing the wheels downwardly with a selected force equal to a minor portion of the weight of the platform and drilling means comprising a hydraulic actuator connected to the wheels and a pneumatic accumulator for supplying a preselected pressure to the hydraulic actuator.

6. A portable drilling station as defined in claim **5** further comprising means for towing the drilling station from one location to another.

7. A portable drilling station as defined in claim **6** comprising a plurality of watertight compartments having sufficient buoyancy for floating the platform in water.

8. A portable drilling station as defined in claim **5** wherein the drilling means includes a motor and wherein the means for supplying air is selectably connectable to the motor whereby the same motor is used during drilling operations for powering the drill means and during transport for powering the means for supplying air.

9. A portable unitized drilling station comprising:
a platform;
drilling means mounted on the platform for drilling oil wells and the like; the drilling means comprising:
a drill tower mounted on the platform, said drill tower being foldable between an erect drilling position and a lowered transporting position, and wherein the center of gravity of the drill tower is substantially on a common vertical line in both the erect and lowered positions;
a motor;
a draw works;
means for selectively connecting the motor to the draw works; and
means for selectively connecting to the motor to the means for supplying air;
flexible skirt means around the periphery of the platform for cooperation with a surface for minimizing air flow therebetween;
means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling means;
a plurality of wheels for contacting a supporting surface;
means for moving the wheels into contact with a surface comprising a hydraulic actuator connected to the wheels and a pneumatic accumulator for supplying pressure to the hydraulic actuator for resiliently biasing the wheels downwardly with a selected force equal to a minor portion of the weight of the platform and drilling means, and
means for towing the drilling station from one location to another.

10. A portable unitized drilling station comprising:
a platform;
drilling means mounted on the platform for drilling oil wells and the like;
a drill well aperture through the platform beneath the drill means;
means for temporarily sealing the drill well aperture;
flexible skirt means around the periphery of the platform for cooperation with a surface for minimizing air flow therebetween;
means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling means; and
means for cooling a surface beneath the station for providing ice thereunder.

11. A portable drilling station as defined in claim **10** wherein the drilling means comprises a drill tower mounted on the platform, said drill tower being foldable between an erect drilling position and a lowered transporting position, and wherein the center of gravity of the drill tower is substantially on a common vertical line in both the erect and in the lowered positions.

12. A portable unitized drilling station comprising:
a platform;
drilling means mounted on the platform for drilling oil wells and the like;
a drill well aperture through the platform beneath the drill means;
means for temporarily sealing the drill well aperture;
flexible skirt means around the periphery of the platform for cooperation with a surface for minimizing air flow therebetween;
means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling means;
surface engaging means for contacting a supporting surface; and
means for providing a frozen base thereunder with sufficient strength to support the station.

* * * * *

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,693,729 Dated September 26, 1972

Inventor(s) Leon C. Blurton, Saverio J. Cina

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 20, "or" should be --of--.

Column 3, line 48, --feet-- should be inserted between "46" and "wide";

Column 3, line 67, --pounds-- should be inserted between "275" and "per".

Column 4, line 5, --lbs-- should be inserted between "110" and "per".

Column 6, line 14, --2-- should be inserted after "FIG".

Column 8, line 31, "radium" should be --radius--.

Column 10, line 15, delete "means for supplying air under pressure within the skirt means for maintaining sufficient pressure therein to support a major portion of the weight of the platform and drilling means".

Column 12, line 3, "an" should be --and--.

Column 13, line 45, "rollers" should be --roller--.

Signed and sealed this 29th day of May 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissinner of Patents