This invention relates to apparatus for storing and employing apparatus for using the rolling of a ship on a ship to perform work. During the recent war a technique was developed for transferring fuel, supplies, ammunition and the like from a supply ship to a war ship while both ships continued on a parallel course at the maximum speed of the slower ship. This technique involved the use of one or more high lines of cable fastened to the war ship and extending to a winch on the supply ship. Goods were passed from the supply ship to the war ship while supported on the high cable. The winch on the supply ship was manually controlled and an effort was made to maintain sufficient tension in the high line to prevent the cable-borne load carrier from hitting the water and to prevent excessive cable stresses. Naturally, to keep the line well above the water, it was led off and on the ships at points high in their superstructure or from cargo booms. Thus, with two ships tied together high up on the structure, considerable motion is encountered, especially when the roll of the two ships is opposite. To maintain a predetermined cable tension to support the load to prevent overstressing of the cable and to pull out and retrieve cable as required by the relative movements of the ships, automatic tension winches must be used. These winches being subject to overhauls when the cable tension exceeds a predetermined value and serving to take up automatically when the cable tension falls below a predetermined value.

Automatic tension winches of small capacity are now known, but the use of the high line system of supplying one ship from another while both proceed has been hampered because of the very high horsepower requirements of the winches when used with high lines between rolling ships. For instance, if a tension of 12,000 pounds and a speed of 800 feet per minute is to be maintained, 250 to 300 horsepower is required at the winch, depending on the over-all efficiency, and this is usually too high a requirement for the generators of a supply ship since four to six winches per ship are required. To install extra generators just to operate the winches is, of course, possible but is not economically feasible.

It is proposed therefore, as a part of the present invention, to store the energy of the power generated incident to that portion of the cycle of roll of the ships when they are moving apart and the cable is being pulled out, and to convert this energy back to power to reel in the cable and to overcome all of the friction losses of the system so that the generators of the ships will not be required to furnish any of the power required in maintaining the transfer cable in position.

A more general object of this invention is to store the energy of ship roll and to convert the stored energy to power to meet, or to assist in meeting, any power requirement later encountered.

It is contemplated, according to the present invention, to cause the cable of a high line or the like to do work on a winch or the like during a portion of the roll cycle of a ship and to convert a portion of the work to potential energy which is stored for later use.

It is a further object of the present invention to provide means supplied with energy from ship roll to control the tension on a high line cable.

It is likewise an object of this invention to provide a work-energy converter which can be adjusted to store energy and perform work at a rate depending upon the operational requirements at any given time so that when used with a high line cable the tension on the cable can be maintained at a lower value under light load conditions than under heavy load conditions.

Other objects and advantages of this invention will be apparent upon consideration of the following detailed description of several embodiments thereof in conjunction with the annexed drawings wherein:

Figure 1 is a schematic end view of a high line transfer cable extending between two ships, the broken line indications serving to illustrate several different positions of the cable supports at various stages in the roll cycle.

Figure 2 is a schematic view partially in section of simplified apparatus according to the present invention for demonstrating the principles of operation in receiving energy from and supplying energy to a cable winch used to control line tension in a transfer cable of the type shown in Figure 1;

Figure 3 is a view similar to Figure 1 but illustrating an embodiment of the invention adapted for practical use to control either or both of two cable winches of the type previously mentioned;

Figure 4 is a detail sectional view of the control valve system for the assembly of Figure 3 shown in its locking position;

Figure 5 is a detailed sectional view of the control valve system for the assembly of Figure 3 shown in its reversed position as used during rigging;

Figure 6 is a schematic view similar to Figure 3.
but illustrating a modified type of stroke control in conjunction with the parallel piston type hydraulic motor; and

Figure 7 is a view similar to Figure 6 but showing a different position of the stroke control mechanism.

Referring now in detail to Figures 1 and 2, a pair of ships 10 and 11 are shown, these ships, in the operation of the device, being in motion and proceeding on course although connected by a cable 12 extending from a winch 13 on the ship 10 over a guiding pulley 14 on that ship to and over a guiding pulley 15 on the ship 11, and from thence to an anchor point. Operating on the cable there is shown a cable car 16 which is merely a diagrammatic indication of any sort of cable-supported conveying device for moving supplies or the like from one ship to the other.

If now reference is made to the pulleys 14 and 15, it will be noted that when the ships are erect, they will be in the full line positions. If now the ships are rolling opposite, the pulley 15 will move to the position 15a while the pulley 14 is moving to the position 14a. This will require that considerable length of cable 12 be paid out from the winch 13. In the opposite cycle of the roll, that is, when the ships are rolling toward one another, the pulley 14 will move from the position shown in full lines to the position 14b while at the same time the pulley 15 will move to the position 15b. It is perfectly apparent that as the pulleys move apart, as indicated in Figure 1, work is done on the cable which causes the winch to rotate. On the other hand, as the ships move toward one another, if the cable is to be maintained taut, the winch must do work on the cable to take up the slack.

Naturally, the horsepower requirements of the winch mechanism will vary considerably with the tension on the cable, the load which it is supporting, and the magnitude and rate of the ship roll. In Figure 1 the roll axis of the ship 10 is indicated at 10a and the roll axis of the ship 11 is indicated at 11a.

If now reference is made to Figure 2, it will be noted that the winch 13 includes a drum 17 mounted on an axle 18 which is journal bearing, and the drum 17 is actuated by the driving shaft. One end of the axle 18 is attached to a gear 19 which meshes with a gear 20 mounted on the drive shaft 21 of a parallel piston type pump-motor unit. The unit 22 comprises a non-rotating wobble plate 23 and the piston and cylinder assembly rotatable with the shaft 21. The piston and cylinder assembly includes pistons 24 and 25 operating in cylinders 26 and 27 respectively. A hydraulic conduit 28 leads from the unit 22 to the receiving end 29 of a hydraulic accumulator 30. The accumulator contains a piston 31 having a portion 32 of small diameter operating in the working space of the end 29 and a portion 33 of enlarged diameter working in an enlarged upper portion 34 thereof. The top of the upper portion 34 of the accumulator 30 is connected through air or gas container 35. Between the unit 22 and the pressure accumulator 30 the line 28 is provided with a T-connection 37 which leads to a normally spring closed check valve 38. Beyond the check valve a conduit 39 leads into a storage reservoir for the working liquid. Another conduit leads from the bottom of the storage reservoir back to the unit 22. The conduits 28 and 41 are connected to arcuate valve grooves 42 and 43 respectively. These grooves, coating with ports at the bottom of the cylinders 25 and 26, control the flow of liquid through the unit. The details of the valve grooves 42 and 43 have not been illustrated since they constitute a conventional and well-known arrangement which, per se, forms no part of the present invention.

For a description of the details of a hydraulic unit of the type shown schematically in Figure 2, reference is made to Janney Patent No. 1,020,285 and particularly to Figure 4 thereof.

In operation it is apparent that when the cable 12 is pulled out, as indicated by the arrow in Figure 2, the drum will be caused to rotate and this rotation, through gears 19 and 20, will be imparted to the piston and cylinder assembly of the unit 22. As the assembly rotates from the position shown in Figure 2, the piston 25 will gradually move to the left, while the piston 24 will move to the right. Thus, the piston 25 will effect a suction stroke, while the piston 24 will effect a discharge stroke. The suction stroke will draw fluid from the reservoir 40 of the piston and cylinder assembly while the discharge stroke of the piston 24 will pump liquid through the conduit 28 into the accumulator. It is apparent that the cyclic operation of the pistons in the cylinders is such that each piston and cylinder goes through its complete cycle in 360° of rotation. The output of the unit is the full displacement of both pistons for each rotation of the shaft 21. The valves 42 and 43 control the proper distribution of the liquids. In other words, as piston 24 moves inwardly from the position shown in Figure 2, it stays in communication with channel 42. When the piston 25 has completed its stroke to the right. Shortly after this it is placed in communication with the channel 43 and starts the intake stroke.

As pressure liquid builds up in the lower portion 30 of the accumulator 30, the piston 31 of the accumulator is gradually moved upward bringing about compression of the gas occupying the working space in the upper portion 34 of the accumulator. In order to keep the accumulator within reasonable size limits, the storage tank 36 is connected to the gas chamber of the accumulator. The gas is compressed in the upper portion of the accumulator, in the conduit 35 and in the storage tank 36. The storage of energy in the accumulator 30 continues so long as the cable 12 is being pulled out and work is being done on the drum 17 by virtue of the roll of the ships. When, however, the ships roll toward one another, and it is necessary for the cable to be reeled in, the piston 31 of the accumulator is forced down under the pressure of gas in its upper chamber and liquid is pumped through the conduit 28 into the unit 22 through the pistons and cylinders, and out into the storage reservoir 40. This action imparts rotation to the shaft 21 by causing rotation of the piston and cylinder assembly, and the rotation through the gears 29 and 19 is applied to the shaft 16 of the drum 17. When cable is being pulled out the unit 22 functions as a pump to charge the accumulator, and when cable is being reeled in the unit 22 functions as a motor to drive the drum 17. The valve 38 is simply a pressure relief which operates at a predetermined pressure in the line 28 becomes dangerously high.

With the invention exactly as it is shown in Figure 2, it is quite apparent that the pressure loss in the accumulator caused by a single cycle
of reeling in, will not be made up by a single cycle of pulling out due to the fact that there is some friction loss in the system and the work done by the cable is just about equal to the work done against the winders. The cause for that reason that the form of the invention disclosed in Figure 2 is here termed merely demonstrative and not indicative of the type of apparatus which would be used in a practical installation.

In view of the fact that almost limitless power is necessary for the rolling inertia of the ships, it is apparent that if the piston and cylinder unit could be made to do more work on the liquid during the pulling-out operation than is required to be done during the reeling in operation, friction losses could be made up and, in fact, a considerable excess of energy could be made available. Thus, it is highly desirable that the piston and cylinder unit associated with the cable drum be provided with stroke control apparatus. Likewise, it is desirable to render the operation of the hydraulic piston and cylinder unit adjustable so that only the work it operates during the actual periods when the line is maintained, but also, in conjunction with another unit, during those periods when the line is being rigged in the first instance, and when it is being hauled aboard after the transfer of supplies has been effected. Accordingly, in Figure 3 there is shown a modification of the present invention of the type susceptible of practical use on board ships.

In Figure 3 there are shown two drums 50 and 51 connected by drive shafts 52 and 55 to parallel piston hydraulic units 54 and 55 respectively. The drums 50 and 51 and the associated gear trains 52 and 53 correspond in structure and function to the drum 17 and the gear train comprised of gears 19 and 20. The units 54 and 55 correspond generally in structure and in function to the unit 22, except that stroke control apparatus is associated with the wobble plate of each of units 54 and 55. The stroke control apparatus is generally designated at 56 and 57. The output lines from the hydraulic units are connected to piston valves 58 and 59 respectively and from these valves there extend conduits 60, 61, 62 and 63. The conduits 60 and 62 lead to a selector valve 64, while the conduits 61 and 63 lead to a selector valve 65. The selector valves 64 and 65 are connected to conduits 66 and 67 and are so designed that either or both of conduits 66 and 67 can be placed in communication with conduit 66 and either or both of conduits 61 and 63 in communication with conduit 67. Thus it is that the drums 50 and 51 may be operated separately or together, depending upon the operational requirements at any given time.

The conduit 66 leads to a pressure accumulator 68 corresponding in structure and function to the accumulator 30 shown in Figure 2. A parallel piston hydraulic unit 69 is provided to effect the initial charging of the system and to furnish a pump energy to operate the main hydraulic unit so that the winches can be operated by suitable adjustment of the valves 58 and 59 without charging the accumulator. The unit 69 is driven from an electric motor 70 through a shaft 71.

Now referring in detail to the control piston valve assembly 55, it will be noted that this assembly is connected to lines 71 and 72 extending from the unit 54, and is likewise connected to lines 60 and 61 previously discussed. The valve is comprised of a hollow body 73 and a plunger 74 manually operated by a control lever 75 pivoted at 76 to one end of the plunger 74 and fulcrumed at 76a. Thus, by rocking the lever 75 about its axis at 76a, it is possible to adjust the valve to the three positions shown in Figures 3, 4 and 5. In the Figure 3 position the pistons 77, 78 and 79 of the plunger 74 contact with angular grooves in the valve body 73 so that flow is established from line 71 through the valve body to line 60, and from line 61 through the valve body to line 72. Thus it will be recognized, is the normal automatic operation position which will cause the unit 54 to operate in the manner described in connection with the unit 22 of Figure 2.

If the valve operating lever 75 is moved clockwise from the Figure 3 position to the Figure 4 position, pistons 78 and 79 of the valve plunger 74 block conduits 60 and 61 respectively. Through channels 86, 81 and 82 the line 66 is connected with both ends of the plunger 74 so that no pressure difference can exist between the conduits 60 and 61 from its position of adjustment. In the Figure 4 position both of conduits 71 and 72 are cut off at the valve.

If now the operating lever 75 is moved still further clockwise to the Figure 5 position, then conduit 71 is in communication with conduit 72 and conduit 72, through channel 82, is in communication with conduit 60. Thus it is that in the Figure 5 position of the control valve the relationship of the conduits 71 and 72 to the conduits 60 and 61 is reversed from the relationship existing in the Figure 3 position of the valve.

The foregoing description has been devoted entirely to control valve 58, but it is to be understood that control valve 59 is constructed and operates in the same manner.

The stroke controlling mechanism 56 which is associated with the unit 54, comprises a rod 83 connected to the wobble plate 64 and having at its other end a piston 85 operating within a cylinder 86. The cylinder 86 contains a coil spring 87 which normally urges the piston 85 in the direction of the arrow 88 to maintain the opposite side of the piston 85 from the spring 87 there is a working space which is connected by a line 85 to the line 71. It is now apparent that so long as the pressure existing in the line 88 is insufficient to overcome the thrust of the spring 87, piston 85 will be urged downwardly and the stroke of the pistons and cylinders of the unit 54 will be at maximum. When, however, the pressure in the line 71 builds up, the piston 85 is moved upwardly against the thrust of spring 87 and the stroke is gradually decreased. The stroke control system described in connection with control mechanism 56 is also employed in connection with control mechanism 57 and to accomplish control mechanism 58 applied to the wobble plate of the transmission 69. In each of these cases a vent is provided for the chamber containing the spring.

The pressure exerted on the piston of the stroke control mechanism 58 is derived from the line 66 through a connecting conduit 90. Another conduit 91 branches from the conduit 68 and leads to a check valve 92 and from the check valve 92 through a conduit 93 to one side of the hydraulic pump 69. The other side of the pump is connected to conduit 67 through a branch conduit 94 from that conduit to a working liquid reservoir 95. A return line 95 extends from the reservoir 95 to a relief valve 96 and from there back.
into the line 91. A shut off valve 97 is located in the line 66 between the branch 90 and the accumulator 68.

When now the apparatus of Figures 3, 4 and 5 is to be put into use, it is first necessary to pump pressure liquid from low pressure tank 55 to the accumulator 68. To do this, the required amount of air or gas is introduced on top of the accumulator, valve 97 is opened and piston control valve 58 is set to the Figure 4 position in which lines 71 and 72 from the unit 54 are blocked. The motor 70 is started and units 63 and 65 pump liquid from reservoirs 95 through lines 59, 91 and 66 into the bottom chamber of the accumulator. Naturally to insure this operation of the unit 54 it is also necessary either to set the valves 64 and 65 so that conduits 62 and 63 are cut off, or to adjust the piston value 59 to the Figure 4 position.

The action of the unit 69 continues until the accumulator is fully charged. During the charging operation, the pressure in the line 68 gradually rises causing the stroke control mechanism 69 to adjust the wobble plate of the unit 69 toward zero stroke which is finally achieved when the accumulator is fully charged.

When the pressure in the accumulator 68 has reached the desired value, the next step in the operation is to pay out cable so that a line can be established from one ship to the other. To do this, assuming that only drum 50 is to be operated upon, it is necessary to close valve 97, to adjust valves 64 and 65 to block lines 62 and 63 so that flow is established from line 66 to line 68 and from line 61 to line 67, and to set control valve 58 to the Figure 5 position. With this pre-adjustment, the motor 70 causes the hydraulic unit 69, operating as a pump, to pump liquid drawn from the reservoir 95 through conduits 64, 66, 61, 67 and 72 to the unit 54 to cause that unit to drive the drum 50 in the payout direction. The energy supplied by the motor 70 is stored and the drum 50 is immobilized. Of course sufficient slack cable will be available to effect the connection. Immediately after the connection is effected, the valve 58 is shifted to the Figure 3 position and valve 97 is opened. During the transfer operation the drum 50 will now operate in the manner described in connection with the drum 17 of Figure 2, that is, liquid will be drawn through conduits 64, 67, 61 and 72 into the unit 54 and pumped out through conduits 71, 66 and 68 to the accumulator during that portion of the roll cycle when cable is being pulled out. During the portion of the roll cycle when cable is reeled in, the unit 54 is supplied with pressure fluid from accumulator 68 through conduits 66, 60 and 71 and this liquid is returned to the reservoir 95 through conduits 71, 67 and 63.

Throughout the loading period, while the cable is being paid out from one ship to the other, the piston control valve 58 is left in the Figure 3 position and motor 70 is kept running. Although the motor 70 is kept running, the rolling inertia of the ship provides ample power through the accumulator. If the operator determines that reeling in is required, the motor 70 serving only to provide a safety factor. The power supply to the motor 70 during the automatic operation is extremely low due to the fact that the pressure in the line 66 acting on the stroke control device 68, keeps the unit 69 at zero stroke so that the load on the motor 70 is only that imposed by its own friction and that of the unit 68. Should conditions demand that the roll does not keep the pressure in the system to the desired value, motor 70 acts as a helper to keep the accumulator charged. These conditions result from the nature of the cable used. In other words, although the roll of the ship can afford ample power to compensate for the work which must be done when cable is reeled in, there may be practical limitations on the size of the cable which mean that excessive cable tensions cannot be tolerated, which in turn reduces the effective output horsepower of the hydraulic units during the accumulator changing portion of their operating cycle. If heavy enough cable is used, it is quite possible to shut down the motor 70 during the loading period so that all of the cable tensioning is accomplished by pressure liquid stored in the accumulator during the portion of the roll cycle when cable is being pulled out.

It will be noted that the stroke control device 56 associated with the unit 54 increases the stroke as pressure decreases in the line 71. Thus, during reeling in of the cable when the pressure in the line 71 drops, the stroke of unit 54 is increased so that the unit 54 pumps the maximum amount of working liquid. In other words, during reeling in, the pressure in the accumulator falls and the stroke of the unit 54 is increased so that the unit 54 pumps the maximum amount of oil back to the accumulator. It is also desirable to maintain a high stroke when pressure is low in order to obtain maximum torque output at low pressure. This stroke angle exists, therefore, at the beginning of the pulling out operation so that a maximum amount of oil is pumped back to the accumulator. It is also desirable to maintain a constant torque output pressure varies.

It can now be seen that the stroke control apparatus associated with the units 54 and 55 is automatically adjusted, in accordance with the teachings of the present invention, so that during the pulling out cycle when energy is being supplied to the accumulator, the stroke is high and the energy stored is great, while during reeling in when energy is expended from the accumulator, the stroke is such that less energy is spent than that which is stored. The apparatus can therefore be adjusted exactly to compensate for the friction losses of the system so that under ordinary conditions of operation no output from the unit 69 will be required during the entire transfer operation.

In the foregoing discussion nothing has been said regarding the operation of the drum 51. If the drum 51 is to be operated in lieu of the drum 50, the procedure will be as outlined above except that the valves 64 and 65 will be adjusted to connect control valve 58 rather than control valve 56 to the accumulator system. If both of drums 50 and 51 are to be used concurrently, the valves 64 and 65 are adjusted to connect both of valves 58 and 59 to the accumulator system in parallel. It is likewise apparent that any number of cable drums may be operated in like manner by a suitable combination of operating the motor 70 serving only to provide a safety factor. The power supply to the motor 70 during the automatic operation will have to be.
After the transfer of loads from one ship to the other has been completed and it is desired to reel in the cable, the cable is disconnected from the receiving ship and is reeled in by the action of the accumulator until the supply of pressure fluid therein is exhausted, at which time, if necessary, the motor 78 and the unit 99 take over to complete the reeling in operation.

In the foregoing discussion no mention has been made of the function of valves 92 and 96. Actually, the valve 92 is used to prevent high pressure working liquid from the accumulator from entering the vessel 94. When the vessel 94 is low in liquid, such as 96 is provided for safety’s sake in case the pressure in the system becomes excessive.

Now referring to Figures 6 and 7, there is shown a hydraulic system similar to that described in conjunction with Figure 3, but involving a different type of control apparatus for the main unit which is attached to the winch. In Figure 6 the hydraulic unit, which corresponds in structure and function to the unit 54 of Figure 3, is designated by the numeral 100. The unit is connected through conduits 101 and 102 to a piston valve 103 corresponding in structure and function to the piston valve 58. The piston valve is also connected to conduits 104 and 105, corresponding in structure and function to 51 and 60 respectively.

A stroke control device 106 is provided, said device having a piston 107 and a piston rod 108 attached pivotally at 109 to the wobble plate of the unit 100. The piston 107 is normally urged upwardly by a coil spring 110 so that the normal bias is to maintain the wobble plate in the zero stroke position. The cylinder 111 in which the piston 107 operates, affords a working space 112 above the piston 107 and the working space is connected through a conduit 113 to a piston valve 114. The piston valve is connected to the conduit 101 by conduits 115 and 116 and a check valve 117 is placed in the conduit 101 between the point of attachment of conduit 115 and the point of attachment of conduit 116. Another conduit 118 extends from the piston valve 114 to the conduit 104.

By the arrangement just described the hydraulic unit 100 can be put on high stroke during pulling out so that it will pump a larger quantity of oil during that period than the oil which is used during retrieving. The control valve 114 and the check valve 117 together provide means of registering the direction of oil flow. This allows the control device 106 to introduce pressure on top of the stroke control piston 107 during pulling out.

More specifically, during pulling out, when the drum is driving the unit 100 and the unit 100 is functioning as a pump, liquid is being forced in the direction of the arrow of Figure 6 in line 101. Since valve 117 is closed, the liquid flows into line 101 and up line 115 to act on a plunger 119 located in valve 114. The plunger 119 is normally biased by a spring 120 into the position shown in Figure 7, but when pressure is supplied through the conduit 115, spring 120 is compressed, and the plunger 119 assumes the position shown in Figure 7. The pressure in line 119 establishes flow from conduit 115 through conduit 113 to working space 112, whereby as pulling out occurs pressure is introduced in working space 112 and the unit 100 is urged to the maximum stroke position. On the other hand, during reeling in or retrieving the liquid in conduit 101 is flowing toward the unit 100 instead of away from it. Thus, valve 117 is opened and liquid flows through conduit 101 and exerts pressure in parallel through conduits 115 and 116. This being the case, valve plunger 119 under the bias of spring 120 remains in the Figure 7 position cutting off pressure in conduit 113 so that spring 110 returns the piston 107 to the upper position and restores the wobble plate of the unit 100 to a lower stroke position.

In Figures 6 and 7 there is shown in association with the tilt plate mechanism a pair of adjustable stops 121 and 122. These stops act on a tongue 123 extending from the wobble plate of the unit 100. These stops function to keep the rolling space so that the correct stroke for oil pumping and torque output for any given pressure can be achieved by adjustment. The advantage of the stops 121 and 122 will be appreciated when it is borne in mind that the load imposed on the cable connecting the two ships will vary with the nature of the cargo being transferred. If the load conditions are light, the cable can be maintained in the predetermined position by subjecting it to much less tension than is required when the load is great. If a light load is encountered, the stops 121 and 122 are adjusted so that the stroke of the unit 100 is kept short, thereby reducing the load imposed on the cable and allowing the entire system to operate at less than capacity. The stops 121 and 122 do not prevent the unit 100 from operating at full capacity, since if a full capacity load is encountered, it is necessary only to adjust the stops to permit maximum stroke operation. It is to be understood of course that the stops need not be associated with the tongue 123 but can be associated with any part of a wobble plate assembly.

In the foregoing discussion of the operation of the piston valve 116, the details of construction of that valve were not described and, in fact, they are susceptible of some modification. However, the form shown in Figure 8 includes the valve body a channel 124, and in the piston, radial ports 124 communicating with the central core in which the spring 120 is mounted. It can be seen therefore that when pressure liquid is flowing, as indicated in Figure 8, pressure is exerted on the bottom of the piston 116, and through the port 123, and an annular groove in the piston 119, this liquid is made available to the line 113 and the working space 112. Most of the pressure liquid, however, flows out through line 116 back into line 101 on the other side of the valve 117. In the Figure 8 position of line 118, through radial channel 125, is in communication with the center of the piston, wherein liquid from line 118 is trapped.

In the Figure 7 position communication is established from line 101 and line 116, and in this way liquid dispelled from working space 112 is returned to the system at line 104. The liquid in line 101 continues through line 115 to act on the bottom of the piston, but because of ports 124 and line 116, this same liquid also operates on the other side of the piston.

It will be understood that the foregoing description is demonstrative of the invention but is not nearly indicative of all of the forms which it may assume. Thus, not only are the principles of the present invention utilisable in connection with the pulling out and reeling in of cable, but they are of wide general utility in employing the rolling inertia of ships to provide means to meet some or all of the power require-
ments of it. Throughout the specification reference has been made to hydraulic units of the parallel piston type. It is quite apparent, however, that other types of hydraulic units such as the radial type can be used or that the entire system be operated by electrical rather than by mechanical means.

What is claimed is:

1. In combination, a ship, a piston and cylinder type hydraulic work-energy converter of the type equipped with means to vary the stroke of the pistons to vary the energy output of the converter, said converter including a winch mounted on a portion of the ship, a structure separate from the ship and including a connection point relatively movable in response to wave-induced roll with respect to said winch, a cable connecting said winch and said connection point so that the converter is driven when said portion and said point move relatively away from one another and the converter causes the winch to reel in cable when said portion and said point move relatively toward one another, a hydraulic accumulator means connecting said accumulator to said converter, and means responsive to a pressure change in said connecting means to control the stroke of the pistons of the converter.

2. In combination, a ship, a hydraulic work-energy converter of the piston and cylinder type equipped with means to vary the stroke of the pistons to vary the energy output of the converter, said converter including a winch mounted on a portion of the ship spaced from the axis of roll, a structure separate from the ship and including a connection point relatively movable in response to wave-induced roll with respect to said portion of the ship, capable connecting said winch and extending between said converter and said connection point so that the converter is driven when said portion and said point move relatively toward one another, a hydraulic accumulator, conduits connecting said accumulator to said converter and means responsive to the direction of flow in one of said conduits to control the stroke of the pistons of the converter.

3. In combination, a ship, a hydraulic work-energy converter of the piston and cylinder type equipped with means to vary the stroke of the pistons to vary the energy output of the converter, said converter including a winch mounted on a portion of the ship spaced from the axis of roll, a structure separate from the ship and including a connection point relatively movable in response to wave-induced roll with respect to said portion of the ship, a cable connecting said winch and extending between said converter and said connection point so that the converter is driven when said portion and said point move relatively away from one another and the converter causes the winch to reel in cable when said portion and said point move relatively toward one another, a hydraulic accumulator, a reservoir, a conduit connecting said accumulator to said converter, another conduit connecting said converter to said reservoir, means responsive to decrease in pressure in the conduit connecting said accumulator and converter for increasing the piston stroke of said converter, said converter including a winch mounted on a portion of the ship, a structure separate from the ship and including a connection point relatively movable in response to wave-induced roll with respect to said winch, a cable connecting said winch and said connection point so that the converter is driven when the winch and the point move relatively away from one another and the converter causes the winch to reel in cable when the winch and the point move relatively toward one another, a hydraulic accumulator, conduits connecting said accumulator to said converter, means responsive to one direction of flow in one of said conduits for applying pressure from said conduits to said converter to convert the range of variation of the conversion ratio of said converter, said converter including a winch mounted on a portion of the ship, a structure separate from the ship and including a connection point relatively movable in response to wave-induced roll with respect to said winch, a cable connecting said winch and said connection point so that the converter is driven when the winch and the point move relatively away from one another and the converter causes the winch to reel in cable when the winch and the point move relatively toward one another, a hydraulic accumulator, conduits connecting said accumulator to said converter, the pressure responsive means normally biased said conversion varying means toward the minimum conversion ratio, valve means responsive to the direction of flow in one of said conduits for applying pressure from said conduits to said converter to convert the range of variation of the conversion ratio of said converter, said converter including a winch mounted on a portion of the ship, a structure separate from the ship and including a connection point relatively movable in response to wave-induced roll with respect to said winch, a cable connecting said winch and said connection point so that the converter is driven when the winch and the point move relatively away from one another and the converter causes the winch to reel in cable when the winch and the point move relatively toward one another, a hydraulic accumulator, conduits connecting said accumulator to said converter, means responsive to one direction of flow in one of said conduits to isolate said pressure responsive means from the pressure in said one of said conduits so that the biasing means is effective.

5. In combination, a ship susceptible to generally cyclic motion, a mass remote from the ship, said mass constrained to motion differing from that of the ship, means interconnecting the mass and the ship, a work to energy converter connected to the connecting means, energy storing means connected to said converter to receive energy therefrom, a load connected to said energy storing means, said mass constituting means responsive to one portion of the cyclic motion of the ship connected to drive said converter to cause it to supply energy to said storage means, load-responsive means for controlling the energy output of the converter and means for adjusting the range of operation of the load-responsive controlling means.

6. In the combination of a floating element subject to wave action, a work to energy converter on said element, said converter being adjustable as to energy input and work output, energy storing means to receive energy from said converter and means responsive to wave induced movement of the floating element to do work on said converter to cause it to deliver energy to said storing means, said converter including means movable in response to changes in the magnitude of the energy stored in said storing means and linkage means connected to said movable means and to said converter and controlled by said movable means to adjust the rate of energy output of said converter to said energy storing means in inverse proportion to the magnitude of the energy stored in said storing means.

JOSEPH C. PATTERSON, Jr.

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