# United States Patent

[11] 3,612,486


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[45] Patented **Oct. 12, 1971**



[73] Assignee **Her Majesty the Queen in right of Canada as represented herein by the Minister of National Defence of Her Majesty's Canadian Government**


[54] **VERTICAL LOAD TRANSFER**
**14 Claims, 5 Drawing Figs.**


[52] **U.S. Cl.** ..... **254/172,** 254/173, 254/144
[51] **Int. Cl.** ..... **B66d 1/50,** B66d 1/48
[50] **Field of Search** ..... 254/144, 147, 172, 173, 186; 187/20, 27



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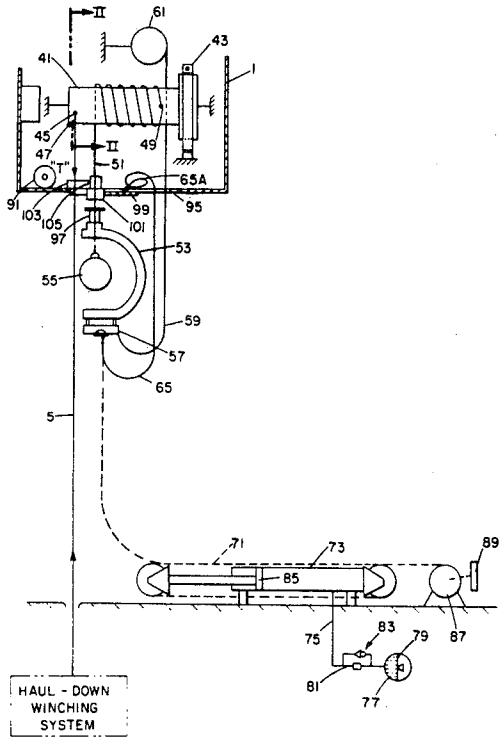
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*Attorney*—Stevens, Davis, Miller & Mosher



**ABSTRACT:** This application discloses a system for lowering a delicate load to the deck of a ship from a helicopter. A first cable maintained at constant tension extends up from the ship, round a pulley or drum carried by the helicopter and down to the said load. This provides support which is substantially constant for the load. A second cable extends down from the load to the ship, and is used to winch the load down to the ship. The system can be used to raise loads from the ship to the helicopter, and can be used for other similar load transfer situations.

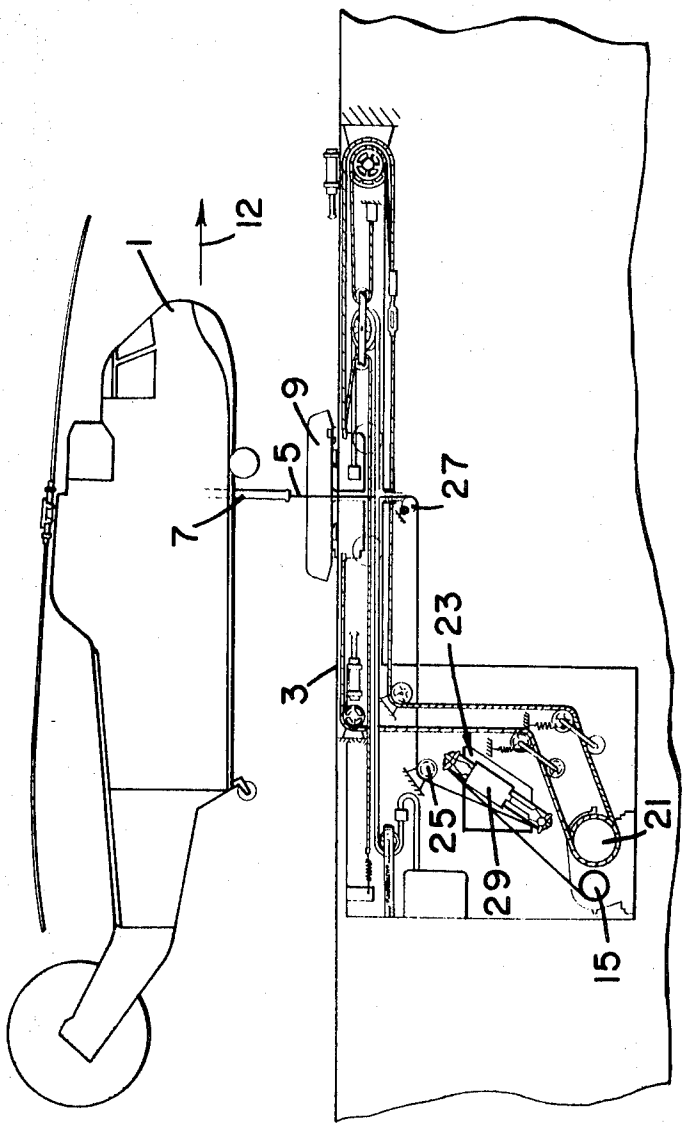



FIG. 1

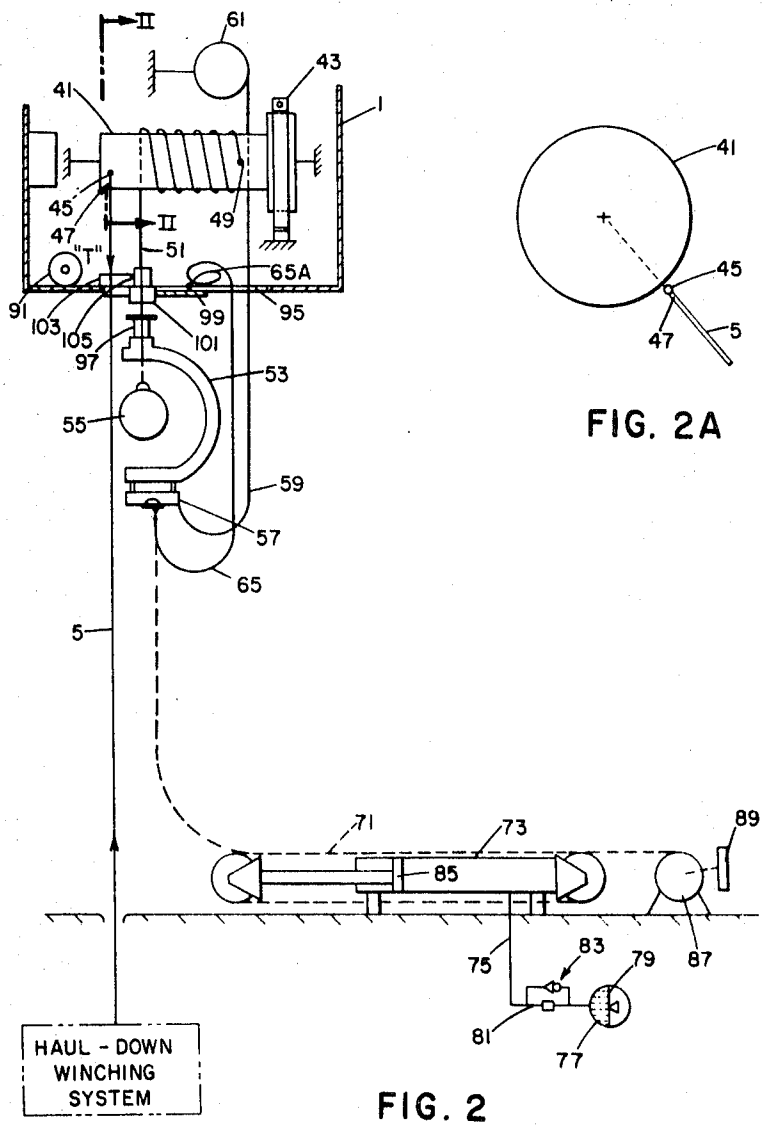

II
61
43
41
1
45
47
"T"
49
II
51
65A
91
103
105
97
99
101
95
53
55
59
57
65
5
71
73
89
85
75
83
79
87
81
77
HAUL - DOWN
WINCHING
SYSTEM

FIG. 2


41
45
47
5

FIG. 2A

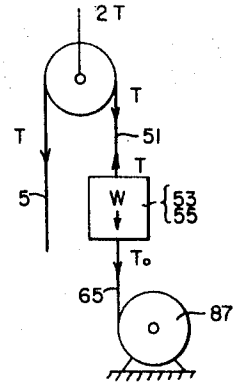

2T
T
T
51
T
5
W
53
55
To
65
87

FIG. 3

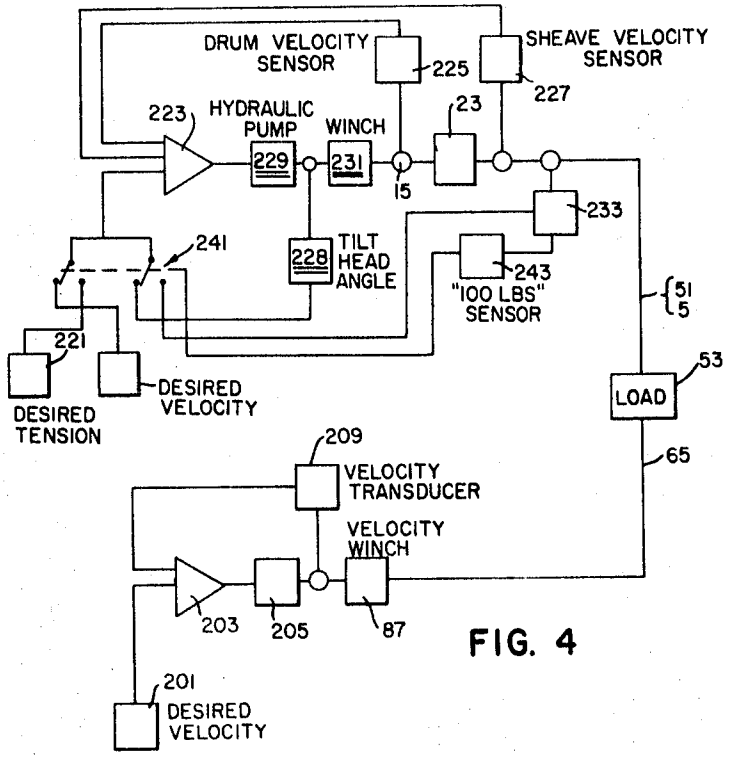

DRUM VELOCITY SENSOR
225
SHEAVE VELOCITY SENSOR
227
223
HYDRAULIC PUMP
229
WINCH
231
23
15
233
241
228
TILT HEAD ANGLE
243
"100 LBS" SENSOR
51
5
221
DESIRED TENSION
DESIRED VELOCITY
LOAD
53
65
209
VELOCITY TRANSDUCER
VELOCITY WINCH
203
205
87
201
DESIRED VELOCITY

FIG. 4

# VERTICAL LOAD TRANSFER

This invention relates to the provision of a system which will enable a delicate load to be lowered to the deck of a ship from a helicopter with minimum possibility of damage to that load. It will be appreciated that when the ship is pitching, the load is liable to impact the deck violently, and it is important to lower the load onto the deck of the ship with minimum practical acceleration with respect to the ship's . deck.

According to the present invention, means suitable for effecting the vertical or substantially vertical transfer of objects between an upper station and a lower station subject to unpredictable but limited relative vertical movements, comprise constant tension winch means carried by the lower station, pulley means carried by the upper station, first cable means connected at a first end to the winch means and extending from the winch means to the pulley means carried by the upper station and attached at their second end to a load to be lowered from the upper station, and further cable means extending downwardly from the said load to haul down winch means also carried by the second station, whereby the load is supported by the first cable means with a substantially constant force, and the load is forcibly drawn from the upper station to the lower station by the force in the further cable means.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a diagrammatic side elevation of a helicopter and of a ship-borne haul-down system for that helicopter, and is included to show the form of a constant tension haul-down winching system utilized in the carrying out of the present invention.

FIG. 2 is a diagrammatic representation of the arrangement of tackle between a helicopter and a ship during the transfer of loads between the helicopter and the ship;

FIG. 2A is a diagram in the form of a sectional end elevation taken on the line II—II of FIG. 2;

FIG. 3 is a force diagram showing how forces acting on a load during lowering are balanced; and

FIG. 4 is a circuit diagram indicating the control of a tension winch and a velocity winch shown in FIG. 2.

Referring first to FIG. 1, it has been proposed in copending Canadian Pat. application Ser. Nos. 887,011 and 914,140 that a helicopter 1 shall be hauled down onto the deck 3 of a ship at sea by a cable 5 acting against the lift produced by the helicopter rotor. This enables the helicopter to land safely despite pitching of the ship and despite the action of wind on the aircraft. In those proposals, a probe 7 carried by the helicopter 1 is seized in a trap 9 carried by the ship so that once the helicopter has landed it is held firmly against movement relative to the ship, and eventually the trap is used to transport the helicopter bodily into a hanger in which the helicopter is stored.

As described in those earlier patent applications, an electric motor (not shown) is coupled to the driving shaft of a variable displacement hydraulic pump, connected in closed circuit to a fixed displacement hydraulic motor. Such an arrangement is well known in the art, and commonly makes use of a pump with a tiltable swashplate or a pump with a fixed swashplate but an adjustable tilt head. The output shaft of this hydraulic motor is connected through a gearbox alternatively either to a drum 15 of haul down winch or to a drum 21 of a trap traversing winch. The cable 5 has one end wound on the drum 15 and extends from the winch drum first over pulleys of a rope accumulator 23 and then round a guide sheave 25 and finally over a sheave 27 before passing upwardly through the deck 3 to the helicopter 1. The rope accumulator includes a first set of pulleys and a second set of pulleys, the two sets being biased apart by a pneumatic cylinder device 29 which has a force/displacement characteristic such that the force biasing the two sets of pulleys apart increases progressively as the two sets are forced closer together by the tension in the cable 5.

The present invention does not relate to the probe 7 or the trap 9 or the trap traversing winch associated with drum 21. However it does make use of the cable 5 and the associated drum 15 and rope accumulator 23.



As shown in FIG. 2, mounted inside the fuselage of the helicopter 1 is a winch drum 41 arranged with its axis horizontal and provided at one end with a drum brake 43. This drum 41 is free to rotate in each direction when not held by brake 43. At its end remote from brake 43, drum 41 is provided with an eye bolt 45 to which a cable 5 can be connected by a shackle 47. Near the brake 43, the drum 41 is provided with an anchor 49 to which one end of a load cable 51 is connected by a suitable shackle. Load cable 51 is long enough to reach from the helicopter to the ship deck 3 during a load-lowering operation, but as shown is normally wrapped round the drum 41 and has its other end connected to the upper end of a C-shaped load support frame 53. This frame 53 is big enough to extend round a load 55 to be lowered from the helicopter to the ship deck, and carries in its upper part a suitable support by which the load 55 can be suspended. If desired, the load 55 can be supported on the lower part of the frame 53.

Fitted to the underside of the frame 53 is an electrically releasable shackle 57, and an actuating electrical cable 59 for this shackle extends from the shackle up round the frame 53 to an electric cable reel 61 carried by the helicopter. The reel 61 is provided with a reversible driving motor, by means of which an operator can pay out or reeve in cable 59 as he deems necessary. A load transfer winching cable 65 is connected at one end to the frame 53 in a readily detachable manner through the shackle 57, the cable 65 extending up past the frame 53 and being stored as a loose coil at 65A on the floor of the helicopter.

Additional equipment provided on the deck 3 of the ship includes another rope accumulator 71 generally similar to the rope accumulator 29. Accumulator 71 includes an hydraulic cylinder 73 connected through a pipe 75 to a hydropneumatic accumulator 77 having a diaphragm 79 separating a gas under pressure from the liquid used in the cylinder 73. The pipe 75 includes a flow restricting orifice 81 shunted by a nonreturn valve 83 which permits free flow of liquid during inward movement of piston 85 in the cylinder 73. Thus inward movement is not seriously impeded but outward movement is seriously dampened. Associated with accumulator 71 is a deck wince 87 provided with a clutch 89 which can be operated to cause the winch drum to freewheel. A messenger winch 91 driven by a reversible electric motor is provided in the helicopter, but if desired this can be omitted and a messenger winch of the haul-down system used in its place.

The floor of the helicopter is provided with an aperture 95 through which the various cables can extend, and this aperture is of such size that the upper part of the load support frame 53 can be drawn up into the helicopter body. The top of the frame 53 is provided with a spring-loaded buffer 97, and a slidable shutter 99 can be moved from the position shown, in which a stop 101 on the shutter 99 engages the buffer when the frame 53 is raised excessively, to an open position in which the upper part of frame 53 is free to rise into the body of the helicopter. Respectively adjacent aperture 95 and on shutter 99 are provided first and second power operable guillotines 103 and 105. These are arranged when actuated (the frame 53 being below the helicopter) to sever respectively the cable 5 and the cable 51.

Turning now to the use of the load handling system of FIGS. 2, 2A and 3, the two winches 15 and 87 are required to operate the load handling system of the present invention. The primary winch 15 is used to provide a constant tension in cable 5, which during loading and unloading is shackled to the drum 41 and thus is effectively connected through the cable 51 to the load support frame 53 as if cables 5 and 51 were a single length of cable. The tension during use in cables 5 and 51 must exceed the cable tension necessary to support the weight of the load 55. The secondary deck winch 87 is used to control the rate of descent of the load 55 onto the deck 3 of the ship, and cable 65 at this time is connected (see dotted line in FIG. 2) at one end to the winch 87 and at the other end to the shackle 57 of the load support frame 53.

## SEQUENCE OF OPERATION

To raise the load **55** from the deck of a supply ship to the helicopter, the helicopter **1** hovers over the supply ship at a height of about 50 feet and lowers a light messenger cable to the deck crew by means of the messenger winch **91**. The deck crew attach the shackle **47** on cable **5** to the messenger cable, and the helicopter crew then winches the messenger cable with the free end of the cable **5** up to the helicopter. Once cable **5** is inside the helicopter, the shackle **47** is transferred to the eyebolt **45**. At this time, the helicopter will be about 50 feet above the ship and slightly aft of the ship, so that the cable **5** will extend upwardly at a slight inclination to the vertical, as indicated in FIG. **2A**, which is a view of the drum **41** as viewed from one side of the helicopter and the ship. It is important that the force on cable **5** shall be applied to the helicopter through the axis of drum **41** and therefore at the time of connection the drum **41** is held by the brake **43** with the eyebolt **45** in the position shown in FIG. **2A**.

The winch **15** is now set by a controller on the ship to produce an appropriate constant tension to the cable **5**, and the helicopter is then tethered to the ship, the force produced by the helicopter rotor being sufficient to counter balance both the tension T in the cable **5** and the weight of the frame **53** and the other downward forces acting on the helicopter.

The free end of the load transfer winching cable **65** (i.e. the part of that cable in coil **65A**) is now lowered by the helicopter crew to the ship deck. This cable can be dropped, but usually it will be thought better to lower it by the messenger cable of messenger winch **91**. The crew of the ship reeve the free end of the cable **65** round the pulleys of the accumulator **71** and attach the free end to the drum of winch **87**. With the cable **65** slack, the helicopter crew slacken the brake **43** so that the drum **41** revolves until the clockwise and anticlockwise torques on it, produced by cables **5** and **51**, are balanced. It is to be noted that the total force in cable **51** is less than the total force in cable **5**, and this must be so if the frame **53** is not to descend unchecked. However, initially the line of action of cable **5** is through the axis of drum **41**, so that it produces zero torque, and the position of rest will be reached in less than a quarter turn of the drum **41**, which in the worst initial case of cable **5** being vertical would bring cable **5** into tangential position relative to the drum.

The controller on the ship now operates deck winch **89** to take in the slack on the cable **65** and to apply a tension to the cable. This will increase the load in cable **51** and thus the torque applied by that cable on drum **41**. The drum will change its angular position to maintain the two torques on it equal, but since the torque which cable **5** can produce is limited by the (constant) tension in this cable, once the torque produced by cable **51** rises above the limiting value for cable **5**, the load frame **53** will commence to descend.

During descent, the forces acting on the frame **53** and the drum **41** will be as shown in FIG. **3**. For non accelerating transfer of the frame **53**, the force T in cable **5** and the equal force T in cable **51** will set up a downward force of 2T on the drum **41** which will be balanced by the reaction of the drum bearings. The force T in cable **51** will set up an upward force T on the frame **53**, and this will be balanced by the sum of the downward force W produced by the weight of frame **53** and the downward force *T0* produced by the tension T*O* in the cable **65**. For the sake of simplicity, the weights of the cables **5**, **51** and **65** are ignored in the present discussion, but in practice these would need to be considered if cables **5** and **65** had a different "weight per foot length." During descent, any change in the relative positions of the helicopter and the ship are accommodated by the action winch the winch **15**, which operates automatically to keep the tension in cable **5** constant. Ideally, a change in the distance of the helicopter from the ship would not cause any change in the effective length of cable **65**, so that the load supporting frame **53** would remain at a constant distance from the ship. This means that the distance of the frame **53** from the helicopter would vary, and this is compensated for automatically by the control system for the winch **15**. Changes which are too fast for the winch **87** to follow would be accommodated by the taking-in or the paying-out of cable **5** at the accumulator **23**. In practice, the accumulator **71** would operate to smooth out snatch loadings such as would arise if the ship drops suddenly in the trough of two waves. The speed of descent is controlled by the speed of winch **87**.

When the load frame **53** is settled on the deck of the ship, the ship crew attach the load **55** to the frame **53**. This causes no upset in the force system, since the force *T0* falls to such a level that the force T*O* plus the weight of the frame **53** and the weight of load **55** together equal force T in cable **51**. The deck winch **87** is now operated to pay out cable **65** so that the frame **53** with the load **55** rises towards the helicopter. The frame **53** is drawn up until the buffer **97** engages the stop **101**, and the brake **43** is then applied. Care is taken that the drum **41** is locked in the position shown in FIG. **2A**. The clutch **89** is now released so that the force *T0* falls to zero (apart from the weight of the cable). The helicopter winch **91** is used to lower the messenger cable, the lower end of cable **65** is freed from winch **87** and accumulator **71**, and this end of cable **65** is drawn up by the messenger cable and stored in the helicopter at **65A**. The controller on the ship progressively reduces the tension in the tethering cable **5** and when this tension is zero (apart from the weight of the cable) the shackle **47** is released from the winch eyebolt **45** and this end of cable **5** lowered to the ship. It may be dropped, or it may be lowered by the messenger cable of winch **91**, as desired.

The helicopter is now free to fly to the ship to which the stores, represented by load **55**, are to be transferred. The procedure described above, as used at the supply ship, will be repeated, except that of course during the lowering of frame **53** it will contain the load **55** and during raising it will be free of the load.

Also shown in FIG. **2** is a hydraulic motor-and-clutch unit **201** which can be supplied if desired. This motor-and-clutch unit **201** is normally disconnected by its clutch from the drum **41**, but when desired the clutch can be engaged and, with the brake **43** released, the motor used to drive the drum **41** to raise or lower the frame **53**. This is a useful ancillary facility, and does enable the helicopter to dispose of the frame **53** and load **55** when for any reason the system described above cannot be used.

The helicopter **1** cannot take off or land with the frame **53** in the position shown in FIG. **2**. During landing and takeoff, the frame **53** can be drawn up partly into the helicopter **1** to enable the usual landing means to be operative. Alternatively, the frame **53** can be lowered onto the deck of a ship; the brake **43** applied to lock the drum **41**; cables **51** and **59** disconnected from the frame **53**; cable **59** reeled in by its winch **61**; the brake **43** allowed to slip so that the tension in cable **5** rotates drum **41** firstly to unwind cable **5** from that drum and secondly to wind cable **51** back on that drum, the drum **41** finally being braked again in the orientation shown in FIG. **2A**; the tension in cable **5** removed progressively, the shackle **47** disconnected from the eyebolt **45** to free the helicopter from the ship, and the free end of the cable **5** lowered to the ship.

The following data relate to one embodiment of the invention:

The proposed system has been designed within following assumptions:

1. The helicopter will lift a load greater than 5,000 lbs. fully fueled.
2. The maximum load is limited to 3,000 lbs.
3. Maximum velocity between ship and helicopter 20ft./sec.
4. Maximum acceleration between ship and helicopter 20ft./sec$^2$.
5. The height of the helicopter undercarriage above deck for transfer is 50 ft. $\pm$ 30 ft.
6. Maximum velocity of velocity winch 3ft./sec.
7. Maximum tension variation on helicopter: $\pm$15 percent of total load on helicopter.

FIG. 4 illustrates a control system which controls the operation of the tension winch **15** and the velocity winch **87**. As regards the velocity winch **87**, and control **201** operated by the controller of the transfer operation sets the desired rate of ascent or descent of the load frame **53**. Through an amplifier **203** the signal from control **201** determines the operation of motor/gear box unit **205** driving the velocity winch **87**. A velocity transducer **209** provides the amplifier **203** with a second input which indicates the actual speed of operation of the winch and thus the actual velocity of the cable **65**.

As regards the constant tension winch **15**, a control **221** operated by the controller of the transfer operation sets the desired tension in the cables **5** and **51**. The output from control **221** is applied to an amplifier **223** together with a second input from a tachometer **225** which indicates the actual velocity of the drum of the winch **15** and a third input from a tachometer **227** which indicates the actual velocity of the cable **5** at the point where it leaves the ship. Control of the winch **15** is by adjustment of the "tilt-head" **228** of the hydraulic drive for the winch, the winch being driven by an electric motor which drives a hydraulic pump **229** arranged to drive the hydraulic motor **231** of the winch. A tension transducer **233** associated with a sheave carried by the ship and about which the cable **5** is wrapped before it extends upwardly to the helicopter, provides an indication of the actual tension in the cable **5**. The output from this transducer is used during "constant tension" operation to buck the signal from the control **221** and so provide an indication of error between desired tension and actual tension in the cables **5** and **51**. It will be noted that in FIG. **4** a switch **241** is provided by which the winch **15** can be changed from "constant tension" operation to "velocity" operation during taking up of slack in the cables. The output from tension transducer **233** is applied to a sensor **243** which is effective when the cable tension reaches 100 pounds, during "velocity" operation, to change the setting of the switch **241** and so transform the winch operation automatically from "velocity" to "constant tension."

It may occasionally be necessary in an emergency to abort a transfer operation and rapidly to disconnect the helicopter from the ship. This can be done by activating the guillotine **103** to sever the cable **5** and by releasing the shackle **57** to release the cable **65** from the frame **53**. The helicopter can then veer away from the ship. The guillotine **105** is provided so that if necessary the frame **53** with the load **55** can be jettisoned by cutting the cable **51**. However, this would not be done while the helicopter was still over the stern of the ship.

We claim:

**1.** Means suitable for effecting the vertical or substantially vertical transfer of objects between an upper station and a lower station subject to unpredictable but limited relative vertical movements, comprising:

a. constant tension winch means carried by said lower station;
b. pulley means carried by said upper station;
c. first cable means having a first end and a second end;
d. a first connection between said first end of said first cable means and said winch means;
e. a second connection between said second end of said cable means and said object;
f. an intermediate part of said cable means extending from said first end to said pulley means and thence to said second end;
g. further cable means having a first end and a second end;
h. a third connection between said first end of said further cable means and said object;
i. haul down winch means carried by said lower station;
j. a connection between said second end of said further cable means and said haul down winch means;
k. readily releasable means which serve as said third connection between said first end of said further cable means and said object;
l. messenger winch means provided at said upper station; and
m. said messenger winch means being adapted when operated to raise said second end of said further cable means from said lower station to said upper station;

whereby said object is supported by said first cable means with a substantially constant force, and said load is forcibly drawn from said upper station to said lower station by the force in said further cable means.

**2.** Transfer means according to claim **1**, and in which:

a. said first cable means include a first cable and a second cable;
b. said pulley means are in the form of a drum;
c. said drum is adapted to accommodate several turns of said first cable and several turns of said second cable;
d. a first end of said first cable constitutes said first end of the cable means;
e. a second end of said first cable is connected to said drum;
f. a first end of said second cable is connected to said drum; and
g. a second end of said second cable constitutes said second end of said cable means.

**3.** Transfer means according to claim **2**, and in which:

a. said drum is mounted in a freely rotatable manner; and
b. a brake is associated with said drum and is effective to hold the drum in a desired position.

**4.** Transfer means according to claim **3**, and in which motor means are provided operatively connected to said drum, and effective when activated to drive said drum in either direction as desired.

**5.** Transfer means according to claim **1**, and in which;

a. a snatch absorbing device is provided; and
b. said further cable means during vertical transfer of said object extend from said object to said snatch absorbing device and then to the haul down winch.

**6.** Transfer means according to claim **5**, and including;

a. a first set of pulleys;
b. a second set of pulleys;
c. biasing means arranged to bias the two sets of pulleys apart by a force which increases as said sets of pulleys approach one another;

said sets of pulleys and said biasing means with part of a cable of said further cable means forming a cable accumulator which serves as said snatch absorbing device.

**7.** Transfer means according to claim **1**, and in which:

a. a snatch absorbing device is provided;
b. the first cable means pass through the snatch absorbing device; and
c. the snatch absorbing device is positioned close to the constant tension winch means.

**8.** Transfer means according to claim **7**, and including:

a. a first set of pulleys;
b. a second set of pulleys;
c. biasing means arranged to bias the two sets of pulleys apart by a force which increases as the sets of pulleys approach one another;

said sets of pulleys and said biasing means with part of a cable of said first cable means forming a cable accumulator which serves as said snatch absorbing device.

**9.** Transfer means according to claim **8** and including:

a. a first transducer providing an output indicative of the speed of said first cable means at said winch side of said cable accumulator;
b. a second transducer providing an output indicative of said speed of said first cable means at said load side of said cable accumulator;
c. sensitive means arranged to received these two outputs; and
d. a control system including said first and second transducers and said sensitive means and arranged to control said constant tension winch means; said control system being arranged in accordance with the output from said sensitive means to provide an anticipatory control of said winch means tending to keep the cable tension constant.

**10.** Transfer means according to claim **1**, and including:

a. a transducer providing an output indicative of the speed of said second cable means;
b. a control providing an output indicative of a desired speed for said second cable means;
c. sensitive means to which these two outputs are applied; and
d. a control system including said transducer, said control and said sensitive means, and arranged to control the operation of said haul down winch means, and arranged to control said winch means to keep the speed of the second cable means constant.

**11.** Transfer means according to claim **1**, and in which said object includes a C-shaped load support frame adapted to accommodate and support the weight of a load to be transferred between said upper and lower stations.

**12.** Transfer means according to claim **11**, and in which said C-shaped load support frame is provided at its top with a buffer by which upward movement of the frame is checked when it reaches said upper station.

**13.** Transfer means according to claim **1**, and in which said further cable means are coupled to the bottom of said object through a remotely releasable shackle.

**14.** Means suitable for effecting the vertical or substantially vertical transfer of objects between an upper station and a lower station subject to unpredictable but limited vertical movements, comprising:
a. constant tension winch means carried by the lower station;
b. first cable means including a first cable and a second cable and having a first end and a second end;
c. drum pulley means carried by the upper station adapted to accommodate several turns of the first cable and several turns of the second cable;
d. a connection between the first end of the first cable and the winch means;
e. a connection between the second end of said first cable and the said object;
f. said first end of the first cable connected to the drum by a readily detachable coupling;
g. a first end of the second cable connected to the drum;
h. a second end of the second cable constituting the said second end of the cable means;
i. an intermediate part of the cable means extending from the said first end of said first cable to the pulley means and thence to the second end;
j. further cable means having a first end and a second end;
k. a connection between the first end of the further cable means and the said object;
l. haul down winch means carried by the lower station;
m. a connection between the second end of the further cable means and the said haul down winch means; whereby the said object is supported by the first cable means with a substantially constant force, and the load is forcibly drawn from the upper station to the lower station by the force in the further cable means;
n. readily releasable means serve as the said connection between the first end of the further cable means and the said object;
o. messenger winch means provided at the upper station; and
p. said messenger winch means are adapted when operated to raise the said second end of the further cable means from the lower station to the upper station.