March 10, 1942. E. FRISCH 2,275,953

CONTROL SYSTEM FOR TOWING AND MOORING WINCHES

Filed Oct. 27, 1938 3 Sheets-Sheet 1

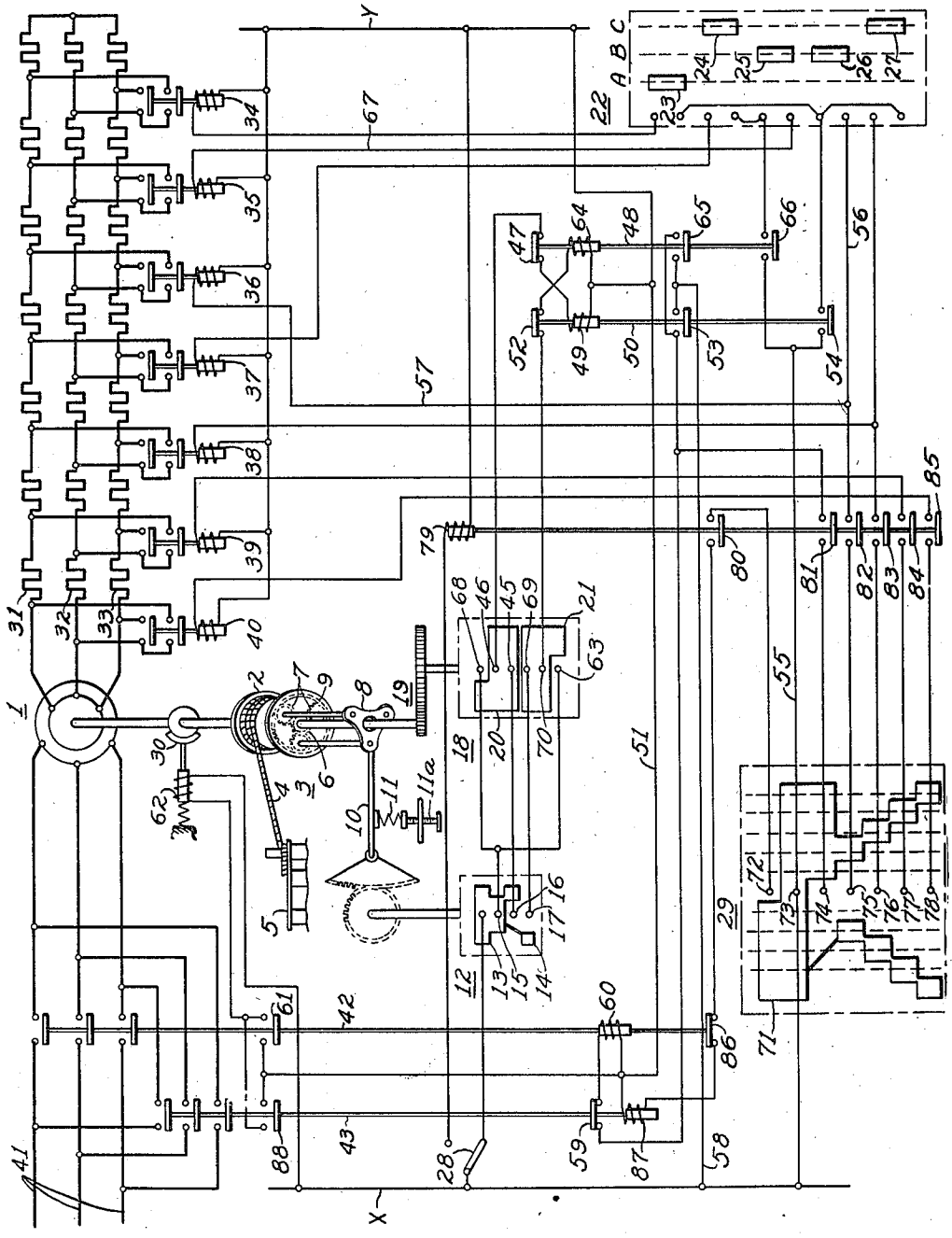


Fig. 1

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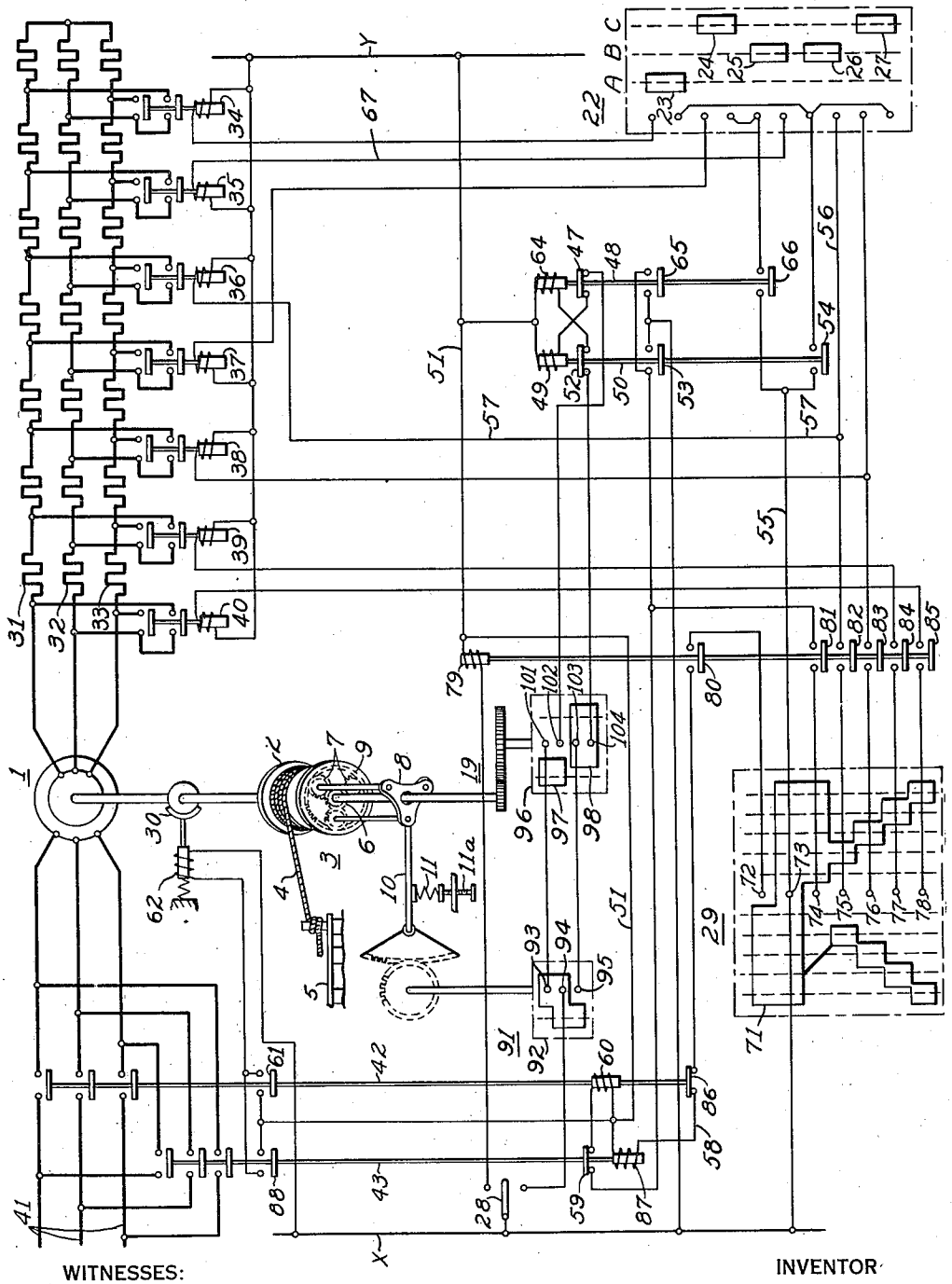


Fig. 2.

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CONTROL SYSTEM FOR TOWING AND MOORING WINCHES

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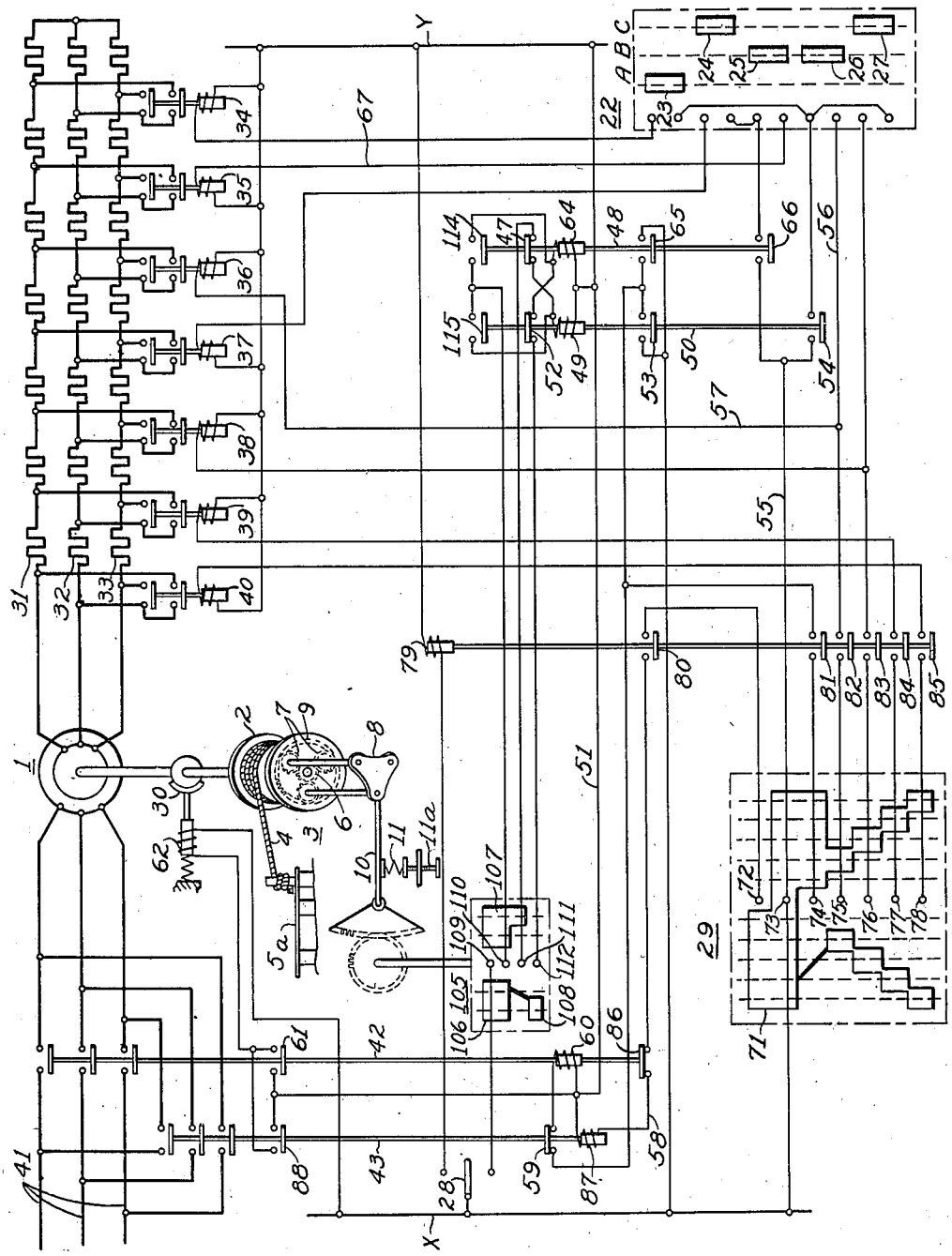


Fig. 3.

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2,275,953

CONTROL SYSTEM FOR TOWING AND MOORING WINCHES

Erling Frisch, Pittsburgh, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application October 27, 1938, Serial No. 237,293

7 Claims. (Cl. 254—172)

This invention relates to winches, such as towing winches or mooring winches, for maintaining a predetermined or desired tension, or length, or both in the towing or mooring cable.

One object of my invention is to provide a winch system for controlling a rope or cable to maintain the tension of the rope or cable within a predetermined tension range.

Another object of the invention is to provide a towing winch system for maintaining an average rope tension, and also for maintaining the effective towing length within a predetermined average range.

Another object of the invention is to provide a winch control system employing an alternating current motor that shall be controlled automatically, in accordance with the tension in the rope, to re-establish and maintain an average tension whenever the rope tension shall vary, during operation, beyond the limits of the permitted range.

Another object of the invention is to provide a system in which the permitted tension range, and the automatic control for maintaining the tension within such range, may be easily and readily adjusted.

In general, a towing or mooring winch comprises a drum, upon which the towing rope is to be wound, and a motor for controlling the operation of the drum.

In this system, operating according to the principles of my invention, auxiliary equipment is provided to control the circuit and energization of the motor to rotate the drum in one direction to heave in the rope, or to permit the rotation of the drum, under certain tension conditions in the rope, to permit the rope to pay out. When the rope tension is within a predetermined range the motor will be deenergized and a magnetic brake will be applied to lock the motor against casual rotation.

The motor is arranged to drive the drum through a planetary gear system with the ring gear fixed to the drum and the planet gears mounted upon a rotatably mounted spider. The spider is held against rotation, however, by a torque arm. The planet gears may thus rotate but not revolve. The reaction force of the drum against the planet gears is transmitted to the spider and tends to rotate the spider whether the motor is rotating or at rest. Since the torque arm holds the spider against movement, the reaction force against the spider is transmitted to the torque arm, and that force may thus be measured whether the motor and the drum are stationary or rotating.

In order to measure the torque applied to the drum by the towing rope, the torque arm is secured at one end to the spider, with its other end free to rotate with respect to the bed plate upon which the winch motor and drum are mounted, thereby by its position measuring the reaction force developed by the tension in the rope. Such reaction force developed in the torque arm is then employed to operate one of two limit switches respectively disposed at the limits of the permissible tension range, and the limit switches in turn control the appropriate circuits for initiating the type of control necessary in the motor to reestablish the rope tension within the permissible or desired range.

Briefly, the general operation is such that when the rope tension exceeds the maximum value of the permitted tension range, the corresponding high tension limit switch will cause its circuit to energize the brake release coil, to remove the brake from the motor, and to energize the motor to develop a stalled rotor torque less than the minimum value of the permitted tension range. Consequently, the towing rope tension will overcome the torque of the motor, and rope will be paid out until the rope tension diminishes to a value within the permitted tension range. The torque arm which measures the tension of the towing rope will then move back to a position at which the operated high tension limit switch will be reopened, and the equipment will operate automatically to deenergize the motor and to reset the brake to prevent further operation of the winch in response to the towing rope tension.

I also provide in the towing system, an additional control function to maintain the effective towing length within a predetermined range. Upon the termination of a paying out operation of the towing rope, in response to an excessive tension in the towing rope, such other control function will become effective after the rope tension has dropped to a value within the normal tension range, and the motor will then be energized to operate the winch to heave in rope until the effective towing length is brought back within the desired range, subject always, however, to the rope tension as the primary control function of the system.

If, conversely, the rope tension diminishes to a value below the lower limit of the tension range, the torque arm will be controlled to operate the low tension limit switch, and the motor will be energized in turn to operate the winch to heave in rope until the rope tension is increased to a value within the tension range. Here again, after the proper tension has been reestablished in the rope, its effective length will be readjusted, if necessary, to bring it back into the desired range of towing length.

In another control system, the tension limit switch and the rope length limit switch are modified to permit paying out and heaving in with the single control function of excess tension available for control. If the tension drops be-

low normal, variations in the rope length are permitted, instead of being diminished to restore normal tension.

In still another arrangement, the control system is applied to a mooring winch, where an additional function is desired, that requires a closer degree of control of the rope length within the permitted range. In a mooring winch system, it is necessary to keep the tension constant in a rope to hold a moored ship which is tied up to a dock, or being hoisted in a lock, to hold the ship in proper position in the lock or at the dock under changing conditions of draft or water level in response to loading or unloading.

Winch control systems, in which the control equipment for a motor is arranged to operate in accordance with the principles of my invention, are shown in the accompanying drawings, in which:

Figure 1 shows a circuit diagram of a control system according to my invention for controlling the rope tension and the rope length of the rope of a towing winch;

Fig. 2 shows a diagram of a system similar to that in Fig. 1, but modified in the structural and functional details of the tension limit and rope length switch; and

Fig. 3 is a diagram showing a system similar to that in Fig. 1, but applied to the control of a mooring winch, with a closer degree of control of the rope length.

As shown in the diagram of Figure 1, a winch suitable for towing or for mooring operation is illustrated as comprising a motor 1 and a drum 2 operated through planetary reduction gearing 3, all of which are mounted upon a bed plate (not shown) disposed on a tug boat or other boat or ship. The drum 2 is operated by the motor 1 to wind or to unwind a cable or towing rope 4 which is to be controlled by the motor and the associated equipment to maintain an average tension within the rope 4 and, when desired, maintain an average towing rope length, or distance between the towing winch and the barge or other object 5 to be towed by the rope.

The planetary gear system 3 consists of a sun or internal gear 6 secured on the motor shaft, three planetary gears 7, mounted on a spider 8, engaging the internal gear 6, and an external or ring gear 9 that engages the three planetary gears 7. The ring gear 9 is fixed to the drum 2. The spider 8 that supports and spaces the planetary gears, is rotatably disposed on the sun gear shaft and is free to rotate except as held against rotation by a torque arm 10 rigidly secured to the spider. The tension of the rope is transmitted to the drum and the ring gear 9. Whether the motor operates or not, the tension of the rope establishes a force between the ring gear 9 and the planet gears 7, which is translated into a reaction force against the spider 8, and thence, through the spider and the torque arm, is translated into a force acting on a spring 11, provided with an adjusting element 11*a*.

The torque arm 10 and the equipment to be controlled thereby will normally be arranged to permit the rope tension to vary between the limits of a predetermined tension range. The torque arm 10 is disposed to operate, by any suitable means as shown, a tension controller 12 shown developed in Fig. 1. Since the planetary gears and their supporting spider are symmetrically disposed around the motor shaft, that shaft is also the center of oscillation of the torque arm 10. The corresponding directions of rotation and motion are shown by the arrows.

The tension controller 12 is provided with segments 13 and 14, for engaging associated contact fingers 15, 16 and 17. Contact finger 16 will be engaged when the rope tension diminishes to a value at or below the lower limit of the permitted tension range, and contact finger 17 will be engaged when the rope tension attains or exceeds the upper limit of the permitted tension range. So long as tension in the rope is anywhere within the permitted range, the average tension contact finger 15 will be engaged.

In order to be able to measure the varying effective length of the towing rope, as modified by the continual tension adjustments, a rope length limit controller 18 is provided. This controller is operated by the motor 1 in proportion to movement of the winch drum 2, through a suitable reducing gear transmission 19, and operates the controller 18 according to the direction and extent of rotation of the drum 2.

In order to provide rope length control, the controller 18 is provided with two segments 20 and 21 coacting with appropriate contact fingers for controlling the operation of the switching equipment according to the direction and extent of movement of the controller 18.

As previously explained, the reaction spring 11 for the torque arm 10 is provided with an adjustment 11*a* by means of which the tension range, within which the towing rope shall operate, may be selectively varied. In order to vary the control of the electrical equipment correspondingly, a tension set-up controller 22 with several operating positions is employed to set up several circuits by means of which appropriate selected circuits may be established to control the electric motor 1 to establish the proper tension conditions in the rope.

The tension set-up controller 22 is illustrated as having five segments, numbered, respectively, 23 to 27. The controller has three positions, and, according to the position at which the switch will be set, one or more of the respective segments 23 to 27, inclusive, will be closed and held closed. Although three positions are illustrated, it will be obvious that any number of tension adjusting positions may be provided, to correspond to the mechanical adjustments available at the spring 11.

In order to permit either manual or automatic operation, a selector switch 28 is provided to place the entire system under manual control or automatic control, and a manually-operable master controller 29 having suitable segments and contact fingers is provided to permit the winch to be operated manually.

While the tension of the towing rope is in the permitted or desired range, the motor 1 will be deenergized and a brake 30 will be in such a position as to lock the motor against rotation by the towing rope through the winch drum and gear 3.

The motor 1 is shown as an induction motor having a wound rotor, or secondary. Three resistor banks 31, 32 and 33 are provided for the three phases of the secondary circuits, and torque control contactors 34 to 40, inclusive, are provided to connect different selected resistors into the secondary circuit of the induction motor to vary the torque to be developed in the motor. Energy for the motor is derived from an alternating current circuit 41 through either one of two directional contactors 42 and 43. The con-

tactor 42 connects the motor to the circuit 41 for rotation in one direction, that is, the heave-in direction; and the contactor 43 connects the motor to the circuit for rotation in the opposite direction, that is the pay-out direction.

Energy for the control circuits is derived from the buses X and Y. The buses X and Y may be connected to one phase of the energized circuit 41 or to any suitable source of control potential.

A still better understanding of my invention may be had from a study of typical operating cycles.

Rope tension decreases below operating tension range

Assuming the rope tension drops below the operating range selected by the tension set-up controller 22 and assuming that automatic operation is desired so that selector switch 28 is thrown to the lower position to energize the segments of controller 12, then the torque reaction arm 10 will operate the controller 12 in such a direction that contact finger 16 is engaged by segment 13. An energized circuit is thus established from bus X through selector switch 28, segment 13, contact finger 16 of controller 12, contact fingers 45 and 46 of controller 18, back contact members 47 of relay 48, actuating coil 49 of relay 50 and conductor 51 to bus Y.

Operation of relay 50 causes the opening of back contact members 52 to prevent erroneous operation of the directional contactors, and the closing of contact members 53 and 54.

If the tension set-up controller 22 is, for example, considered to be in position B, then the closure of contact members 54 establishes a circuit from bus X through conductor 55, contact members 54, controller segment 26, conductors 56 and 57, torque control contactor 36 to the bus Y. Another circuit is established from bus X through conductor 58 through the contact members 53 of relay 50, back contact members 59 of directional contactor 43, actuating coil 60 of directional contactor 42 and conductor 51 to bus Y.

Operation of directional contactor 42 connects the motor to the source of supply 41 for a direction of operation to heave in the cable and operation of the torque control contactor 36 inserts enough resistance in the secondary motor circuit to establish a stalled motor torque in excess of the higher limit of the tension range for which the equipment is adjusted. Operation of directional contactor 42 closes contact members 61 to thus release the brake 30.

In this manner when the rope tension drops below the lower limit of the permitted operating tension range, the motor energization is controlled to establish a high stalled rotor torque, to assure that the motor torque is sufficiently in excess of the permitted tension range to enable the motor torque to overcome the existing low tension in the tow rope, so that the motor may operate the winch to heave in rope until proper tension is reestablished in the tow rope at a value somewhere within the predetermined operating tension range.

When the rope tension is thus again increased to a value within the operating range, the torque arm 10 will be operated to move the tension controller 12 to an intermediate position, and thereby open the circuit for relay 50 at contact finger 16. The relay 50 will thus open the circuit of the operating coil 60 of the directional contactor 42 and also will open the circuit for the torque control contactor 36. When the directional contactor 42 opens, it opens its auxiliary contact members 61 and deenergizes the brake release coil 62 to permit the brake to be reset against the motor to prevent rotation while the motor is deenergized.

If, while the rope tension is less than normal, the winch reels in too much rope, so that the effective towing length is now less than a value in the desired average range, the controller 18 for controlling the effective length of the tow rope will become effective to control the equipment to permit the winch to pay out some of the rope now that the rope tension has been increased to within the proper operating tension range.

After the winch has restored the proper tension and if too much rope is heaved in, then the controller 18 is operated to establish a circuit from bus X through selector switch 28, segment 13, which will now be in the neutral position, contact finger 15, contact fingers 63 and 70, bridged by segment 21, back contact members 52, which will now be closed, actuating coil 64 of relay 48, and conductor 51 to bus Y. Relay 48 thus operates to open its back contact members 47 and closes its contact members 65 and 66. Directional contactor 42 again operates but the circuit for its operating coil is established through contact members 65 instead of contact members 53.

Closure of contact members 66 establishes a circuit from bus X through conductor 55, contact members 66 of relay 48, segment 25 of tension set-up controller 22, conductor 67 to torque control contact 35 and then to bus Y.

The closure of switch 35 inserts resistance into the secondary circuit of the motor. In this case, the amount of resistance is more than was inserted while the tension of the rope was below normal. Consequently, the stalled rotor torque will be less than it was during the previous condition. The motor torque will be sufficiently less than the rope tension to enable the winch to pay out gradually, but without decreasing the rope tension below the permitted tension range. Such paying out operation will continue until the effective towing length has been restored to a value within the desired towing length range.

Such paying out operation will continue, of course, only so long as the tension of the rope remains within its tension operating range. If the tension should be diminished to a value below the desired operating range, the tension limit switch 12 would again assume control of the system and heave in rope until proper tension may be reestablished. However, so long as the rope tension remains within the normal range, rope will be paid out until the effective length reaches a value within the desired range. When that happens, the rope limit switch 18 will be moved back to a position at which segment 21 will open its circuit to deenergize coil 64 of the contactor switch 48. Thereupon the operating coil of directional contactor 42 will be deenergized at contact 65 to open the motor circuit, and the brake release coil will also be deenergized to permit the brake to be mechanically restored to lock the motor against rotation.

Rope tension increases above operating tension range

When the rope tension increases to a value above the upper limit of the tension operating range, the rope tension switch 12 will move segment 14 to engage contact finger 17 in response

to downward movement of the torque arm 10. The high rope tension segment 14, upon closing, completes a circuit to energize the operating coil of the relay 48. The energizing circuit may be traced from bus conductor X, through the selector switch 28, the rope tension switch segment 14, contact finger 17, contact fingers 69 and 70, bridged by the segment 21 of the controller 18, the back contacts 52 of the relay 50, and the operating coil 64 of the relay 48 and conductor 51 to the other bus conductor Y.

Relay 48 thereupon operates to actuate its several contacts. It opens its back contact 47 in the interlock circuit with the operating coils 49 of the other relay 50. It closes its front contact 65 to energize the operating coil 60 of directional contactor 42, and it closes its front contact 66 to energize the motor torque control contactor 35 through segment 25 of the tension set-up controller 22. The directional contactor and another torque control contactor are thereupon energized to close their contacts.

Directional contactor 42 closes to connect the motor 1 to the supply circuit 41, and, at the same time, the brake 30 is released by the energization of its release coil 62. Closure of the secondary resistance torque control contactor 35 inserts enough resistance into the secondary circuit of the motor to establish a stalled rotor torque in the motor slightly less than the lower limit of the tension range for which the equipment is adjusted at position B of the tension set-up controller 22. The motor is thereupon energized to a degree less than the rope tension, and will therefore permit rope to be paid out, but gradually, in response to the excessive tension in the tow rope.

In this manner, when the rope tension increases above the upper limit of the permitted operating tension range, the motor energization is controlled to establish a stalled rotor torque less than the range of normal tension to assure that the motor torque will be sufficiently less than the permitted tension range to enable and to permit the motor torque to be overcome by the excessive tension in the tow rope, so that the motor and the winch may be operated, against the motor torque, to pay out rope until proper tension is reestablished in the tow rope at a value somewhere within the predetermined operating tension range.

When the rope tension is thus again diminished to a value within the operating range, the torque arm 10 will be operated to move tension controller 12 to disengage the high limit rope tension segment 14 from contact finger 17 and the relay 48 will be deenergized. The operating coil of the directional contactor 42 and also that of the torque contactor 35 will be deenergized, and both contactors will open. The brake release circuit will thereupon also be deenergized and the brake will be restored to effective braking position.

If, while the rope tension is more than normal, the winch pays out too much rope, so that the effective towing length becomes more than the desired average range of length, the rope length controller 18 will become effective to control the equipment to cause the winch to reel some of the rope back in, now that the rope tension has been diminished to a value within the proper tension range.

When the winch pays out rope to reduce the rope tension to proper value, rope length controller 18 is operated to cause segment 20 to engage its contact finger 68. Contact finger 63 remains disengaged and contact fingers 69 and 70 remain engaged by segment 21, so long as the amount of rope paid out does not exceed the maximum permitted limit. Under those conditions, the circuits controlled by contact fingers 68, 45, 46, 69 and 70 of the rope limit controller are closed.

Assuming that the rope tension diminishes to a permitted value, the tension controller 12 will disengage segment 14 from contact finger 17 to deenergize the relay 48 as was explained. The deenergization of relay 48 causes the reclosure of its back contact 47, which, together with segment 20 and contact finger 68 of rope length controller 18 and the contact finger 15 of rope tension controller 12, completes the energizing circuit of the relay 50.

Since the tension set-up switch 22 is still in its B position, operation of relay 50 completes the circuits to close the directional contactor 42 to the motor, and to energize the brake release coil to release the brake and to close the secondary torque control contactor 36.

As was previously explained, the closure of secondary torque contactor 36 establishes a stalled rotor torque in the motor in excess of the higher limit of the tension range for which the equipment is adjusted at position B of the tension controller 22. The motor is thereupon energized to operate the winch in the heave-in direction. However, in view of the fact that the rope tension is within the normal range, the difference between the motor torque and the present tension value of the rope will be merely sufficient to operate the winch to heave rope in gradually, but without materially increasing the rope tension to a value in excess of the permitted tension range. Such heave-in operation will continue until the effective towing length has been restored to a value within the desired towing length range. When that happens, the rope length controller 18 will be moved to a position at which the segment 20 will deenergize the relay 50. Such heave-in operation will continue, of course, only so long as the tension of the rope remains within its tension operating range.

Thereupon the operating coil of the directional contactor 42 will be deenergized, the brake release coil will be deenergized, and the operating coil of secondary torque contactor 36 will be deenergized. The contactors 42 and 36 will open and the brake will resume its position to lock the motor against rotation.

Operation for different tension settings

The tension controller 22 may be adjusted to any one of three positions to close its contacts associated with those positions, as illustrated in the diagram, to set up appropriate control circuits. Such adjustment of the tension controller 22 will be made each time the tension spring 11 is adjusted to some other tension.

The heave-in and pay-out operations will be the same at either of the settings of the tension controller 22, so far as the resulting operation of the motor is concerned, with respect to the particular selected tension setting. Different contactors in the secondary circuit will be controlled, however, to insert different amounts of resistance in the secondary circuit of the motor to establish the proper torque relations between the motor and the particular operating range for the rope tension corresponding to the selected setting of the tension controller 22.

Manual operation—Heave-in

When the winch is to be manually operated, the full range of flexibility of control will ordinarily be needed. In order to provide such flexibility, the manually-operable master controller 29 is provided with segments 71 movable to five operating positions for controlling the motor to heave in, and to five operating positions for controlling the motor to pay out the tow rope. Contact fingers 72 to 78, inclusive, control the secondary circuits. For control of manual operation, the selector switch 28 is moved to its upper contact to complete a circuit to energize a transfer relay 79 which closes its contacts 80 to 85, inclusive.

When the master controller 29 is to be operated to reel in rope, it will be moved to the left where its segment 71 will engage its contact finger 74 and complete a circuit to close the main directional contactor 42. That circuit may be traced from bus X, through segment 71, contact finger 74, relay contact 81, interlock 59 of contactor 43, coil 60 of contactor 42, and conductor 51 to bus Y. Contactor 42 will thereupon close, and will also energize the brake release coil to release the brake. No secondary switches or torque control contactors will at this stage be closed, so that all of the secondary resistance is in the secondary circuit at this time, and the motor will develop its minimum torque.

When the manual controller 29 is moved to the left to its second position, segment 71 will engage contact finger 75 to close the circuit through relay contact 82 to the operating coil of secondary torque control contactor 36, and the motor will operate with increased torque to reel in rope, since less resistance is included in the secondary.

When the master controller 29 is moved further to the left, to its third position, the segment contact 71 engages contact finger 76 and completes the circuit set up at relay contact 83, to energize the operating coil of the secondary torque control contact 38 to further increase the torque on the motor and to continue reeling in rope.

When the master controller 29 is moved further to the fourth position, its segment 71 engages contact finger 77 to complete the circuit set up at relay contact 84, to the secondary torque control contactor 39 to further increase the motor torque and to continue reeling in the towing rope.

When the controller 29 is moved to the left to the fifth position, its segment 71 engages contact finger 78, to complete the circuit set up at relay contact 85, to the operating coil of the torque control contactor 40, which will shunt out all secondary resistance to energize the motor for maximum torque development in the heave-in direction.

Restore neutral manual position

When the master controller 29 is then moved to its neutral position, it will disengage its segment 71 from contact fingers 74 to 78, inclusive, and will deenergize the operating coil of the directional contactor 42. The circuit breaker will open and the brake will be restored to lock the motor against rotation. All other controller segments will be open and will deenergize and open the secondary torque control contactors. The towing line will thereupon be held in the position to which it has been moved by the operation of the master controller 29.

Manual operation—Pay-out

When the master controller 29 is moved to the right, to the first pay-out position, its segment 71 will engage contact finger 72 to complete the circuit to the operating coil of the directional contactor 43. That circuit may be traced from the bus conductor X through the controller segment 71, contact finger 72, contact members 89 of relay 79, the back contact interlock 86 of directional contactor 42, and the operating coil 87 of directional contactor 43 to conductor 51 and the other bus conductor Y. The directional contactor 43 will thereupon connect the motor to the energizing circuit 41 in a direction to rotate the winch in a pay-out direction. At the same time, the brake release coil will be energized through interlock contact 88 to release the brake. The motor will operate at its minimum torque since all secondary resistance is in circuit.

When the master controller 29 is moved to the second pay-out position, it keeps contact finger 72 energized, and energizes contact finger 75 to energize the secondary torque control contactor 36, through the circuit set up at relay contact 82. The torque of the motor is now developed to permit the motor to pay out at a certain speed.

As the master controller is moved progressively to the right to the third, fourth and fifth positions, the secondary torque control contactors 38, 39 and 40 are sequentially and individually energized, in the same manner as previously described, by the engagement of the segment 71 and the respective contact fingers 76, 77 and 78 to complete the circuits set up at contacts 83, 84 and 85, respectively, to establish gradually increased torques and speeds in the motor, to pay out the rope.

Modified circuit of Figure 2

By a different cooperative relationship between the tension controller and the rope length controller, I establish a modified type of control of the rope tension without continually adjusting the towing length, but permitting a low tension condition to exist without reeling in rope, and correcting only for excess tension conditions by paying out rope and then restoring the average length.

In Fig. 2, the tension controller 91 is provided with a segment 92 and three fingers 93, 94 and 95. Contact finger 94 provides operating voltage. Contact finger 93 is normally engaged and contact finger 95 is normally disengaged. When contact finger 95 is engaged by segment 92, contact finger 93 will be disengaged.

A rope length controller 96 is provided with two segments 97 and 98, and four contact fingers 101 to 104, inclusive. Segment 97 normally is disengaged from contact fingers 101 and 102 but will engage them as soon as rope is paid out beyond a normal length limit. Segment 98 normally engages contact fingers 103 and 104 but will disengage them when practically all rope on the winch has been unwound and paid out. The winch will be stopped at this point and a suitable warning signal bell may be provided to warn the attendant. Otherwise, the same set-up relays 48 and 50, and associated equipment are employed as in Fig. 1, to close the directional contactors and to control the torque control contactors during automatic adjustment of rope tension and length.

Rope tension too high

When the rope tension exceeds the high tension setting, tension controller segment **92** engages contact finger **95** and completes the circuit through rope limit controller segment **98**, back interlock contact **52** of relay **50**, operating coil **64** of relay **48**, to conductor **51** and bus Y. Relay **48** operates, and energizes, directional contactor **42**, and through interlock **66** energizes the coil of the corresponding secondary torque control contactors **35** or **37**, depending upon the setting of the tension set-up controller **22**, with the same resulting operation as described above in explaining the operation of the system in Fig. 1.

While the tension remains high, rope will be paid out and the segment **97** of the rope limit controller **96** will engage contact fingers **101** and **102**. Thus both rope limit controller segments **97** and **98** will engage their contact fingers until the maximum permitted length of rope is paid out. Segment **98** will then disengage contact fingers **103** and **104** to deenergize the relay **48**. If, in the meantime, the rope tension is reduced to normal before the length control segment **98** disengages contacts **103** and **104**, the tension controller segment **92** will open and deenergize relay **48**. Directional contactor **42** will open, and brake **30** will hold the motor. Secondary torque contactor **35** (or **37**) will open.

However, rope length controller **96** has operated to engage contact fingers **101** and **102** by segment **97** to set up the circuit to the operating coil of the relay **50**. That circuit is open at interlock contact **47** while relay **48** is energized. As soon as relay **48** opens due to segment **98** disengaging its contact fingers, the back interlock contact **47** closes and completes the circuit of relay **50** through the tension controller segment **92** and the rope length controller segment **97**.

Relay **50** operates, and, as in Fig. 1, closes directional contactor **42**, closes secondary torque contactor **36** (assuming tension set-up controller **22** at position B) to establish a torque exceeding the maximum value of the rope tension range, removes brake **30**, and opens the circuit of relay **48** at interlock **52**. Motor **1** thereupon reels in rope until the rope length controller **96** moves to a position where segment **97** disengages its contact fingers to deenergize relay **50**.

If, however, when the maximum length of rope is paid out, the rope tension remains high, the circuit of relay **48** will be set up at tension segment **92** and contact finger **95**, but will be held open at rope length controller segment **98**. The circuit of relay **50** will be kept open at the same time since the segment **92** of the tension controller will disengage finger **93** so long as the tension in the rope is enough to hold segment **92** on contact finger **95**. The breaker **42** and the secondary torque contactors will be open and the brake applied. When the tension diminishes, the rope length will be readjusted as explained.

Modification of Figure 3—Mooring winch system

By a slight modification of the rope tension controller, I have also made this system available for automatically controlling a mooring winch. For that application, the mooring winch must keep the mooring cables of a vessel under constant tension while the vessel is tied up to a dock **5***a*, or is being hoisted in a lock. That is necessary in order to hold the vessel in position with respect to the dock or the lock, and to prevent parting of the cables under changing conditions of draft or water level.

Mooring winch systems—Cable tension high

The circuit diagram is shown in Fig. 3. Except for the change in the tension controller to control the relays **48** and **50**, the control circuits for the motor and for the secondary torque control contactors are the same as in the system in Fig. 1.

In this system, in Fig. 3, the mooring tension controller **105** is provided with three segments **106**, **107** and **108**, and with four contact fingers **109** to **112**, inclusive. The contact fingers **109** and **110** are engaged by segment **106** or **107** as soon as the tension varies from the average value between the two limit values of the tension range for which the apparatus is adjusted. The segment **108** engages a finger **111** when rope tension reaches the corresponding high limit value of the tension range developed in the mooring cable. The segment **107** engages finger **111** when the rope tension diminishes to the low limit value of the range.

It will be observed that the average tension contact finger **110** is energized together with each limit contact finger **111** or **112**. In addition, a front interlock is provided on each relay **48** and **50** to maintain a holding circuit to by-pass the circuit connection between each segment **107** and **108** and their respective contact fingers **111** or **112**.

While the cable tension is at average value (according to the mechanical adjustment of spring **11** and the position of set-up controller **22**), tension controller **105** is in neutral position, as shown in Fig. 3.

When the rope or cable tension increases beyond average value, but is still below the high limit value, contact fingers **109** and **110** are engaged by segment **106**. As soon as the tension reaches or exceeds the high limit value, segment **108** engages contact finger **112** and completes the energizing circuit to relay **48**. Relay **48** thereupon completes the various control circuits, as described in Fig. 1, to close directional contactor **42** and secondary torque control contactor **35**, and to release the motor brake. The motor then pays out cable to reduce the tension.

In addition, as here modified, relay **48** locks itself in by its front interlock contact **114**, which bridges segment **108** and contact finger **112** and contact **52** of relay **50** in series. The purpose of that lock-in connection is to keep the circuit of relay **48** energized even after the tension has diminished to a value below the high limit value of the tension range, at which the high tension segment **108** opens so that the motor will continue to be operated against its lower stalled torque value until the cable tension diminishes to the average value. Segment **106** will then open at finger **110** and will deenergize relay **48**. Directional contact **42** and secondary torque contactor **35** will open and the brake will be released to reset and lock the motor against further rotation.

Cable tension low

If the cable tension decreases below average value, segment **107** engages finger **110** but nothing results since the circuits from contact finger **110** to relays **48** and **50** are open at the lock-in contacts **114** and **115**. When the tension drops to or below the lower limit, segment **107** engages finger **111**. Relay **50** is then energized through contact **47**, and closes its switch contacts to energize the operating coils of directional contactor **42** and of secondary torque control contactor **37**.

The brake is released. In addition, relay 50 locks itself in by its front contact 115 that bridges segment 107 and finger 111 and contact 47 in series.

The motor torque exceeds the cable tension and reels in cable until the cable tension exceeds the low limit value. Segment 107 disengages finger 111 but contact 115 keeps relay 50 energized. The motor continues to reel in until the rope tension reaches the desired average value at which segment 107 opens the circuit of relay 50.

The tension controller 105 thus controls the cable tension to maintain a predetermined average tension value, and pays out or heaves in, not only to maintain the cable tension within a predetermined range, but also at a predetermined average value. That value, of course, is predetermined by the adjustment of spring 11.

Résumé

Thus by means of the systems described, a towing winch may be operated either manually to establish a desired and effective towing length; or it may be operated automatically to establish and to maintain the tension of the tow rope within a predetermined operating tension range, and also to establish and maintain the effective towing length of the rope within a desired range of effective operating lengths.

In addition, the tension range may be varied according to the amount of load to be towed so that the system may be controlled automatically to maintain optimum operating conditions withing such selected tension range.

Moreover, by the modification shown in the tension controller in the system in Fig. 3, the control system may be adapted to a mooring winch where a closer degree of tension control is desired.

My invention is not limited to any of the construction details of the tension controllers, since they may be designed and disposed to be controlled in any suitable manner in response to the tension developed in the rope at all times, to provide a control function for the control equipment, and the control equipment may be variously arranged to effect the desired operations in combination with the controllers, without departing from the spirit and scope of the invention as set forth in the appended claims.

I claim as my invention:

1. A winch control system comprising a winch, a reversible induction motor therefor having a wound rotor, a source of energy for the motor, resistance means for insertion in the rotor circuit, switching means between the source and the motor, a switch responsive to the tension of the rope on the winch, means controlled by the said switch upon excess tension in the rope for inserting part of the resistance into the rotor circuit to establish a stalled rotor torque below normal rope tension in order to permit the motor torque to be overcome by the rope pull to cause the winch to pay out rope until the rope tension becomes normal.

2. A winch control system comprising a winch, a reversible induction motor therefor having a wound rotor, a source of energy for the motor, resistance means for insertion in the rotor circuit, switching means between the source and the motor, a switch responsive to the tension of the rope on the winch, means controlled by the said switch upon subnormal tension in the rope for inserting part of the resistance into the rotor circuit to establish a stalled rotor torque in excess of normal rope tension in order to establish the motor torque, to assure that the motor torque will overcome the subnormal rope pull to cause the winch to heave in rope until the rope tension becomes normal.

3. A winch control system comprising a winch, a reversible induction motor therefor having a wound rotor, a source of energy for the motor, resistance means for insertion in the rotor circuit, control means for varying the resistance value of the resistance means, switching means between the source and the motor, a switch responsive to the tension of the rope on the winch, means controlled by the said switch when the rope tension varies beyond a predetermined operating range, said means being operative at that time to operate said control means to insert a selected part of the resistance into the rotor circuit to establish a stalled rotor torque that will control the winch to operate in the direction of deviation of rope tension, from normal, until the rope tension becomes normal.

4. A towing winch control system comprising a winch, a reversible induction motor therefor having a wound rotor, a source of energy for the motor, resistance means for insertion in the rotor circuit, control means for varying the resistance value of the resistance means, switching means between the source and the motor, a switch responsive to the tension of the rope on the winch, means controlled by the said switch when the rope tension varies beyond a predetermined operating range, said means being operative to actuate said control means to insert a selected part of the reistance into the rotor circuit to establish a selected stalled rotor torque of such value that the motor will, when subjected to a torque other than the selected value, operate in the direction of deviation of rope tension until the rope tension becomes normal, and means responsive to the then effective length of towing rope for controlling the motor to reestablish the effective length of towing rope to a predetermined average towing length, subject, however, to temporary variations in response to changes in rope tension beyond the average pull range.

5. A winch control system comprising a winch, a tow rope controlled by the winch, a wound rotor induction motor for operating the winch, a source of energy for the motor, a brake for the motor, a resistor bank for connection to the wound rotor to control the torque to be deveolped by the motor, control means for connecting various portions of the resistor bank in the rotor circuit, means for measuring the tension in the tow rope, switch means having parts coupled to the tension measuring means to thus be responsive to a variation of the tension beyond a permitted predetermined range, means controlled by the switch means for connecting the motor to its source of energy and for selectively operating said control means to thus connect a selected portion of the resistor bank into the rotor circuit to establish a selected stalled rotor torque in the motor of such value that the motor will, when subjected to a torque other than the selected value, operate in a direction to restore the rope tension to the predetermined range, said switch means then being operative in response to such reestablished tension for operating the means controlled by the switch means for deenergizing the motor and means responsive to the motor deenergizing operation of the means controlled by the switch means for applying the brake.

6. A towing winch control system comprising a winch, a tow rope controlled by the winch, a wound rotor induction motor for operating the winch, a source of energy for the motor, a brake for the motor, a resistor bank for connection to the wound rotor to control the torque to be developed by the motor, control means for connecting various portions of the resistor bank in the rotor circuit, means for measuring the tension in the tow rope, switch means having parts coupled to the tension measuring means to thus be responsive to a variation of the tension beyond a permitted predetermined range, means controlled by the switch means for connecting the motor to its source of energy and for connecting a predetermined portion of the resistor bank into the rotor circuit to establish a selected stalled rotor torque in the motor of such value that the motor will, when subjected to a torque other than the selected value, operate in a direction to restore the rope tension to the predetermined range, and means operative in response to such reestablished tension and a change in rope length from a given range of length for restoring the effective length of the rope to within the given predetermined average range, if the effective length has moved beyond such length range in the step of readjusting the rope tension.

7. A winch control system comprising a motor; a source of energy therefor, a winch connected to the motor and provided with a planetary driving transmission embodying a sun gear, planet gears, a ring gear, and a floating spider support for the planet gears, a torque arm connected to and oscillatable by the floating support, an adjustable spring restraint for the torque arm; resistance means to be connected to the motor to control its torque, means for presetting selected connections to the resistance means to enable the motor to establish certain torques related to the setting of the adjustable restraining spring for the torque arm and means controlled by the torque arm for controlling the connections of the means for presetting selected connections to the resistance means and for controlling the connection of the source to the motor.

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