Jan. 8, 1963 E. SENNEBOGEN 3,072,264

OVERLOAD SAFETY CONTROL APPARATUS FOR HOISTING EQUIPMENT

Filed March 22, 1961 2 Sheets-Sheet 1

Fig-1

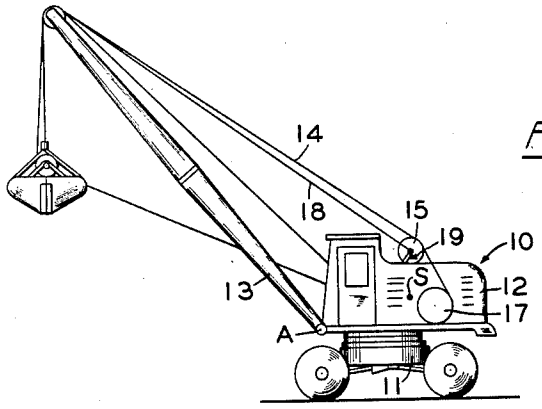
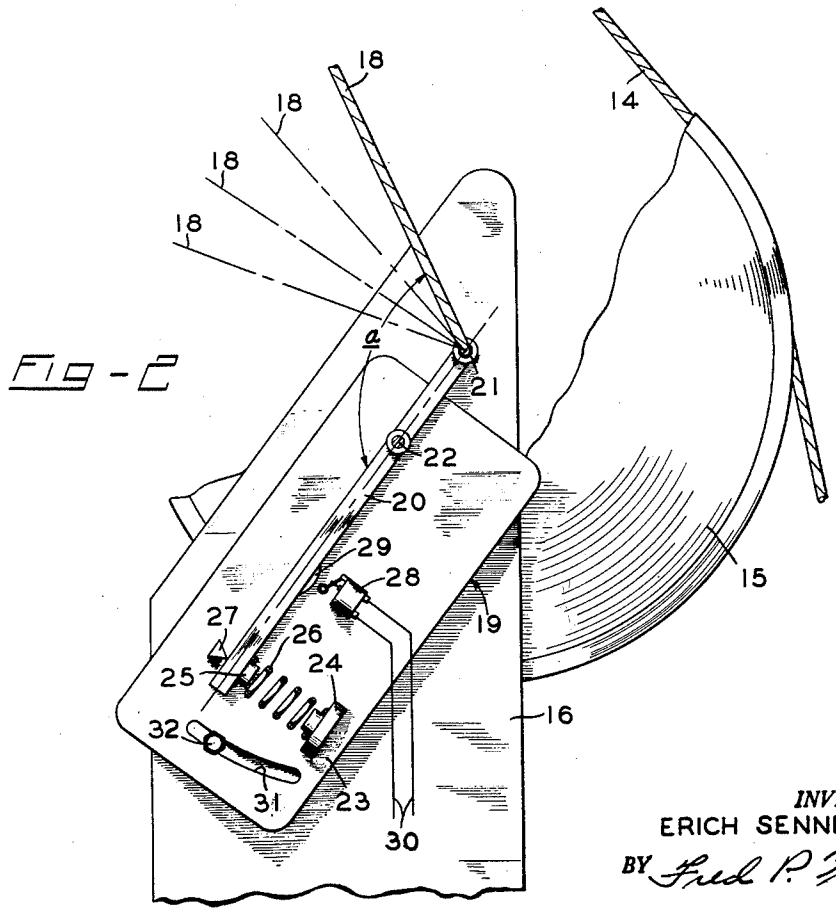


Fig-2



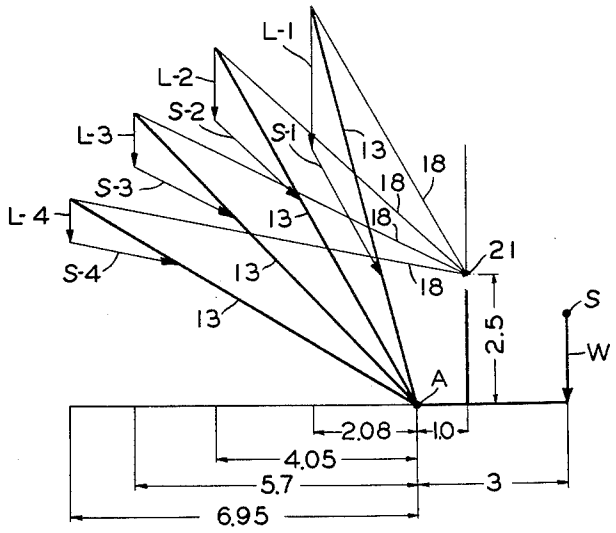
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OVERLOAD SAFETY CONTROL APPARATUS FOR HOISTING EQUIPMENT

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Fig -3



1 cm = 1 Kg
1 cm = 1 m

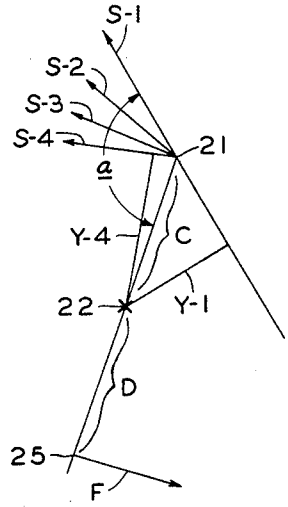


Fig -4

1 cm = 1 Kg
1 cm = 1 m

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OVERLOAD SAFETY CONTROL APPARATUS FOR HOISTING EQUIPMENT

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8 Claims. (Cl. 212—39)

This invention relates to overload safety control arrangements for hoisting equipment and, more particularly, to an overload safety control arrangement employed in hoisting equipment, such as, cranes, excavators and the like which are characterized by a boom which is pivotally supported at one end for angular movement in a vertical plane.

It is conventional to provide hoisting equipment having angularly movable booms with means for measuring the moment of force applied by the load and means to cut off the driving mechanism when the measured moment of force exceeds the static moment of the equipment so as to prevent the equipment from pitching.

The moment of force which causes the hoisting equipment to pitch is commonly known in the art as the pitching moment of the equipment.

One type of prior control means comprises generally a means for measuring the weight of the load being lifted and additional means for determining the angular position of the boom which corresponds to the moment arm of the load. When the product of the load and the moment arm is such as to create a moment of force substantially equal to the pitching moment, a means responsive to the moment of force being measured is rendered operative to cut off further operation of the hoisting equipment. These responsive means may be either electrically or hydraulically actuated.

In another well-known type of overload safety control arrangement, the forces applied through the hoisting cable to lift the load are transmitted to the cable supporting frame by a compression spring and the end of the cable is connected to a control medium which moves in an arc upon swinging of the boom to different angular positions. Operatively associated with the control mechanism is a cam lever which is arranged so that as the moment arm of the boom increases the distance between the arcuately movable control medium and cam lever decreases. The cam lever and control medium are further arranged so that under identical boom positions the distance between the control medium and cam lever is decreased when the load being hoisted is large and increased when the load is small. When the moment of force created by the load and the position of the boom approaches the pitching moment of the hoisting equipment, the cam lever engages the control medium so as to energize switch means for deactivating the hoisting mechanism.

A further well-known arrangement for stopping operation of the hoisting equipment in the presence of excessive moment of force is the provision of a support for the cut-off switch which is movable eccentrically relative to the path of a control medium of the general type, above described, so that the switch moves into the path of the control medium as the horizontal projection, i.e., moment arm, of the boom lengthens. With this arrangement the smaller limiting loads which may be applied at the lengthened moment arms cause the switch to be contacted by the control medium to cut off operation of the hoisting equipment while at the same time maintaining the switch and control medium out of contact at shorter moment arms which may be subjected to heavier limiting loads.

The above type of safety overload devices have the common disadvantage of being of complex structure and expensive to manufacture and further require reconstruction to accommodate for the differences in pitching moment characteristics of the different types and sizes of hoisting equipment in which the device may be employed.

It is an object of the present invention to provide a safety overload arrangement for hoisting equipment which is capable of being adapted for use in boom type hoisting equipment having different overload or pitching moment characteristics without any material reconstruction thereof.

It its a further object of the invention to provide a hoisting equipment overload arrangement which is of simple design and economical to manufacture.

Briefly, this invention comprises a lever pivoted about a fixed fulcrum and connected to the return run of the boom elevating or hoisting cable so that the pulling or tension forces on the cable exerted on the boom during hoisting of the load are imparted to the lever. The lever is arranged at a predetermined angle relative to the return run of the boom hoisting cable so as to overcome the action of a biasing spring having a predetermined loading resisting compression so that when the pitching moment of the hoisting equipment is approached the spring yields and the lever is turned about its fixed fulcrum thereby to close a switch and energize a circuit for interrupting further hoisting of the load until the overload conditions are removed.

Advantageously, the lever is superposed on a base plate which is also mounted on the fixed fulcrum of the lever. The plate is provided with means for supporting the compression spring in contact with one side of the lever and also with a stop member contacting the lever on the opposite side from the spring to hold the lever against movement away from the spring.

In its more specific aspects the base plate is adjustably connected on a bracket supporting the boom hoisting cable sheave to permit adjustment of the angle of the lever relative to the return run of the boom hoisting cable so that the tension forces corresponding to the pitching moment in the different angular positions of the boom are imparted to the biasing spring as an equal force. To this end the plate is formed with an arc or slot which accommodates a locking screw for locking the plate in an angular position about the fixed fulcrum.

A typical design in accordance with the invention is set forth in detail hereinafter, as shown in the following drawings, in which:

FIG. 1 illustrates an elevational view of an excavator embodying the present invention.

FIG. 2 is a fragmentary elevational view showing the details of the present invention.

FIG. 3 is a vector diagram showing the relationship of the static moment forces of the hoisting equipment with respect to the forces exerted by the load at different positions of the boom.

FIG. 4 is a vector diagram of the hoisting cable forces applied to the lever of the safety control arrangement of the present invention.

Referring now to the figures, in particular, FIGS. 1 and 2, the invention is shown as embodied in an excavator 10 comprising an undercarriage 11 supporting a cab superstructure 12, a boom 13 pivotally connected to the cab superstructure 12 at A for swinging movement in a vertical plane into different angular positions relative to the horizontal. For lifting the boom or changing the relative angular position of the boom 13 there is provided a boom retracting cable 14 which is trained over a guiding sheave 15 suitably supported on bracket 16. One end of the retracting cable 14 is connected to the winding winch 17 and the cable return run 18 is operatively connected to the safety control overload arrangement 19 of the present invention, as more fully to be explained hereinafter.

Referring now to FIG. 2, the safety overload control arrangement 19 comprises a lever 20 of which one end 21 is connected to the cable return run 18. The lever 20 is pivotally supported on a fixed fulcrum or stud 22 fastened to the bracket 16.

Also pivotal about the stud 22 is a base plate 23 having a projecting flange 24 formed on one end remote from the lever end 21 and adjacent lever end 25. The flange 24 supports a compression spring 26 which contacts the underside of the lever end 25 of the lever 20. Also provided on the base plate 23 adjacent the lever end 25 is a stop member 27 which serves to prevent clockwise movement of the lever 20 about the stud 22.

Mounted on the plate 23 intermediate the stud 22 and the lever end 25 is a limit switch 28 which is adapted to be engaged by a cam piece 29 fixed to the lever 20 upon counterclockwise movement of the lever 20 to close the switch 28 and thereby energize an electric circuit 30 which is connected to means for activating the stopping mechanism for cutting out further operation of the hoisting equipment until the pitching moment loading conditions are relieved. The means for stopping the hoisting equipment may be of any conventional type. These stopping devices are generally of an electro-pneumatic nature in which the pneumatic means are operative to activate brakes and to cut off the operation of the boom hoisting winch and the winch associated with the load hoisting cable.

Formed in the lower end of the plate 23 is an arcuate slot 31 which accommodates a locking screw 32 adapted to be threaded into the bracket 16 so as to clamp the base plate 23 in a fixed angular position relative to the cable return run 18. Adjustment of the angular position of the base plate 23 also results in adjusting angle *a* of the longitudinal axis of the lever 20 relative to the position of the hoisting cable return run 18. The angle *a* between the longitudinal axis of the lever 20 and the cable return run 18 is of significance in the operation of the overload safety control arrangement, as more fully to be explained hereinafter.

The compression spring 26 is of a predetermined compression loading so as to resist the varying forces transmitted thereto via the lever 20 and cable return run 18 as long as these forces are of lesser value than those corresponding to the pitching moment of the excavator 10 in any one of the angular positions of the boom. When the loading conditions on the boom 13 are such that the tension forces transmitted to the spring 26 via the cable return run 18 and lever 20 are such as to approach the pitching moment of the apparatus, the spring 26 is compressed so that the lever 20 is turned counterclockwise about the stud 22 whereby the member 29 contacts the limit switch 28 so that the electrical circuit 30 is energized to activate the stopping equipment. The manner in which the forces on the cable return run 18 vary in different angular positions relative to the pitching moment and how the spring compression loading is determined will be more fully explained hereinafter.

In order to provide a more complete and better understanding of the arrangement and the results achieved thereby, especially with respect to the forces which are developed in the operation of the excavator and to explain the significance of the angle *a*, reference is made to the vector diagrams illustrated in FIGS. 3 and 4.

As illustrated in the vector diagram of FIG. 3, the point S represents the center of gravity of the cab 11 of the excavator 10, the vector W represents the weight of the cab, the point A the pivot point of the boom 13 on the cab 12 and the point 21 represents the point of attachment of the hoisting cable return run 18 to the lever 20. The boom 13 is disclosed at angles of 30, 45, 60 and 75 degrees relative to the horizontal and the cable return run 18 is shown in its operative position in each one of the respective angular positions of the boom 13.

If it is assumed that the cab 12 of the excavator 10 has an empty weight of 2,000 kilograms and the horizontal projection of the distance from the center of gravity S to the boom pivot point A is three meters, the static moment of the apparatus is equal to $3\times2{,}000$ or 6,000 kilogram meters.

In addition, if it is further assumed that the length of the boom equals 8 meters and further that the end or point 21 of the lever 20 of the control mechanism 19 is spaced 1 meter horizontally and 2.5 meters vertically from the pivot point A of the boom, the load L which can be safely carried in each one of the respective angular positions of the boom can be determined in accordance with the equation

$$L=\frac{Ms}{Bhp}$$

wherein Ms represents the static moment and Bhp represents the length of the horizontal projection of the boom. From the foregoing equation it can be determined that the maximum load which may be lifted at the different angles 30, 45, 60 and 75 degrees of the boom without exceeding the pitching moment of the apparatus are as follows:

$$L\text{–}1\ (75°)=\frac{2000\times3}{2.08}=2{,}884 \text{ kilograms}$$

$$L\text{–}2\ (60°)=\frac{2000\times3}{4.05}=1{,}481 \text{ kilograms}$$

$$L\text{–}3\ (45°)=\frac{2000\times3}{5.7}=1{,}052 \text{ kilograms}$$

$$L\text{–}4\ (30°)=\frac{2000\times3}{6.95}=862 \text{ kilograms}$$

These maximum loads at the different positions of the boom create the following tension forces in the return run length 18 of the cable 15 and which may be graphically determined are as follows:

S–1=2,800 kilograms
S–2=2,300 kilograms
S–3=2,200 kilograms
S–4=2,200 kilograms

From the foregoing it is evident that the tension forces in the cable return run 18 of the boom hoisting cable 14 are not equal when the maximum loads are applied at the different angular positions of the boom 13. However, as mentioned heretofore, the compression spring which permits turning of the lever 20 about the stud 22 so as to permit contacting or closing of the limit switch 28 is of a predetermined magnitude and will yield only under a predetermined force. It is, therefore, necessary to adjust the angular position of the lever so that the unequal tension forces S–1, S–2, S–3 and S–4 in the cable return run 18 are transmitted as a constant force to the spring 26 so that the latter will yield whenever the loading conditions in any one of the different angular positions of the boom is substantially equal to the pitching moment of the apparatus.

The angle *a* is determined by the vector diagram illustrated in FIG. 4 in which the tension forces S–1, S–2, S–3 and S–4 in the return cable run 18 at the 30°, 45°, 60° and 75° positions of the boom, respectively, are shown as acting against the end 21 of the lever 20. For the purpose of simplifying the mathematics involved, the fulcrum 22 is shown as being located halfway between the ends 21 and 25 of the lever such that the moment arms C and D on either side of the fulcrum 22 are of equal length. The length of the illustrated moment arms C and D is assumed to be 3 meters by way of example only. The lever 20 is arranged relative to the forces S–1, S–2, S–3 and S–4 so that when the forces S–1, S–2, S–3 and S–4 are each resolved into their parallelogram of forces, the components thereof normal to the longitudinal axis of the lever 20 are all equal. In this manner, of course, the forces F exerted on the opposite end 21 of the lever are also equal.

As is evident from FIG. 4, when this condition exists, the

angle *a* is defined by the force S–1 in the 75° position of the boom 13 and the longitudinal axis of the lever 20. As before described, the plate 23 is adjusted on the bracket arm 16 so as to obtain the required angle. In the illustrated example, the angle *a* is approximately 129°. To further demonstrate that the unequal forces S–1, S–2, S–3 and S–4 applied to the lever end 21 result in the application of a constant force F to the end 25 of the lever 20, the formula

$$F=\frac{S\times Y}{C}\times\frac{C}{D}$$

in which the value Y is the length of the perpendicular from the fulcrum 22 to the line of force S being applied may be employed. In the vector diagram of FIG. 4 only the Y–1 and Y–4 perpendiculars are shown. However, as mentioned above for the purpose of illustration, the lever moment arms C and D are taken to be equal so that their ratio is unity and, therefore, may be disregarded in the calculations. Of course, in the event that the ratio of the moment arms C and D is not unity, then it must be employed. In accordance with the above formula, the following relationship of forces are obtained at the lever end 25 when the values as graphically determined in accordance with the vector diagram are substituted therein.

$$F \text{ at } 75°=\frac{2{,}800\times 2.35}{3}\cong 2{,}200 \text{ kilograms}$$

$$F \text{ at } 60°=\frac{2{,}300\times 2.87}{3}\cong 2{,}200 \text{ kilograms}$$

$$F \text{ at } 45°=\frac{2.200\times 3}{3}\cong 2{,}200 \text{ kilograms}$$

$$F \text{ at } 30°=\frac{2{,}200\times 3}{3}\cong 2{,}200 \text{ kilograms}$$

From the foregoing it is also evident that these vector diagrams may be employed to select the particular spring appropriate or suitable to react against the applied forces on the end 25 of the lever. In the instant example, the spring should be capable of resisting forces less than 2,200 kilograms and compressing or yielding under forces of 2,200 kilograms so as to permit turning of the lever and contacting of the limit switch 28 to energize the conventional shut-off mechanism.

It should also be readily apparent that the safety overload device is operative throughout the full range of pitching moments of the boom in the different angular positions thereof so as to activate the lever 20 in counterclockwise direction about the stud 22 whereupon the switch 28 is energized by way of the camming piece 29.

Furthermore, the safety overload apparatus of the present invention may be adapted for use in different models of boom type hoisting equipment having different pitching moment characteristics by merely adjusting the angle *a* between the cable return 18 and the lever 20 so that the forces on the return run 18 corresponding to the maximum and minimum pitching moment of the particular model are transmitted as a constant force to the lever end 25 and so selecting the spring 26 that it yields under this constant force to permit closing of the switch 28.

Having now described the invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a hoisting apparatus having a superstructure, a boom pivotally supported on said superstructure at a point spaced from the superstructure center of gravity and being movable in a vertical plane, a cable operatively connected to the free end of said boom for moving said boom into different angular positions and having a return run, and a safety overload device for cutting off further hoisting when the loading on said boom is substantially equal to the pitching moment of said apparatus in the different angular positions thereof comprising a lever connected at one end to said cable return run and pivotable about a fixed fulcrum mounted on said superstructure,

and spring means having a predetermined loading resisting compression contacting the other end of said lever opposing the tension forces in said cable return run during hoisting so as to preclude turning of said lever when the moments exerted by the tension forces in said cable return run on said lever are less than those corresponding to the pitching moment of said apparatus and being yieldable to permit turning of said lever when said moments correspond to the pitching moment of said apparatus, means adjustably mounting said lever for adjusting the angle between the longitudinal axis thereof and the cable return run so that said moments exterted by the forces in said cable return run corresponding to the pitching moment of the apparatus in the different angular positions of the boom are transmitted as a substantially constant force to compress said spring, and switch means located so as to be operated when said lever turns and adapted to energize means for cutting out further hoisting until the pitching conditions are relieved.

2. The invention as defined in claim 1 in which said adjustable mounting means comprises a base plate underlying said lever and which is mounted on said fixed fulcrum for limited turning adjustment thereabout.

3. The invention as defined in claim 2 in which said base plate is provided with means for mounting said spring contacting said other end of said lever and stop means on said plate contacting said lever to prevent turning of said lever away from said spring.

4. The invention as defined in claim 3 in which said base plate supports said switch means.

5. The invention as defined in claim 4 in which said lever is provided with means for closing said switch means upon turning about said fulcrum.

6. In a hoisting apparatus having a superstructure, a boom pivotally supported on said superstructure spaced from the center of gravity thereof and being movable in a vertical plane into different angular positions, a cable operatively connected to the free end of said boom for moving said boom and having a return run, a sheave over which said cable is trained and means supporting said sheave on said superstructure, a safety overload device operative when the loading on said boom is substantially equal to the pitching moment of said apparatus in the different angular positions of said boom comprising a fulcrum fixed on said sheave supporting means, a lever connected at one end to said cable return run and pivotable intermediate its ends about said fixed fulcrum, spring means having a predetermined loading resisting compression contacting the other end of said lever opposing the forces in said cable return run during hoisting so as to preclude turning of said lever when the moments exerted by the forces in said cable return run on said lever are less than those corresponding to the pitching moment of said apparatus and being yieldable to permit turning when said moments correspond to the pitching moment of said apparatus, a base plate supporting said lever and being mounted on said fixed fulcrum for limited turning adjustment thereabout so as to adjust the angle between the longitudinal axis of said lever and the cable return run so that said moments exerted by the forces in said cable return run corresponding to the pitching moment of the apparatus in the different angular positions of the boom are transmitted as a substantially constant force to compress said spring, and control means located so as to be operated when said lever turns and adapted to cut out further operation of the hoisting equipment until the pitching conditions are relieved.

7. In a hoisting apparatus having a superstructure, a boom pivotally supported on said superstructure at a point spaced from the superstructure center of gravity and being movable in a vertical plane, a cable operatively connected to the free end of said boom for moving said boom into different angular positions and having a return run, and a safety overload device for cutting off further hoisting when the loading on said boom is substantially

equal to the pitching moment of said apparatus in the different angular positions thereof comprising a lever connected at one end to said cable return run and pivotable about a fixed fulcrum mounted on said superstructure, means adjustably mounting said lever for adjusting the angle between the longitudinal axis thereof and the cable return run so that the component of force of said cable force applied normal to the axis of said lever for the pitching moment of the apparatus in different angular positions of the boom is substantially a constant value, resilient means having a predetermined loading resisting compression engaging said lever and opposing said component of force in said cable return run during hoisting so as to preclude turning of said lever when said component of force in said cable return run is less than said constant value and being yieldable to permit turning of said lever when said component of force is at least equal to said constant value, and switch means located so as to be operated when said lever turns and adapted to energize means for cutting out further hoisting until the pitching conditions are relieved.

8. In a hoisting apparatus having a superstructure, a boom pivotally supported on said superstructure spaced from the center of gravity thereof and being movable in a vertical plane into different angular positions, a cable operatively connected to the free end of said boom for moving said boom and having a return run, a sheave over which said cable is trained and means supporting said sheave on said superstructure, a safety overload device

operative when the loading on said boom is substantially equal to the pitching moment of said apparatus in the different angular positions of said boom comprising a fulcrum fixed on said sheave supporting means, a lever connected at one end to said cable return run and pivotable intermediate its ends about said fixed fulcrum, a base plate supporting said lever and being mounted on said fixed fulcrum for limited turning adjustment thereabout, means adjustably mounting said lever for adjusting the angle between the longitudinal axis thereof and the cable return run so that the component of force of said cable force applied normal to the axis of said lever for the pitching moment of the apparatus in each different angular position of the boom is substantially a constant value, resilient means having a predetermined loading resisting compression engaging said lever and opposing said component of force in said cable return run during hoisting so as to preclude turning of said lever when said component of force in said cable return run is less than said constant value and being yieldable to permit turning of said lever when said component of force is at least equal to said constant value, and switch means located so as to be operated when said lever turns and adapted to energize means for cutting out further hoisting until the pitching conditions are relieved.

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