Aug. 17, 1965 L. G. VERMES 3,200,963

MOMENT COMPARATOR

Filed July 5, 1963

FIG. 1.

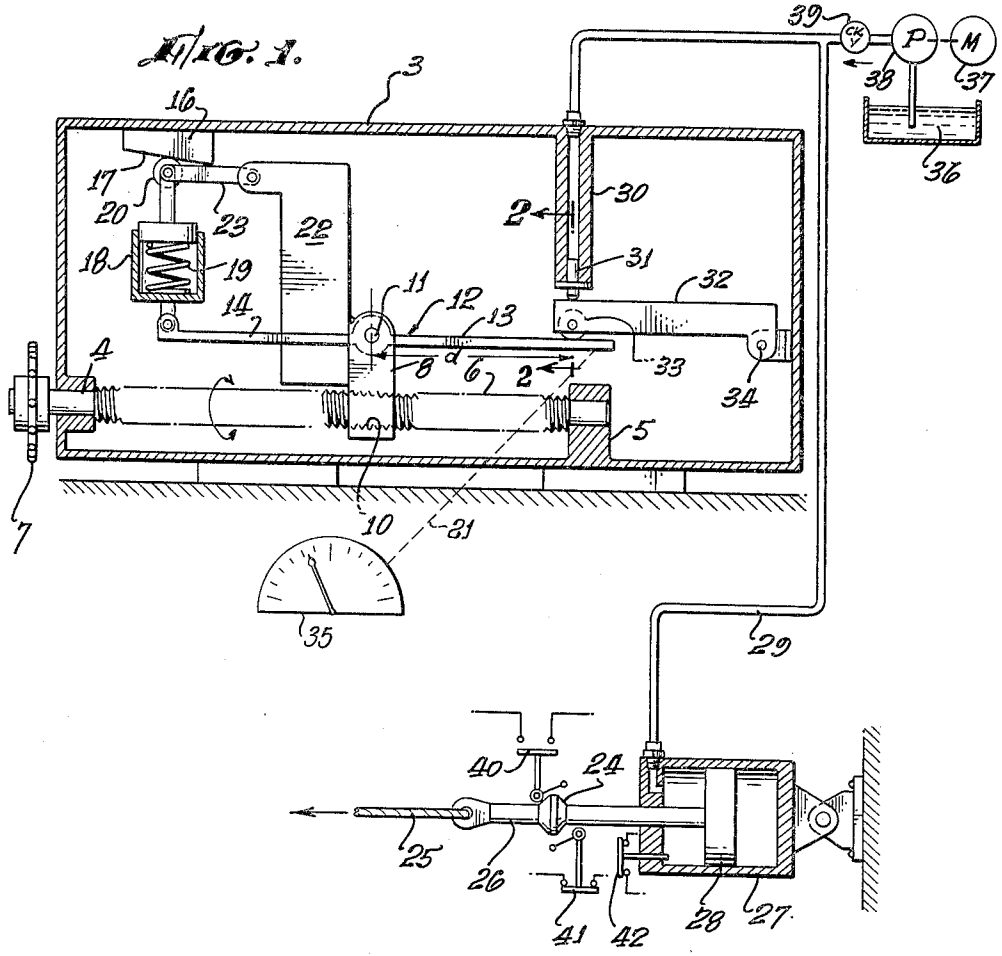


FIG. 3.

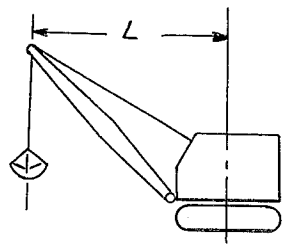
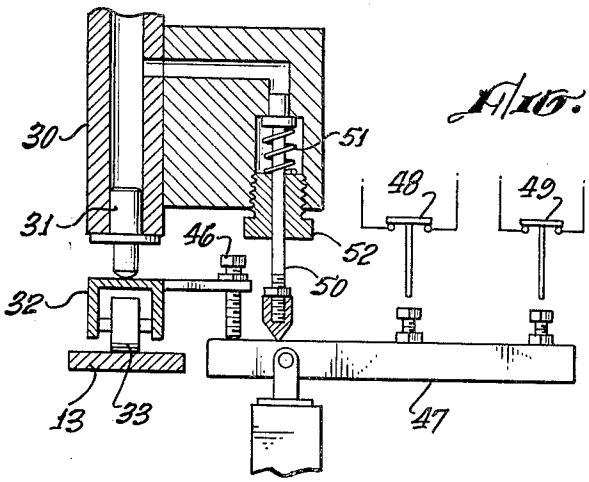


FIG. 2.



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MOMENT COMPARATOR

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The present invention relates to a means for comparing one mechanical moment with another. More particularly, the present invention relates to a moment comparator that can be utilized as a crane safety device in comparing the load moment being experienced by the crane with the maximum safe moment for the crane. In such a crane environment, the function of the invention is to prevent the crane from tipping over or otherwise being damaged, and to safeguard operating personnel, nearby workmen, and property in the vicinity of the crane.

The type of device currently being used on cranes to perform this safety function is merely a mechanical indicator which indicates how far the crane boom is extended. The operator then guesses the weight of the load and whether or not an allowable load moment will be experienced when he attempts the lift.

One of the big disadvantages of this approach is the fact that for reasons of personal safety the crane operator utilizes only about 70 percent of the capacity of the crane. Further, if he is incautious in this matter, due to innumerable human factors such as being tired, or hurried, or inexperienced, he may cause considerable destruction and death, including his own.

The present invention removes the guess work from this portion of crane operations by measuring the actual load moment experienced and comparing it with the maximum safe moment allowable for that particular crane. Visual and/or audio signals can be used to inform the crane operator how close he is bringing his crane to the limit of its safe operating characteristics. If desired, the crane can be automatically stopped or "frozen" by the present invention at any pre-selected ratio between the actual load moment and the maximum safe moment of the crane.

The advantages of the present invention include, then, not only a great increase in safety but a substantial increase in the capacity utilization factor. As a fringe benefit it is probable that insurance premiums will be reduced, but no actual experience is available yet in this matter. It is also worth noting that installation of the present invention on existing cranes is only an overnight task, so that loss of operating time for installation is either completely negated or, at least, held to a minimum.

Referring now to the sheet of drawings, FIGURE 1 thereof can be briefly described as a schematic drawing of one embodiment of the present invention. This schematic drawing, with cutaway views of various parts for purposes of clarity, show a housing 3 containing certain levers and other mechanisms, a hydraulic cylinder 27, and a source of hydraulic fluid and pressure in reservoir 36 and pump 38. Further, FIGURE 1 shows the items mentioned to be interconnected by hydraulic fluid lines. Finally, an indicating device 35 is shown in FIGURE 1 as being connected by a generic mechanism 21 to movable parts within housing 3.

FIGURE 2 is a plan view of an indicating device which will convert position information regarding one of the levers in housing 3 into electrical signals. It is merely one embodiment of a replacement for the indicating device 35 and linkage 21 of FIGURE 1. For purposes of clarity, portions of FIGURE 2 are broken out. Generally speaking, the physical arrangement is such that as lever 13 is depressed, one end of lever 47 is thereby

caused to rise and come in contact with one or more electrical switches.

FIGURE 3 is merely a schematic of a crane showing a variable distance L between the centerline of the crane and the load being lifted by the crane. Reference will be made to distance L later on in this specification.

Turning now to a consideration of the apparatus of the present invention, reference is made to the schematic drawing of FIGURE 1 which discloses a preferred embodiment of the present invention. This drawing shows a housing 3 secured to the crane, which housing contains a bearing type opening as shown at 4, and a bearing type support 5. A spindle shaft 6 is shown threaded along its length save for the smooth cylindrical bearing surfaces at each end. As illustrated, one end of the spindle shaft is disposed in support 5 and the other end protrudes through opening 4 to the exterior of housing 3. On the protruding end of the spindle shaft is secured a gear or sprocket 7.

Typically, the motion of the boom of a crane is controlled by a gear assembly. Sprocket 7 is intended to be engaged with such a gear assembly so that as the boom moves in and out the spindle shaft rotates one way or the other. The mechanics of this gear to gear engagement is well within the state of the art and it has not been thought necessary to illustrate the details thereof. With regard to the bearing opening 4 and in support 5 it should be noted that high strength and wear resistant bushings can be used as desired.

A fulcrum post 8 having a threaded hole 10 therethrough is positioned on the spindle shaft, the threaded shaft being disposed through and engaged with threaded hole 10 so that rotation of the shaft moves the post translationally along the shaft. The fulcrum post can be kept from rotating with the spindle shaft by the use of lugs on the fulcrum post disposed in raceways in the sides of housing 3, or by a number of other obvious means. The post 8 is forked at its upper end with a pin 11 positioned between the forks and supported thereby as shown. A lever 12 is secured to pin 11 and extends therefrom on both sides of the fulcrum post, having an arm 13 extending in one direction and another arm 14 extending in the opposite direction, both arms lying essentially parallel to spindle shaft 6.

A cam 16 is secured to the housing 3 in such manner that the cam face 17 faces lever arm 14 near the end extremity thereof. A spring loaded unit 18 is secured to the extremity of lever arm 14 as shown and extends upward to contact cam face 17. This spring loaded unit, containing compressed spring 19, creates a force tending to push lever arm 14 away from cam face 17. It can be seen that the upper portion of the spring loaded unit contacts cam face 17 by means of a roller or bearing 20 that is free to move over the cam face 17. The unit 18 is held substantially perpendicular to lever arm 14 by an extension of the fulcrum post. This extension is designated by the numeral 22 and includes an arm 23 connected by pins to both extension 22 and spring unit 18. It should be noted here that there are other ways to maintain the substantially perpendicular relationship between lever arm 14 and spring unit 18 and that FIGURE 1 merely illustrates one embodiment.

Turning now to a consideration of the hydraulic portion of the present invention, FIGURE 1 shows the load supporting cable 25 of the crane secured to a piston rod 26. Rod 26 enters hydraulic cylinder 27 and is connected to piston 28 disposed therewithin. A hydraulic line 29 is connected into cylinder 27 to transmit the pressure created in the cylinder to housing 3. Housing 3 contains a hydraulic cylinder or chamber 30 to receive this pressure as shown. A piston 31 is disposed in cham-

ber **30** and extends therefrom to apply a force to lever arm **13** in response to the pressure in chamber **30**. A lever **32** with roller **33** is shown disposed between piston **31** and lever arm **13** to permit lever arm **13** to move back and forth beneath the piston. It is to be noted that pin **34** holding lever **32** in place is in a straight line with fulcrum pin **11** and the contact point between roller **33** and lever arm **13**. This arrangement minimizes moments that might be induced by friction forces between roller **33** and lever arm **13**. While lever arm **13** may move up and down, such movement will not produce any appreciable friction induced moments.

With this hydraulic system arrangement it is seen that the load force on the cable **25** is proportionally transmitted to lever arm **13**, the proportionality being governed by the ratio between the surface areas of pistons **28** and **31**. A hydraulic reservoir **36** is shown as a source of hydraulic fluid. A motor **37** is connected to operate pump **38** in drawing hydraulic fluid from the reservoir and supplying it through check valve **39** to hydraulic line **29**. Two electrical switches **40** and **41** are disposed one on each side of flange **24** on piston rod **26**. If through leakage, or for other reasons the volume of fluid in the hydraulic system drops too low then switch **40** will be closed and activate motor **37**. When the volume of fluid reaches the proper level then switch **41** will be caused to open, stopping motor **37**. The electrical switch **42** is an emergency switch coming into operation in the event of a rupture in the hydraulic system. More about its function, however, when the operation of the invention is discussed.

As previously indicated, visual and/or audio signals can be used to indicate a dangerous loading condition on the crane. FIGURE 2 discloses a simple approach to transferring information regarding the position of lever arm **13** into electrical signals. As lever arm **13** is depressed by lever **32**, a set screw **46** attached to lever **32** depresses one end of lever **47**. The other end of lever **47** is thereby caused to rise and operate first one electrical switch **48** and then another **49**. Set screw **46** can be adjusted to cause the first switch operation to occur at, say 90% of the crane's safe loading moment, and the second switch at the maximum safe loading moment. Of course, proper switch spacing is also required. The operation of these switches can be utilized to stop the crane in its current position, or initiate visual warning lights, audio signals, or other devices.

It is obvious that other "pick off" mechanisms could be used such as potentiometers, electrical coil and magnetic core devices, and the like. Many of these pick off devices could be used to provide a continuous indication of the percentage of safe crane operating capacity being employed. A potentiometer, for instance, could be used to operate a needle and dial indicator.

An added safety feature is shown in FIGURE 2, consisting of a spring restrained plunger **50**. The restraining spring **51** is chosen and adjusted by screw cap **52** so that plunger **50** cannot move lever **47** and operate switches **48** and **49** until the hydraulic pressure in line **29** reaches a level indicating a completely unsafe loading condition, at which point the switches **48** and **49** should have been activated anyway.

Having described the apparatus of the present invention, attention is now directed to the operation of same. Referring again to FIGURE 1 it is seen that the crane's load supporting cable **25** transmits the weight (force) of the load being lifted to piston **28**. The hydraulic system proportionately transmits this force to piston **31** which presses down on lever **13** in response to the hydraulic pressure. The other end of the lever (lever arm **14**), however, is being acted on by spring loaded unit **18**. This spring loaded unit imposes a force, let us call the force F, on the end of lever arm **14**. If the effective length of lever arm **14** is designated D, then $F \times D$ is the moment about fulcrum pin **11**. The spring **19** is chosen

so that the product $F \times D$ is proportional to the maximum safe loading moment that the crane is safe to withstand.

If the force applied to lever arm **13** by piston **31** is indicated by the letter W, and the effective moment arm length of lever arm **13** is designated d, which effective moment arm d is indicated in FIGURE 1, then the product $W \times d$ is proportional to the actual load moment being experienced by the crane and the moment $W \times d$ is imposed about the fulcrum pin **11** in opposition to the maximum safe moment $F \times D$. By this means the maximum safe moment and the actual moment being experienced are compared. When the actual moment approaches the limits of safety, then the electrical switches **48** and **49** are activated (or closed—as desired).

It must be remembered, however, that the crane's boom moves in and out so that distance d must somehow be made to change as it does so. As previously mentioned, a gear assembly is used to control the boom motion, and spindle shaft **6** is connected to such assembly by sprocket **7**. If it is assumed that the distance which the crane arm or boom extends per rotation of the sprocket **7** is a constant, then the distance d is directly proportional to the distance which the crane arm has been extended, the rotation of spindle shaft **6** causing d to change. To summarize this feature:

If L=load distance from centerline of crane, and Q= load on crane arm at distance L then $L \times Q$ is proportional to $W \times d$ and the proportionality is kept constant by the fact that d is made to change as L changes.

So far, this description of the operation of the apparatus has assumed that there will be a linear relationship between the distance L and the distance d. For many cranes, however, this will not prove to be a valid assumption. A typical crane where this assumption will not hold true is one which has a folding boom rather than a rigid boom. Thus, the relationship between L and d might prove to be sinusoidal, hyperbolic, parabolic, or what have you. It is to be recalled at this point that the moment $W \times d$, which represents the actual moment being experienced by the crane, is constantly compared with the maximum safe moment $F \times D$. This being the case, if the crane is such that d is not directly proportional to L then this may be compensated for by varying the quantity F. As shown in the schematic, the quantity F is made to vary as the spring unit **18** moves along the cam **16**. Thus, by imposing a sinusoidal function on the cam face **17**, the force F can be made to vary sinusoidally as the spring unit **18** travels across its face in response to rotation of spindle shaft **6**.

Thus, the present invention can be mass produced for cranes, with the exception that the cam **16** is a part that must be made to suit each particular crane.

It is to be noted that while the use of cam **16** takes care of the situation where the distance d is not directly proportional to L, it also takes care of the situation where the maximum safe moment is also not a constant quantity but is some function of L. If the quantity d is some function of $L(d=f(L))$ and the maximum safe moment is some function of $L(M=F(L))$, then f(L) and F(L) are both superimposed on the cam face **17**.

While the above description sets forth the operating principles of the device, there are other features which should be mentioned as being significant. In this regard, attention is directed to the fact that should a major break occur in the hydraulic line **29** then piston **28** would move to the left and actuate emergency switch **42**. Switch **42** could be used to halt the crane or to initiate other safety operations. If desired, switch **42** could be placed in the same electrical circuit as limit switch **49**.

While it was previously mentioned that only the cam **16** must be changed from crane to crane during the mass production of the apparatus, it might prove economical to have various "sets" of hydraulic cylinders **27**, pistons **28**, and springs **19** to be used in accordance with the

size and maximum lifting capacity of the crane. In this manner, a large hydraulic cylinder would not be installed on a small crane that would utilize only a third of its capacity.

Although specific embodiments of the present invention have been described and illustrated, it is to be clearly understood that the same are by way of illustration and example only; it is to be understood that the invention is not limited thereto, as many variations will be readily apparent to those versed in the art and the invention is to given its broadest possible interpretation within the terms of the following claim.

I claim:

1. A moment comparator generally comprising a fulcrum, a lever positioned to be pivotally movable about said fulcrum, a first variable force means spacially fixed relative to said lever and applying a first force to a fixed point on said lever to move the lever about said fulcrum, a second variable force means imposing a second force on said lever to urge it about said fulcrum in a direction opposite to that induced by said first force, and means connected to said fulcrum, lever, and first force means for moving them relative to said second force means so as to vary the point of application of said second force to said lever, thus changing the moment about said fulcrum occasioned by said second force, without changing the moment about said fulcrum occasioned by said first force means, and means associated with the above for indicating the moments applied to the lever.

2. A moment comparator generally comprising a fulcrum, a lever connected to said fulcrum and positioned to be pivotally movable about said fulcrum, a first variable force means connected to said lever and applying a first force to a fixed point on said lever to move the lever about said fulcrum, a second means for applying an output second force to said lever in response to force inputs to said second means, said output second force being applied to said lever to urge it about said fulcrum in a direction opposite to that induced by said first force, and a third means connected to said fulcrum, lever and first variable force means for moving said items in translational motion relative to said second means so as vary the point of application of said output second force to said lever, thus changing the moment about said fulcrum occasioned by said output second force without changing the moment about said fulcrum occasioned by said first force, said third means inducing said translational motion of said fulcrum, lever and first variable force means in response to imput motions to said third means, and means associated with the above for indicating the moments applied to the lever.

3. A moment comparator generally comprising a fulcrum, a lever connected to said fulcrum and positioned to be pivotally movable about said fulcrum, a cam spaced apart from said lever and fixed in position, a first variable force means having two ends with one end connected to said lever and the other end contacting said cam so as to apply a first force to a fixed point on said lever in accordance with the dictates of said cam, said first force being applied in a direction to urge said lever pivotally about said fulcrum, a second means for applying an output second force to said lever in response to force inputs to said second means, said output second force being applied to said lever to urge it about said fulcrum in a direction opposite to that induced by said first force, and a third means connected to said fulcrum, lever and first variable force means for moving said items in translational motion relative to said second means so as to vary the point of application of said output second force to said lever and the point of contact between said first variable force means and said cam, said third means inducing said translational motion of said fulcrum, lever and first variable force means in response to input motions to said third means, and means associated with the above for indicating the moments applied to the lever.

4. In a crane having a movable boom, a boom moving mechanism, and a load supporting cable, a moment comparator generally comprising a fulcrum, a lever connected to said fulcrum and positioned to be pivotally movable about said fulcrum, a first variable force means connected to said lever and applying a first force to a fixed point on said lever to urge the lever about said fulcrum, a second means for applying a force to said lever, said second means having a force input mechanism adapted to be connected to a load supporting cable of a crane and a force output mechanism contacting said lever and applying an output force to said lever to urge it about said fulcrum in a direction opposite to that induced by said first force, said output force of said second means for applying a force to said lever being proportional to the input force experienced by the force input mechanism of said second means, means adapted to be connected to boom moving mechanism of a crane for converting motion of a boom moving mechanism into translational motion of said fulcrum, lever, and first variable force means to move same in translational motion relative to said second means so as to vary the point of application of said output second force to said lever, and means associated with said lever for indicating the moments applied to the lever.

5. In a crane having a movable boom, having a boom moving mechanism, having a load supporting cable, and having a variable distance L between the centerline of the crane and the centerline of any load being lifted by the crane, a moment comparator comprising a fulcrum, a lever connected to said fulcrum and positioned to be pivotally movable about said fulcrum, a cam spaced apart from said lever and fixed in position, a first variable force means having two ends with one end connected to said lever and the other end contacting said cam so as to apply a first force to a fixed point on said lever in accordance with the dictates of said cam, said first force being applied in a direction to urge said lever pivotally about said fulcrum, a second means for applying a second force to said lever, said second means having an input mechanism adapted to be connected to a load supporting cable of a crane to receive load forces therefrom, said second means having an output mechanism contacting said lever at a variable distance *d* from said fulcrum and applying an output force to said lever to urge it about said fulcrum in a direction opposite to that induced by said first force, said output force being proportional to load forces which said input mechanism is adapted to receive, means adapted to be connected to a boom moving mechanism of a crane for converting motion of a boom moving mechanism into translational motion of said fulcrum, lever, and first variable force means to move the fulcrum, lever, and first variable force means in translational motion relative to said output mechanism of said second means so as to vary the distance *d*, and so as to move said first variable force means over the face of said cam, said cam having two mathematical functions imposed thereon, one said function being the relationship between L and *d* where L is the distance between the centerline and load of an associated crane, and the other said function being the maximum safe moment of an associated crane expressed as a function of L, and means associated with said lever for indicating the moments applied to the lever.

6. In a crane having a movable boom, a boom moving mechanism, and a load supporting cable, and having a variable distance L between the centerline of the crane and the centerline of any load being lifted by the crane, a moment comparator comprising a fulcrum, a lever connected to said fulcrum to be pivotally movable thereabout, a cam spaced apart from said lever and fixed in position, a compressive spring loaded unit having first and second ends, the first of said ends connected to said lever and the second end contacting said cam, said unit being held approximately perpendicular to said lever by an extension of said fulcrum, said unit applying a first

force to a fixed point on said lever in accordance with the dictates of said cam, said first force being applied in a direction to urge said lever pivotally about said fulcrum, a second means for applying a force to said lever, said second means having an input mechanism adapted to be connected to a load supporting cable of a crane to receive load forces therefrom, said second means having an output mechanism contacting said lever at a variable distance *d* from said fulcrum and applying an output force to said lever to urge it about said fulcrum in a direction opposite to that induced by said first force, said output force being proportional to load forces which said input mechanism is adapted to receive, a threaded spindle shaft disposed through an engaged in a threaded hole in said fulcrum so that rotation of said spindle shaft moves said fulcrum towards or away from the output mechanism of said second means, said spindle shaft being adapted to be connected to an associated boom moving mechanism of a crane for converting motion of the associated boom moving mechanism, through rotation of the spindle shaft, into translational motion of said fulcrum, lever, and compressive spring loaded unit either towards or away from the output mechanism of said second means so as to vary the distance *d* between the fulcrum and said output mechanism, and so as to move the second end of said compressive spring loaded unit over the face of said cam, said cam having two mathematical functions imposed thereon, one said function being the relationship between L and *d* where L is the distance between the centerline and load of an associated crane, and the other said function being the maximum safe moment of the associated crane expressed as a function of L, and means associated with said lever for indicating the position of said lever.

7. The moment comparator of claim 6 wherein said

second means for applying a force to the lever is a mechanical-hydraulic system comprising an input hydraulic cylinder adapted to be secured to an associated crane, a movable input piston positioned therein, a piston rod extending from said piston to the exterior of said cylinder and adapted to be connected to a load supporting cable of an associated crane so as to receive load forces therefrom, hydraulic fluid within said input hydraulic cylinder, an output hydraulic cylinder containing a movable output piston, said output piston contacting a roller containing member movable in response to said piston, said roller contacting said lever and rolling on same as said lever moves translationally back and forth, a hydraulic line connecting said input hydraulic cylinder to said output hydraulic cylinder whereby load forces that may be received by the input piston are proportionately transmitted to said output piston and thence to said lever, and a source of hydraulic fluid connected to said hydraulic line by means of a motor, pump, and check valve.

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