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Jackson et al.

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[54] **MOMENT MONITORING SYSTEM FOR HYDRAULIC-PISTON TYPE CRANES**

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[21] Appl. No.: **401,832**

Related U.S. Application Data

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[52] **U.S. Cl.** ..... **212/39,** 212/37, 212/86, 212/132, 340/267 C

[51] **Int. Cl.** **B66c 13/48**

[58] **Field of Search** ..... 212/39 R, 39 B, 37, 39 MS, 212/86, 132; 340/267 C

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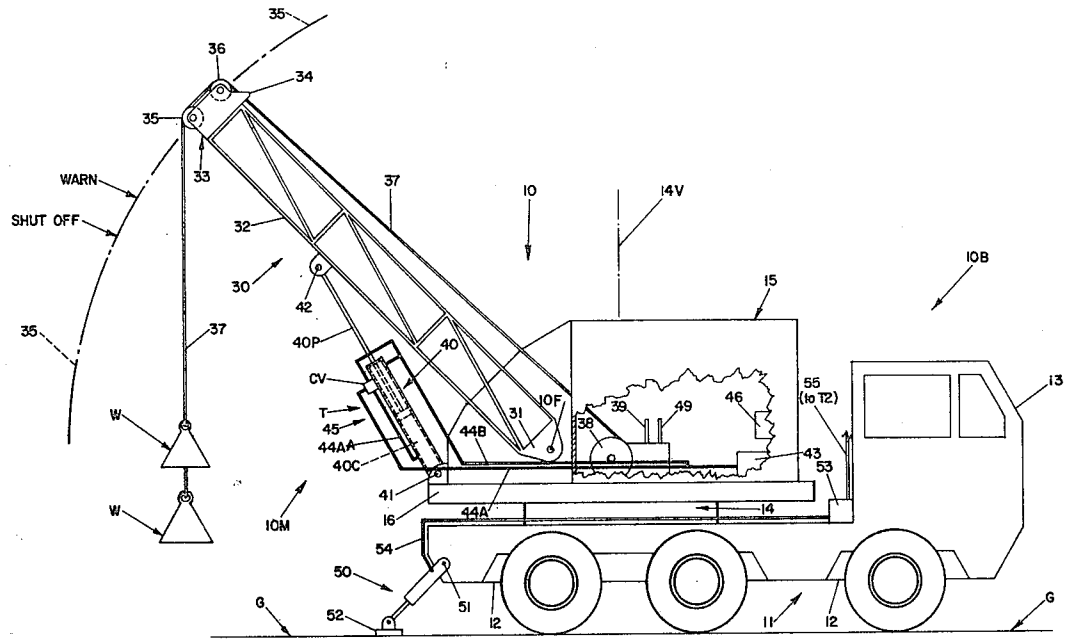
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[57] **ABSTRACT**

Cranes, forklift trucks, and other burden manipulation apparatus generally comprise an elongate boom or analagous burden member that exerts a controllably variable moment, as effected through a hydraulic-piston, etc., with respect to the normally stably supported weighty base member of the apparatus. The present invention discloses a moment monitoring system so as to caution or apprise the apparatus operator that the burden member moment has attained an arbitrarily prescribed subcritical-level which is quantitatively below the moment critical-level (i.e., the burden moment at which the base member and the entire apparatus is rendered unstable, tipped, or otherwise rendered inoperative). The moment monitoring system generally comprises hydraulic pressure differential sensing means extending between the two sides of the hydraulic-piston reciprocatable plunger, the differential sensing means being actuatably connected through a ram portion of a reciprocatable hydraulic pump including therewithin an isolated hydraulic metering fluid which exerts variable pressure upon a suitable pressure-responsive device such as a Bourdon-tube, at least one hydraulic-electrical transducer including a said pressure-responsive device and which transducer is electrically connected to a warning indicator for warning the apparatus operator that an arbitrarily prescribed subcritical-level of burden moment has been attained, and yieldable resistance means (such as as weighted pivotal lever) which means increasingly resists effects of the pressure-responsive device at steeper boom angles thereby compensating for progressive decreases in the burden moment critical-level mathematical value coincident with progressively steeper boom angles.

8 Claims, 8 Drawing Figures



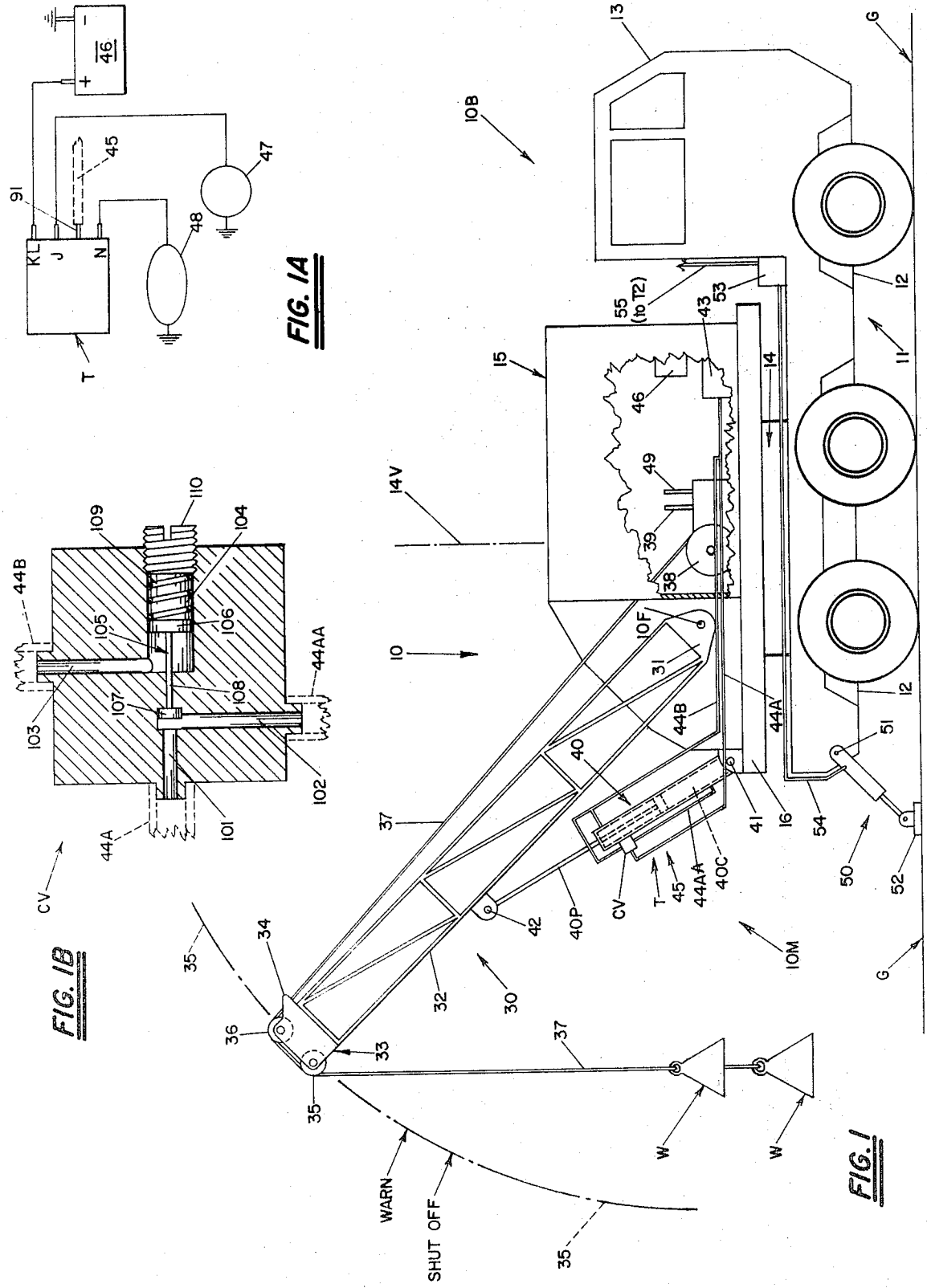

FIG. 1
FIG. 1A
FIG. 1B
WARN
SHUT OFF
W
W
CV
T
10
10B
10F
10M
11
12
13
14
14V
15
16
30
31
32
33
34
35
36
37
38
39
40
40C
40P
41
42
43
44A
44AA
44B
45
46
47
48
49
50
51
52
53
54
55 (to T2)
91
101
102
103
104
105
106
107
108
109
110
KL
J
N
G

FIG. 2

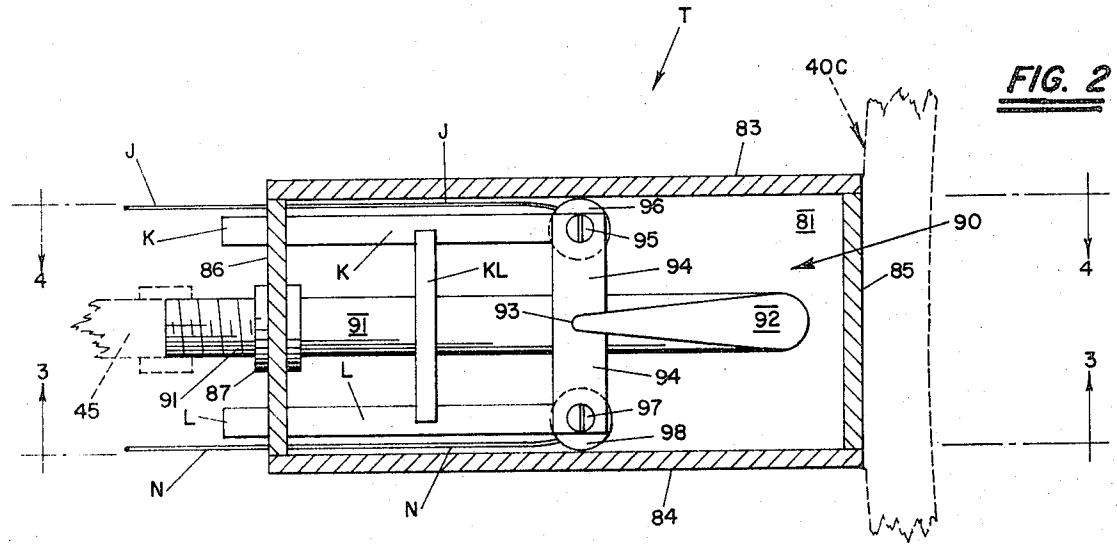


FIG. 3

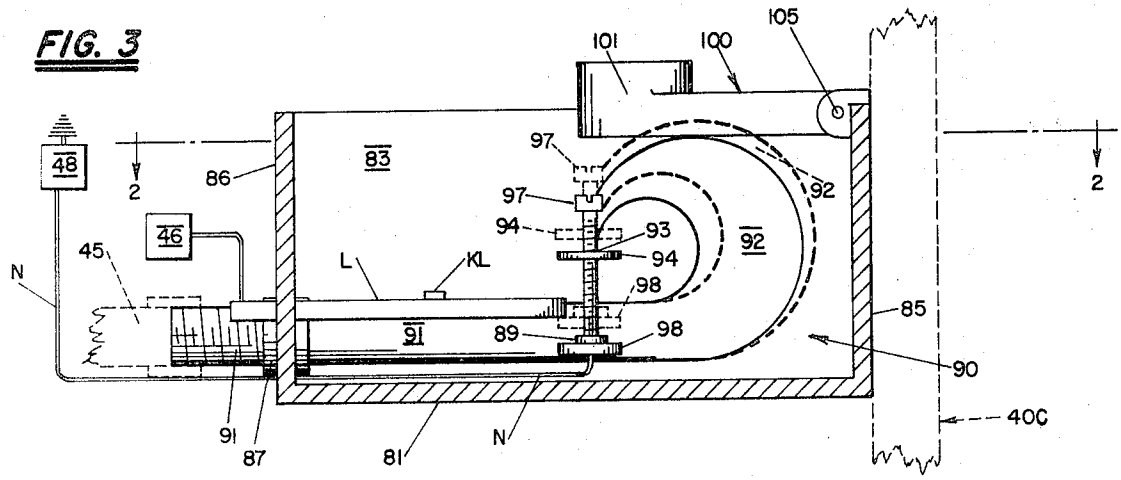


FIG. 4

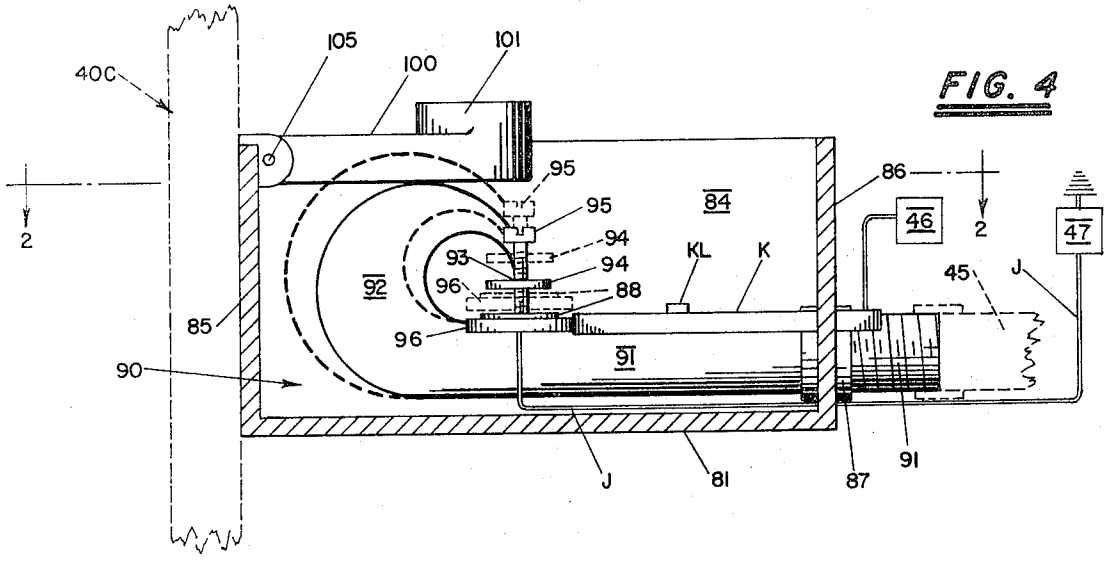
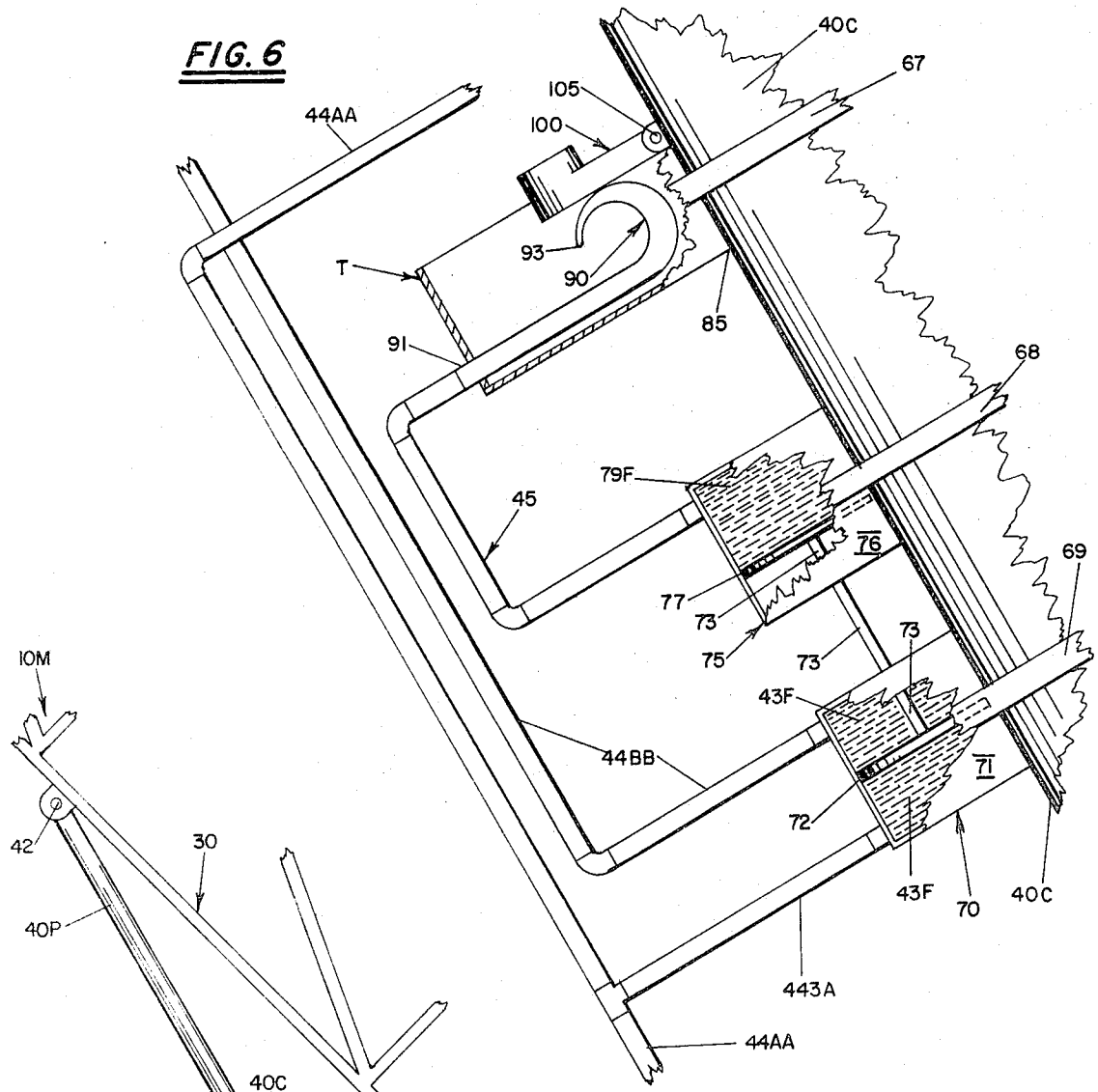


FIG. 6


40C
67
105
100
44AA
T
93
90
85
91
68
79F
45
76
69
77
73
75
73
73
43F
44BB
71
72
43F
70
40C
443A
44AA

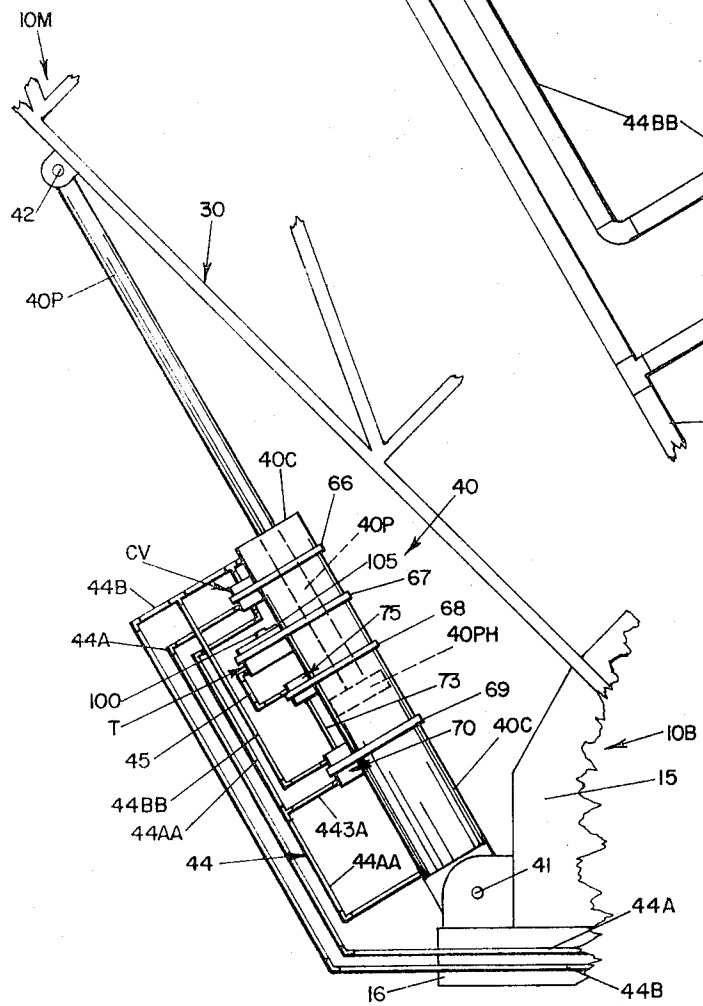

10M
42
30
40P
40C
66
40
40P
CV
105
44B
67
75
68
44A
40PH
73
69
100
T
70
40C
10B
45
15
44BB
44AA
443A
44
44AA
41
44A
16
44B

FIG. 5

MOMENT MONITORING SYSTEM FOR HYDRAULIC-PISTON TYPE CRANES

This application is a continuation-in-part of patent application Ser. No. 259,565 (filed June 5, 1972) now U.S. Pat. No. 3,771,667, issued on Nov. 13, 1973 and originally entitled "Moment Monitoring System For Cranes And Other Burden Manipulation Apparatus."

Cranes, forklift trucks, "tuggers," fire-ladder trucks, elongate boom service vehicles, and the like, are sometimes generally referred to as "normally stable burden manipulation apparatus of the controllably variable moment type." For such generic class of apparatus, there is a weighty base member normally stably supported upon the earth or other suitable underlying substrate whereby at apparatus stable conditions the base member extends vertically along an upright-axis and the apparatus center-of-gravity is encompassed within the base member. Such apparatus class further comprises a burden member laterally offset from the base member upright-axis and supported by the underlying substrate through the base member. If the apparatus operator allows the burden moment to become too great with respect to the base member upright-axis, the apparatus center-of-gravity will be shifted too far laterally; the base member and hence the entire apparatus will no longer be stably supported upon the underlying substrate, but rather is apt to topple-over, inimicably tilt, or otherwise be rendered inoperative. For elongate boom cranes and analagous apparatus, the boom member moment is determined both by variable load and by variable lateral distance from the base member upright-axis, said lateral distance sometimes being effected through dual-directional hydraulic-pistons pivotably connected both to the boom and to the base member. The apparatus operator must, of course, be very attentive to the manner in which he controls the powered burden manipulation lest its moment becomes so great as to render the apparatus unstable and inoperative. For example, there are numerous recorded histories of operating cranes and the like where the burden moment with respect to the upright-axis had reached the critical-level and the apparatus toppled or pitched-over, thereby injuring the operator. Attainment of the moment critical-level happens not only to unskilled and inattentive operators, but can also be caused by non-operator factors such as mis-labeled loads, malfunctioning lateral distance controls, uneven underlying substrates, etc.

Prior art workers have recognized that for elongate boom type cranes the burden moment critical-level is not a constant mathematical quantity, but rather progressively decreases in mathematical value as the boom angle becomes progressively steeper, i.e., boom angle decreases with respect to the base member upright-axis. In other words, the crane apparatus is more apt to become toppled or unstable as the elongate boom progressively approaches the horizontal and whereby the manipulated load is relatively further from the base member. In order to compensate for progressive changes in the burden moment critical-level coincident with boom angle changes, the prior art has developed elaborate and costly mechanism for surveilling burden moment such as utilizing computers and other highly sophisticated electronic devices. Nevertheless, most prior art compensating means for burden moment surveillance tend to be unreliable, in non-compliance with

certain Governmental regulations, difficult to maintain, subject to fouling by contaminants, and not readily adaptive for coverting older obsolescent cranes to required safety standards.

It is accordingly the general object of the present invention to provide a moment monitoring or surveillance system for cranes, forklift trucks, and analagous burden manipulation apparatus, which system cautions or otherwise apprises the apparatus operator that the burden moment has attained an arbitrarily prescribed subcritical-level, which in mathematical value is near to but safely less than, the critical-level moment which would render the apparatus unstable or inoperative.

It is another general object of the present invention to provide moment monitoring system for elongate boom type cranes wherein the boom angle is effected and controlled through a dual-directional hydraulic-piston which is pivotably attached to the elongate boom adjacent to the base member and also to the said base member.

It is a further object to provide moment monitoring or surveillance systems for hydraulic-piston type cranes and readily adapted for converting obsolescent cranes into safe condition as well as for incorporation into newly manufactured original equipment cranes.

It is yet another object to provide moment monitoring or surveillance systems especially adapted for elongate boom cranes of the hydraulic-piston type and including improved compensation means (i.e., relative to the phenomenon of the progressively changing burden moment critical-level mathematical value at progressively changing boom angles). It is an ancillary object to provide compensation means that is reliable in operation, economical in construction and maintenance, readily calbrated under numerous apparatus and working conditions, and not apt to become fouled by environmental contaminants.

It is a further object to provide a moment monitoring system providing a visual or an audible warning to the operator whenever the burden moment has attained a selected subcritical-level burden moment and appropriate to the existent boom angle. If the operator fails to heed the warning by taking moment-reducing corrective action at the subcritical-level, the system at a proxcritical-level (yet below the critical-level) shuts off the power to the crane burden manipulation means thereby averting a potentially disastrous situation.

It is yet another object to provide moment monitoring systems admirably adapted for hydraulic-piston type cranes of various designs and levels of sophistication including original equipment, existent or even obsolescent equipment, and those having auxiliary accessories and addenda including pressure relief valves, etc.

With the above and other objects and advantages in view, which will become more apparent as this description proceeds, the moment monitoring system for hydraulic-piston type cranes and analagous burden manipulation apparatus generally comprises: hydraulic pressure differential sensing means between the two sides of the hydraulic-piston reciprocatable plunger, said differential sensing means being actuatably connected through a ram to a reciprocatable hydraulic pump including therewithin a hydraulic metering fluid which exerts variable pressure upon a suitable pressure-responsive means; at least one hydraulic-electrical transducer including a said pressure-responsive device

such as a Bourdon-tube pressure-spring which communicates with the metering fluid of the hydraulic pump; a warning indicator electrically connected to the transducer for warning the apparatus operator that an arbitrarily prescribed subcritical-level of burden moment has been attained and as calibrated into the said pressure-responsive device; and yieldable resistance means bearing against the pressure-responsive device to partially resist its affect by the metering fluid (e.g., resisting the tendency of the Bourdon-tube to be straightened), said yieldable resistance means offering progressively greater resistance to the pressure-responsive device at steeper boom angles thereby providing a compensation means for the angle-dependent burden moment critical-level.

In the drawing, wherein like characters refer to like parts in the several views, and in which:

FIG. 1 is a side elevational view of a typical burden manipulation apparatus herein as an elongate boom crane having a hydraulic-piston for varying the boom angle and with which apparatus the burden moment monitoring or surveillance system of the present invention might be employed.

FIG. 1A is a simplified circuit diagram schematically indicating for FIG. 1 primary functions of the moment monitoring system including at the transducer.

FIG. 1B is a typical check valve in section.

FIG. 2 is a top plan view of a representative form of a hydraulic-electrical transducer which might be utilized within the burden moment monitoring systems alluded to herein.

FIG. 3 is a sectional elevational view taken along line 3—3 of FIG. 2.

FIG. 4 is a sectional elevational view taken along line 4—4 of FIG. 2.

FIG. 5 is a detail view of FIG. 1.

FIG. 6 is a detail view of FIG. 5.

The typical hydraulic-piston type burden manipulation apparatus, e.g., crane 10 of FIG. 1, generally comprises a weighty base member (herein generally referred to as 10B) normally stably supported upon a suitable underlying substrate (e.g., earth's surface G) whereby at apparatus stable conditions the base member extends vertically along an upright-axis (14V). The selected typical apparatus 10 further comprises a burden member (herein generally referred to as 10M) laterally offset from the base member vertical-axis 14V and supported by the underlying substrate G wholly through the apparatus base member (10B). Burden member 10M comprises an elongate boom 30 having its butt end 31 pivotably attached at butt-pivot 10F to the base member carriage 15 and further comprises a manipulatable load (as weights W) depending from the boom tip end 33 whereby said burden member 10M exhibits a moment, measured horizontally laterally outwardly from the base member upright-axis 14V, and mathematically dependent upon the combination of load W plus the weight of boom 30. Thus, as boom 30 pivots about butt-end 10F and its tip portion 33 circumscribes arcuate locus 35, the burden moment is adapted to increase and ultimately to the critical-level extent where the base member 10B is rendered unstable with respect to its substrate G thereby causing the crane apparatus to be inoperative or even toppled i.e. "pitched over."

Crane 10 is of the hydraulic-piston actuated type which means that a pumpable reservoir (43) of hydraulic motive fluid provides the powering means for the dual-directional hydraulic-piston 40 and thus for varying the burden moment through angular changes in elongate boom 30. Base member 10B for crane 10 herein comprises a flat bed truck 12 having depending wheels whereby the weighty base member is stably supported upon the earthen underlying substrate G. The base member 10B further comprises a carriage 15 revolvably supported at 14 and revolvable about upright-axis 14V, carriage 15 being internally provided with operator controls (39, 49). There is a powerably revolvable drum 38 (controlled at 39) for winding load-cable 37 which passes from drum 38 to pulleys 36 and 35 at boom tip portion 33, the load W being attached to load-cable 37. Boom 30 has a controllably variable angle with respect to upright-axis 14V and to substrate G, as through a conventional dual-directional hydraulic-piston 40 having its casing 40C pivotably attached at casing-pivot 41 to base frame member 11 below boom 30 and having its reciprocatable plunger portion 40P pivotably attached at plunger-pivot 42 to boom 30 laterally outwardly adjacent of buttpivot 10F. The boom angle is effected and controlled by the pumpable reservoir (43) of motive hyraulic fluid that is controllably selectably deliverable by the operator, as by valve control lever 49 energized by battery 46 and ignition coil 47. Two hydraulic fluid lines 44A and 44B proceed from the vicinity of control lever 49 with the interior of hydraulic-piston casing 40C and on opposite sides of the plunger 40P slidable encased flange (first line 44A below and second line 44B above). Thus, motive hydraulic fluid controllably deliverable from 43 through first line 44A into casing 40C extends plunger 40P therefrom to increase the boom angle (making it steeper to substrate G) and hence decreases the burden moment. On the other hand, motive fluid delivered into casing 40C through second line 44B retracts plunger 40P thereinto to decrease the boom angle and thereby increases the burden moment. Oftentimes a fluid check valve CV is connected between the second line 44B and biased against the first line 44A to prevent the elongate boom 30 from "creeping" downwardly from a selectably attained boom angle at which the control lever 49 is "set."

The burden member 10M (boom 30 and payload W) provides a progressively increasing burden moment with respect to the base member upright-axis 14V as the boom angle is made to increase with respect to 14V (i.e., to decrease with respect to the horizontal G). Whenever the burden moment increases to the extent to attain a critical-level, the crane apparatus is apt to topple or "pitch over." Interestingly, the burden moment critical-level, customarily mathematically expressed in terms of foot-pounds, is not usually a fixed mathematical quantity for a given crane, but rather is variable and dependent upon the boom angle. Specifically, the burden moment critical-level becomes progressively greater as the boom angle with respect to the underlying substrate G increases (i.e., becomes steeper) and wherein the payload weight W is relatively closer to upright-axis 14V. This progressive change in the mathematical value for burden moment critical-level has proved very troublesome to prior art workers in their quest for economical and reliable burden moment monitoring systems for cranes and analagous apparatus and they have saught suitable compensation means therefor. Complicating this quest is the preva-

lent use of check valves, e.g., CV of FIG. 1B, which are employed to prevent downward "creeping" of the elongate boom (30) from its attained or "set" angle.

FIG. 1B shows in sectional elevation a rudimentary type check valve CV which is adapted for preventing the crane elongate boom (30) from "creeping" downwardly after having its angle "set" by the operator (at 49). Check valve CV herein generally comprises a rectangular housing internally provided with three passages including: first-passage 101 (at hose line 44A); second-passage 102 (at hose line 44AA); and third-passage 103 (at hose line 44B). Axially aligned with first-passage 101 is a housing-bore 104 having therewithin helical spring 109 and also the large-shoulder part 106 of reciprocatable spindle 105. There is a cap 110 threadedly engaged with the housing for empirically adjusting spring (109) tension against spindle 105. Spindle 105 also comprises a small-shoulder part 108 spaced with connectorrod 107 a fixed distance from large-shoulder 106, which part 106 is reciprocatable along housing-bore 104. In FIG. 1B it can be assumed from the position of spindle 105 that pressurized hydraulic motive fluid is entering from hose line 44A into firstpassage 101 causing the shown rightward position of spindle 105 to permit the motive fluid to travel into hose line 44AA via second-passage 102 to increase or "steepen" the angle of boom 30. When the desired boom angle is "set" (as at 49), spring 109 pushes spindle 105 leftwardly (not shown) and blocks first-passage 101 with small-shoulder 108. This prevents downward "creep" of boom 30. If it is thereafter desired to lower the angle of boom 30, hydraulic motive fluid is controlled (as at 49) to enter third-passage 103 from hose line 44B to push the spindle large-shoulder (and the entire spindle 105) again rightwardly as shown in FIG. 1B whereby hydraulic motive fluid coincidentally flows from first-passage 101 to reservoir 43 (via hose line 44A).

The present invention overcomes the compensation means problem in a reliable yet economical manner, and substantially as follows. A hydraulic-electrical transducer including a pressure-responsive device such as a Bourdon-tube (exemplified in FIGS. 2–4) is actuatably connected to a hydraulic sensing or metering fluid confined within the vicinity of a reciprocatable hydraulic pump and hence the metering fluid is wholly isolated from the hydraulic motive fluid. The hydraulic metering fluid is of variable pressure and dependent upon the difference in motive fluid pressure on the two sides of the hydraulic-piston plunger (40P) and herein having check valve CV, which differential pressure is indicative of the burden moment. The pressure-responsive device (e.g., Bourdon-tube 92) portion of the transducer is actuatably electrically connected to a warning device (48) to warn the operator, electrical actuation being effected whenever the metering fluid has attained an arbitrarily selected high pressure to decrease the Bourdon-tube curvature and calibrated empirically to an arbitrarily selected subcritical-level of burden moment. A yieldable resistance means (e.g., 100) bears increasingly vigourously against the Bourdon-tube as the boom angle becomes steeper thereby not prematurely actuating the warning (48). This yieldable resistance means compensates for the fact that the burden moment critical-level (and too the selected subcritical-level) decreases in mathematical value at steeper boom angles.

FIGS. 2–4 illustrate a representative form of hydraulic-electrical transducer, sometimes hereinafter referred to simply as "transducer" or T, which is adapted to convert a change in hydraulic metering fluid pressure into the operator cautioning means (48). Transducer T herein comprises a housing having five rectangular panels including a horizontal floor-panel 81, and among four upright panels a left-panel 83, a right-panel 84, a lofty rear-panel 85, and a front-panel 86. Positioned between panels 83 and 84 is a pressure-responsive device such as a Bourdon-tube type pressure-spring 90–92 and including a generally linearly horizontal leading portion 91 intersecting front-panel 86 (and secured thereat with collar 87), the pressure-spring extending rearwardly from 86 parallel to floor-panel 81 toward rear-panel 85. The pressure-spring also includes a generally C-shaped portion having a progressively increasing tubular diameter terminating at the narrowest trailing-end 93, a horizontal bar 94 being rigidly attached to end 93. Thus, as variable liquid pressure is introduced into the tubular pressure-spring 90 through the larger diameter leading part 91 (and indicated at tubular connection 45), progressively higher liquid pressures will cause the trailing-end and bar 94 to elevate progressively higher above floor-panel 81 with bar 94 remaining parallel to 81 (phantom lines in FIGS. 3 and 4).

While the transducer T might provide only one signal to the apparatus operator, two signal stages at two pressure levels of the metering fluid are preferred. For example, the hydraulic-electrical transducer T might include two horizontal electrically-conductive contact-plates K and L passing through and maintained at constant elevation by housing front-panel 86. Although constant elevation contact-plates K and L are physically located on opposite sides of pressure-spring 90–92 whereby screw 95 overlies contact-plate K and screw 97 overlies contact-plate L. The lower end of screw 95 carries an electrical-insulator 88 to which is attached an electrically-conductive tall disc 96; an electrical conductor wire J is revolvably or flexibly attached to disc 96 and proceeds therefrom through housing front-panel 86. Similarly, the lower end of screw 97 carries an electrically-insulative member 89 to which is attached an electrically-conductive short disc 98; an electrical conductor wire N is revolvably or flexibly attached to disc 98 and proceeds therefrom through housing front-panel 86. Thus, by virtue of the independently adjustable screws 95 and 97, the elevation of the respective electrically-conductive discs 96 and 98 with respect to horizontal bar 94 can be independently established and the transducer calibrated thereby. For example, the elevation between disc 98 and contact-plate L can be established empirically to be such that: for any change in the metering fluid pressure through pressure-spring 90 and a desired finite elevation increase of bar 94 above co-elevation contact-plates K and L, conductor wire N will initiate a warning to the apparatus operator at a subcritical-level moment and before conductor wire J will shut-off the moment control power at a proxcritical-level. As will be pointed out later, the transducer will need to be calibrated empirically for each apparatus and model depending upon its stability characteristics of its base member and the burden member range and effects. As indicated at 40C in FIGS. 2–4 the transducer rear-panel (85) is preferably physically attached at constant perpendicular angle

to the angularly movable hydraulic-piston **40.** Thus, in actuality the transducer floor-panel **81** will not likely be horizontal as illustrated in FIGS. **3** and **4.**

A preferred embodiment of the monitoring system including the compensation means is depicted in the FIGS. **5** and **6** detail views of FIG. **1** and at the vicinity of the dual-directional hydraulic-piston **40.** As alluded to in FIGS. **1** and **1B**, in hydraulic-piston **40** the reciprocatable plunger portion **40P** (having slidable head **40PH** inside casing **40C**) is pivotably attached to boom **30** at plunger-pivot **42.** The pumpable reservoir **43** of the hydraulic motive liquid **43F** enters casing **40C** on both sides of plunger head **40PH**, specifically first line **44A–44AA** below and second line **44B** above head **40PH**, whereby casing **40C** is caused to angularly pivot at casing-pivot **41.** For the purposes of convenience, the intervening check valve CV, which is biased against first line segment **44AA**, is shown securely attached to the laterally outward side of casing **40C** with girth strap **66.**

There is a hydraulic pressure differential sensing means to sense the difference in pressure of the hydraulic motive fluid **43F** on opposite sides of plunger head **40PH** within the hydraulic-piston casing **40C** and including the biasing effects of check valve CV. For example, the hydraulic pressure differential sensing means embodiment **70** comprises a cylindrical hollow housing **71** herein attached to the laterally outward side of casing **40C** in elevation well below check valve CV with girth strap **69.** There is a barrier **72** for motive liquid **43F** and reciprocatably slidably disposed within housing **71.** Tubular lines **44BB** (a branch of second line **44B**) and **443A** (a branch of first line branch **44AA**) communicate with the interior of housing **71** on opposite sides of reciprocatable barrier **72.** Co-reciprocatable with barrier **72** is a ram **77,** and herein a linearly rigid spacer-shaft **73** is employed to space ram **77** a constant distance from barrier **72.**

There is a hydraulic pump means supplied with a metering fluid **79F** (which is wholly isolated from the hydraulic motive fluid **43F**) and which liquid **79F** communicates wth the pressure-responsive device, e.g., C-shaped Bourdon-tube **90–93.** For example, the hydraulic pump embodiment **75** comprises a cylindrical hollow housing **76** herein attached to the laterally outward side of casing **40C** with girth strap **68** at an elevation immediately above differential sensing means **70.** Ram **77** is reciprocatably slidably disposed within housing **76,** the hydraulic metering fluid **79F** being confined to the upper side only of fluid-impervious ram **77.** From the upper side of ram **77** the hydraulic metering fluid **79F** extends into and terminates within the Bourdon-tube **90–92,** there being intervening tubular conduit **45.** Thus, ram **77,** being co-reciprocatable with barrier **72,** tends to increasingly straighten Bourdon-tube **90–92** (and herein to coincidentally move its traling-end **93** upwardly) at increasing burden moments as indicated by the pressure differential of hydraulic motive fluid **43F** on opposite sides of plunger head **40PH,** there being too the biasing effects of check valve CV. The pressure-responsive device **(90–92),** being the hydraulic portion of the hydraulicelectrical transducer T, can provide a warning **(48)** to the crane apparatus operator at metering fluid pressure values empirically calibrated into the adjustable transducer and to correspond with the desired subcritical-level and proxcritical-level burden moments.

However, as has already been mentioned, the critical-level burden moment for elongate boom type cranes is not a constant mathematical value for a given crane, but rather increases as the boom angle steepens, i.e., becomes smaller with respect to the base member upright-axis **14V.** This changing critical-level phenomenon is herein compensated by the yieldable restance means which makes the pressure-responsive device progressively less sensitive to affects from the metering liquid **79F** at progressively steeper boom angles. A preferred type yieldable resistance means was alluded to relative to FIGS. **3** and **4** including a weighted lever therein pivotably associated at **105** with transducer part **85** and bearing gravitationally downwardly against Bourdon-tube **90–92.** In order to have the weighted pivotal lever **(100)** type yieldable resistance means bear downwardly progressively more forcefully at progressively steeper boom angles, the Bourdon-tube hefty leading-end **(91)** should be maintained at constant angular relationship to casing **40C.** For example, the housing of transducer T might be securely attached to casing **40C** with girth strap **67,** rear-panel **86** firmly abutting casing **40C** whereby Bourdon-tube stem **91** and floor-panel **81** remain at fixed angular relationship to casing **40C.** However, since weighted lever **100** is pivotably, and not rigidly, associated with casing **40C,** lever **100** bears increasingly gravitationally downwardly against Bourdon-tube **92** as the boom angle becomes more and more steep. Thus, at steeper boom angles the Bourdon-tube trailing-end **93** is relatively more retarded from moving, this compensation means ensuring that the warning **(48)** is not actuated at a too low subcritical-level of burden moment.

From the foregoing, the construction and operation of the moment monitoring system will be readily understood and further explanation is believed to be unnecessary. However, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction shown and described, but rather is to be embraced by the generic concepts of the appended claims.

We claim:

1. In a crane burden manipulation apparatus comprising a weighty base member normally stably supported upon a suitable underlying substrate whereby at apparatus stable conditions the base member extends vertically along an upright-axis, said crane further comprising an elongate boom type burden manipulation member having a tip end located remotely laterally outwardly offset from the apparatus base member and also having a butt end pivotably attached at a butt-pivot to the base member whereby the elongate boom is supported by the underlying substrate through said weighty base member, the crane apparatus also comprising a dual-directional hydraulic-piston including a plunger portion surrounded by and extendable from a casing with the plunger at a plunger-pivot being pivotably attached to the boom laterally outwardly from the butt-pivot and with the casing at a casing-pivot being pivotably attached to the base member remote from the boom, said crane apparatus including a pumpable reservoir of hydraulic motive fluid controllably deliverable through a first line and through a second line communicating with the casing interior on opposite sides of the extendable plunger thereby permitting selectable changes in the boom angularity and in the resultant

burden moment, the improvement of burden moment monitoring system and including compensation means for the progressive decrease in burden moment critical-level as the boom angle becomes steeper with respect to the underlying substrate and said system comprising:

A. Hydraulic pressure differential sensing means comprising a cylinder internally provided with a reciprocatable barrier for motive hydraulic fluid, said first line and second line sources of motive fluid communicating with the cylinder interior on the forward and the rearward sides respectively of said reciprocatable barrier;

B. A hydraulic pump comprising a housing internally provided with a ram that is co-reciprocatable with said barrier and located externally of the pressure differential sensing means cylinder, the hydraulic pump housing chamber being substantially filled with hydraulic metering fluid which is isolated from the hydraulic motive fluid;

C. A pressure-responsive device communicating with and sensitive to the metering fluid of said hydraulic pump;

D. At least one transducer of the hydraulic-electrical type and including said pressure-responsive device;

E. A warning indicator electrically connected to the transducer to caution the crane operator that some prescribed subcritical-level pressure of metering fluid has been attained whereby the crane operator might take corrective action to decrease the burden moment by increasing the boom angle through the dual-directional hydraulic-piston; and

F. Yieldable resistance means bearing against the pressure-responsive device to make said device less sensitive to the hydraulic metering fluid and progressively less so at steeper boom angles thereby providing compensation means.

2. The burden moment monitoring system of claim **1** wherein a check valve is interposed between the first and the second lines to prevent the elongate boom from creeping downwardly from a set angle, said check valve being biased against that line which tends to steepen the boom angle.

3. The burden moment monitoring system of claim **2** wherein the pressure-responsive device is a pressure-spring of the Bourdon-tube type.

4. The burden moment monitoring system of claim **3** wherein the transducer is mounted on the laterally outward side of the hydraulic-piston casing with the Bourdon-tube portion being so positioned that its narrowed trailing-end tends to move upwardly and relatively straighten said Bordon-tube at increasing pressures of hydraulic metering fluid; and wherein the yieldable resistance means comprises a weighted lever pivotably associated with respect to the hydraulic-piston casing and extending laterally outwardly therefrom and bearing gravitationally downwardly against the Bourdon-tube thereby increasingly resisting the straightenability thereof by the metering fluid as the elongate boom angle steepens with respect to the underlying substrate (i.e., angularly decreases with respect to the base member upright-axis).

5. The burden moment monitoring system of claim **4** wherein the transducer comprises a housing maintained at fixed angular relationship to the hydraulic-piston casing; and wherein the weighted lever is pivotably attached to the transducer above the elevation of the Bourdon-tube narrowed trailing-end.

6. The burden moment monitoring system of claim **5** wherein the check valve is attached to the hydraulic-piston casing and located above the transducer; wherein the hydraulic pressure differential sensing means is attached to the hydraulic-piston casing and located on the laterally outward side thereof; and wherein the hydraulic pump is attached to the hydraulic-piston casing and located in elevation between the transducer and the hydraulic pressure differential sensing means.

7. The burden moment monitoring system of claim **1** wherein the pressure-responsive device is a Bourdon-tube type pressure-spring located within the transducer housing, said transducer housing being attached to the hydraulic-piston casing and maintained at fixed angular relationship with the casing laterally outward side; and wherein the yieldable resistance means comprises a weighted lever pivotably associated with respect to the hydraulic-piston casing and extending laterally outwardly therefrom and bearing gravitationally downwardly against the housed Bourdon-tube thereby increasingly resisting the straight-enability thereof by the metering fluid as the elongate boom angle steepens with respect to the underlying substrate.

8. The burden moment monitoring system of claim **7** wherein the hydraulic pressure differential sensing means is attached to the hydraulic-piston casing and located on the laterally outward side thereof; and wherein the hydraulic pump is attached to the hydraulic-piston casing casing and located in elevation between the transducer and the hydraulic pressure differential sensing means whereby the hydraulic pump ram is located in series between the transducer and the co-reciprocatable barrier of the hydraulic pressure differential sensing means.

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