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(54) Title: SYSTEM AND METHOD TO DETERMINE RELATIVE VELOCITY OF CRANE AND TARGET LOAD

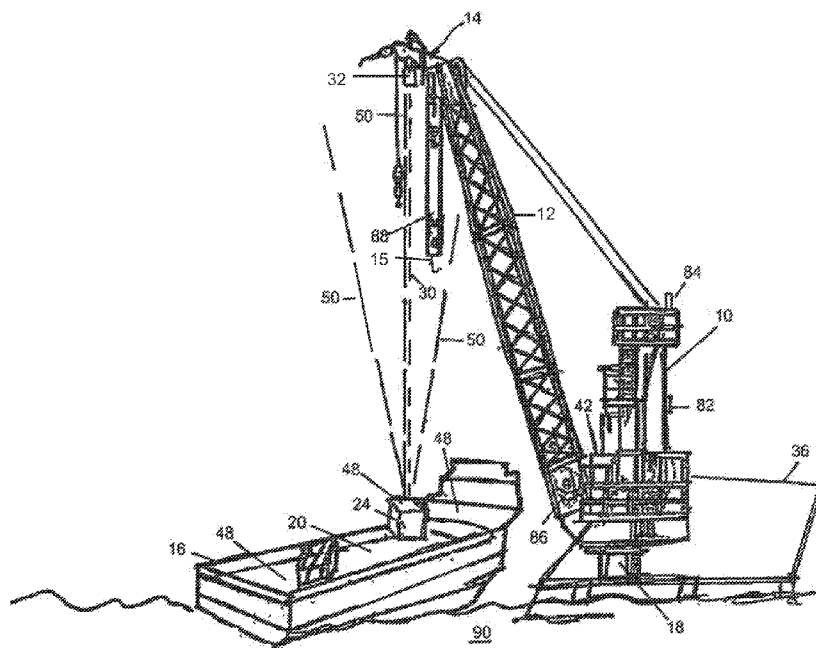


Fig. 1

(57) Abstract: A system and method are provided that allow for direct measurement of relative movement and relative velocity of movement of a crane (10) boom tip (14) in relation to a target load (24) on an adjacent vessel deck (20) allowing real-time determination of work load parameters under then-current conditions. A rangefinder (32) is located proximate boom tip (14) without requirement of a device on the target load or load vessel. A method accumulates relative movement, environmental data and as-built crane design to determine rated capacity of crane (10).



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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**TITLE OF THE INVENTION**

System and Method to Determine Relative Velocity of Crane and Target Load

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit and priority of co-pending Provisional Application No. US 61/654,692 filed June 1, 2012 titled "Crane Capacity Direct Measurement and Calculation Apparatus and Method."

STATEMENT REGARDING FEDERALLY SPONSORED**RESEARCH OR DEVELOPMENT**

Not Applicable.

BACKGROUND OF THE INVENTION

[1] Field of the Invention. The present invention relates generally to a system and method for determining distance and velocity in relation to the crane boom tip of a target load to be lifted by a crane in an offshore environment. More particularly, the present invention is directed to a system and method for determining distance and velocity of a target load of an offshore crane in an offshore environment wherein the target load and the crane are each subject to heave from waves and other environmental conditions and to determination of a rated capacity of a crane in specific environments.

[2] Description of the Related Art. Offshore cranes are commonly used in the oil and gas and commercial industries. Historically, crane manufacturers develop and publish crane rating charts to indicate crane safe lifting limits based on as-built crane design. Crane safe working limit load charts typically express crane safe lifting limits as a function of boom orientation. Load charts are specific to the as-built crane design. Load

1 charts are generated from multiple iterations of calculations based on as-built crane
2 design with variations in boom orientation.

3 [3] In application, crane lifting capacity is affected by, among other things, distance
4 of the target load from the crane, list and trim of the crane relative to vertical, orientation
5 of the crane boom in relation to the load and boom angle. Environmental factors, such as
6 wind speed, affect safe lifting affect safe lifting capacity. In an offshore environment,
7 additional environmental conditions include movement of both the crane and the target
8 load as a result of wind, waves and current. A significant offshore environmental factor
9 is the up and down motion of vessels (“heave”) from wave action. Waves, wind and
10 current additionally cause lateral movement. As waves, wind and current differentially
11 affect vessels of differing sizes and configurations, relative vertical and lateral movement
12 of a load vessel in relation to a crane vessel occurs.

13 [4] To safely lift loads, adjustments to crane capacity are necessary to account for site
14 specific conditions, including relative movement of the load in relation to the crane. As
15 use herein, “rated capacity” is used to mean a load that is allowed to be used under
16 specific environmental conditions and specific positioning of the crane hook at the time
17 of the lift.

18 [5] The American Petroleum Institute (“API”) promulgates guidelines relating to
19 rated capacity of cranes in an offshore environment. A current guideline utilizes
20 “Significant Wave Height” as an indicator of relative movement of the target load in
21 relation to the crane boom tip in calculation of a crane’s rated capacity. The API
22 Significant Wave Height standard is the mean wave height of the highest one-third of the
23 waves. A high Significant Wave Height results in relative lower load capacity.

1 [6] Wave height may be measured by appropriate instruments, but is typically
2 estimated from visual observation. Historically, the crane operator selects an appropriate
3 load rating chart as a factor in determining a crane's load capacity according to applicable
4 standards based on observed estimated wave height and subsequent determination of
5 Significant Wave Height.

6 [7] While Significant Wave Height is an indicator of potential movement of target
7 loads, it is of limited value in indicating relative movement of the target load in relation to
8 the boom tip, and in indicating relative velocity of movement of the target load in relation
9 to the boom tip. Due to the many variables involved and limitations of the method,
10 calculation of rated capacity based on Significant Wave Height must involve a highly
11 conservative estimate. Otherwise, offshore cranes are often not utilized at an otherwise
12 appropriate lifting capacity.

13 [8] An offboard lift is a lift from a separate vessel (as opposed to an onboard lift
14 wherein the crane and load are on the same vessel). A significant consideration in an
15 offboard lift is relative movement of the load-containing vessel and the vessel on which
16 the crane is mounted. It is particularly important that the lifted load not be subject to
17 impact resulting from vessel heave or other movement after initiation of the lift.
18 Accordingly, crane hook lift speed must be sufficient to prevent inadvertent contact of the
19 lifted object with vessel structures after initiation of the lifting operation. API guidelines
20 rely on estimated or calculated wave height and resulting calculated Significant Wave
21 Height as a standard to determine needed hook speed. Lower hook speed increases with
22 increased Significant Wave Height. Due to the many variables involved and limitations
23 of the underlying method, the determination must be a highly conservative estimate as the

1 underlying method does not determine velocity of the target load in relation to the crane
2 boom tip.

3 [9] Other conditions affect rated capacity of cranes used offshore, including list and
4 trim of the crane in relation to vertical, wind speed, boom angle and consequent crane
5 hook radius, and crane hook load.

6 [10] In current practice, the crane operator determines, by measurement, estimation or
7 a combination thereof the Significant Wave Height, crane list and trim, wind speed, boom
8 angle and crane hook load. The crane operator then consults manufacturer load charts to
9 determine a rated load capacity and lower crane hook speed for the crane.

10 [11] In applications not subject to API guidelines, the underlying problem and
11 uncertainties of determination of safe crane lift load and required crane hook speed based
12 on assumed environmental conditions remains.

13 [12] While it is prudent and necessary to limit loads to rated capacities and to
14 determine required hook speed based on environmental factors, current practice results in
15 under-utilization of crane load capacities and overly conservative determinations of
16 required crane hook speed.

17

18 BRIEF SUMMARY OF THE INVENTION

19 [13] A system and method are provided that allow for direct measurement of relative
20 vertical movement and relative velocity of movement of a target load placed on an
21 adjacent vessel deck and a crane boom tip allowing real-time determination of work load
22 parameters under then-current conditions.

23 [14] An exemplary system comprises a rangefinder provided proximate the crane boom
24 tip without requirement of a device on the target load or load vessel. The system and

1 method allows determination of target load movement relative the crane and
2 determination of applicable crane load parameters solely from a system mounted on the
3 crane. In an exemplary embodiment, the system includes a laser transmitter to transmit a
4 pulsed laser beam toward a target surface of the adjacent vessel, a photodiode sensor and
5 signal processor.

6 [15] Accumulated data allows determination of target load movement parameters
7 including extent of movement and velocity of movement of the target load in relation to
8 the crane boom tip.

9 [16] A method of the present invention accumulates environmental information and as-
10 built crane design to determine rated capacity independent of crane manufacturer load
11 charts.

12 BRIEF DESCRIPTION OF THE DRAWINGS

13 Figure 1 depicts a perspective view of a crane and adjacent boat.

14 Figure 2 depicts an exemplary rangefinder.

15 Figure 3 depicts a schematic diagram of a system of the present invention.

16 Figure 4 depicts an exemplary distance determination method of the present invention.

17 Figure 5 depicts an exemplary velocity determination method of the present invention.

18 Figure 6 depicts a schematic diagram of an alternative system of the present invention.

19 Figure 7 depicts a method of determination of rated capacity of the present invention.

20 DESCRIPTION OF THE INVENTION

21 [17] Exemplary embodiments are best understood by referring to the drawings, like
22 numerals being used for like and corresponding parts of the various drawings.

23 [18] Referring first to Figure 1, an offshore crane 10 is depicted with an adjacent vessel
24 16 carrying a target load 24. Crane 10 includes, among other things, an operator cab 42, a

1 boom12 and a boom tip 14. Crane 10 is mounted on a pedestal 18 on a structure such as
2 an offshore rig 36.

3 [19] At least one rangefinder 32 is provided on crane boom 12. In an exemplary
4 embodiment, rangefinder 32 is mounted proximate boom tip 14. Rangefinder 32 includes
5 a transmitter 26, a photodiode 28, and a signal processor 34. Rangefinder 32 is positioned
6 and oriented to determine distance 70 of a target load 24 from rangefinder 32. As
7 rangefinder 32 is proximate boom tip 14 distance 70 is also a measure of distance from
8 target load 24 to boom tip 14.

9 [20] In an offshore environment distance 70 varies due to vessel 16 heave and rig 36
10 heave as a function of wave action. Upon multiple distance 70 determinations over time,
11 upper and lower levels of distance 70 may be determined as well as velocity of change of
12 distance 70 as a result of heave of vessel 16 and rig 36.

13 [21] In an exemplary embodiment, rangefinder 32 comprises a pulsed rangefinder that
14 measures distance using a laser beam, a photodiode and a microprocessor. The
15 rangefinder works based on time of flight measurement by emitting high-frequency
16 pulsed laser light which is diffusely reflected back from the target 24. The return signal is
17 compared with a reference clock. From the amount of time, a resulting distance may be
18 accurately measured. Multiple samples may be taken in a relatively short period, thereby
19 providing data to calculate velocity of target movement. An exemplary system is
20 identified as a model Acuity AR 3000 manufactured by Schmitt Industries, Inc.

21 [22] In other exemplary embodiments the rangefinder 32 may be a laser Doppler
22 velocimeter, a photonic Doppler velocimeter, an optical distance measuring-system and
23 ultrasonic distance-measuring devices.

1 [23] In the exemplary embodiment depicted rangefinder 32 is oriented such that beam
2 30 is directed vertically downward from rangefinder 32 toward target load 24. Such
3 positioning allows for direct measurement on a real-time basis of the distance 70, and
4 more importantly of variations of distance 70 over time thereby providing real-time
5 determination of distance 70 from boom tip 14 to target load 24 and, importantly, real-
6 time determination of velocity of movement of upper and lower limits of movement of
7 target load 24 in relation to boom tip 14 and relative velocity of movement of target load
8 24 in relation to boom tip 24. As used herein relative vertical velocity 72 describes the
9 relative velocity of movement in a vertical direction of the target load 24 in relation to
10 boom tip 14, a function of distance 70 measurements over time.

11 [24] In an exemplary embodiment, rangefinder 32 is attached to boom tip 14 by
12 pendulum 10x, thereby orienting beam 30 downward. Other attachment means may be
13 utilized.

14 [25] Referring to Figure 2, an embodiment of a rangefinder 32 comprises a laser
15 transmitter 26 (not shown) for transmission of a signal through lens 27, a photodiode 28
16 (not shown) for receiving refracted signals through lens 29, and a signal processor 34 (not
17 shown) within a housing 38. Transmitter 26 emits high frequency pulsed laser light,
18 referred to herein as beam 30, through lens 29. Beam 30 is refracted and partially
19 reflected from surface 48 thereby producing refracted beam 50. As used herein, the term
20 “refracted” includes the term “reflected.” A reference clock (not shown) determines time
21 of travel of beam 30 and beam 50. As used herein surface 48, unless specified otherwise,
22 may refer to multiple surfaces encountered by beam 30, including a surface of a target
23 load 24, a deck 20 surface, or other surfaces encountered. Refracted beams 50 are
24 exemplarily depicted in Figure 1.

1 [26] Photodiode 28 senses a portion of refracted beam 50 and transmits resulting input
2 to signal processor 34. Signal processor 34 accumulates data received and calculates
3 travel time of beam 30 and beam 50, and, from travel time, distance 70 of selected surface
4 48. Commercially-available rangefinders 32 are capable of calculating distance
5 measurements thousands of times per second and thereby generating real-time distance 70
6 and velocity 72 measurement.

7 [27] Crane 10 has an onboard data processor 44 (not shown) pre-loaded with software
8 200 (not shown). Rangefinder 32 distance 70 and velocity 72 data is transmitted to data
9 processor 44. Data processor 44 accumulates distance 70 and velocity 72 data to
10 determine real-time distance 70 differentials to determine heave effects in relation to
11 crane capacity and to determine velocity 72 of relative movement of crane tip 14 and
12 target load 24. Specifically, by determining upper and lower values of distance 70, a
13 relative distance 70 range of boom tip 14 to target load 24 may be determined. Relative
14 distance 70 range indicates actual distance 70 variation, a determination of relative
15 vertical motion due to effect of waves on vessel 16 and rig 36.

16 [28] Data processor 44 accumulates distance 70 data during determined time
17 increments to calculate vertical velocity 72 of relative movement of load 24 with boom
18 tip 14 to determine necessary crane hook 15 velocity to prevent re-contact of target load
19 24 with vessel 16 and equipment and structures located on vessel 16 after initiation of a
20 lifting operation.

21 [29] During crane 10 operations boom tip 14 is regularly moved thereby being directed
22 to open water 90 and various surfaces 48 defined by equipment and structures (not
23 shown). Accordingly, beam 30 may be directed to open water 90. When crane boom tip
24 14 is not moving beam 30 may be directed to various surfaces 48 due to relative

1 movement of vessel 16 in relation to rig 70. Accordingly, beam 30 is not continuously
2 oriented directly on target load 24. Generally, target load 24 is relatively small in
3 comparison with the multiple surfaces such as other target loads, deck 20 and other
4 structures of a seagoing vessel such as vessel 16.

5 [30] As beam 30 is oriented toward various surfaces, abrupt variations of distance 70
6 measurement occur. Such abrupt changes are reflected in distance 70 measurements and
7 in velocity 72 measurements and are referred to herein as “outliers.” Outlier distance 70
8 measurements are filtered by accumulating distance 70 measurements over time and
9 determining average distance ranges 74. Deviations of a determined amount from
10 distance ranges 74 are identified as outliers and accumulated over a determined time
11 frame. If multiple outliers are identified within a determined time period, such outliers
12 are included in average distance range 74 determinations. If less than a determined
13 number of outliers are identified within a determined time period, the outliers are
14 excluded from distance 70 measurements and excluded from distance range 74.

15 [31] In an exemplary embodiment, velocity 72 measurements are filtered as velocity 72
16 measurements are subject to distortion due to abrupt variations of distance 70
17 measurements. Outlier velocity 72 measurements are filtered by accumulating velocity
18 72 measurements over time and determining average velocity 76. Deviations of a
19 determined amount from average velocity 76 are identified as outliers and are
20 accumulated over a determined time frame. If multiple outliers are identified within a
21 determined time period, such outliers are included in average velocity 76 determinations.
22 If less than a determined number of outliers are identified within a determined time
23 period, the outliers are excluded from velocity 76 measurements.

1 [32] In the exemplary embodiment of the present invention filtering distance 70 and
2 velocity 72 outliers is accomplished by software 200 of data processor 44.

3 [33] In accordance with the filtering method, if movement of the boom tip 14 causes
4 beam 30 to move from a surface 48 of load 24 to, by example, a surface 48 of vessel deck
5 20, the apparent spike in distance 70 and velocity 72 will be filtered out of the data for
6 determination of distance range 74 and velocity 72.

7 [34] Refraction of beam 30 from water 90 differs substantially from refraction of beam
8 30 from a solid surface 48 due to limited refraction of beam 30 from water 90. Limited
9 refraction occurrences associated with direction of beam 30 to water 90 are filtered from
10 accumulated data through data processor 44 and software 200.

11 [35] Distance 70 and velocity 72 data output from processor 34 may be concurrently
12 output to a user interface for review by an operator (not shown) located in operator cab
13 42. In an application involving published load charts the operator may use such actual
14 measurements of relative vertical velocity 72, as well as other factors including upper and
15 lower distances 70, to determine applicable crane rated capacity from crane load charts.

16 [36] In an application wherein as-built crane design criteria are available and
17 incorporated into software 200, as-built crane design, measured velocity 72 and other
18 known environmental conditions may be utilized to calculate rated capacity utilizing data
19 processor 44.

20 [37] A recording device 46 or data processor 44 internal storage device (not shown)
21 may be used to record data and real time computations completed by data processor 44
22 into an electronic data log for later reference.

23 [38] Fig. 3 depicts a schematic layout of an embodiment 100 of the present invention.
24 Referring to Fig. 3, rangefinder 32 with signal processor 34 is electrically connected with

1 data processor 44 to allow transmission of gathered data to data processor 44. An
2 operator input device 52 allows for manual input of parameters by an operator and
3 operational control of data processor 44. As depicted in Figure 3, crane 10 may be
4 equipped with other sensors 60 to sense various other parameters.

5 [39] Referring to Figure 4, an exemplary method 200 of determination of relative
6 distance ranges of a crane boom tip 14 to a target load based on then-current conditions
7 comprises the following steps:

8 [40] Data Gathering Step 210 comprises a step of transmitting pulsed laser beam 30
9 vertically downward from rangefinder 32 to surface 48 proximate target load 24 and
10 sensing refracted laser beam 50.

11 [41] Distance Averaging Step 212 determines average distance 70 measurements
12 during specified time intervals and transmits distance 70 measurements from signal
13 processor 34 to data processor 44.

14 [42] Range Determination Step 214 determines average upper distance 70
15 measurements and average lower distance 70 distance measurements.

16 [43] Distance Filtering Step 216 filters outlier upper distance 70 measurements and
17 outlier lower distance 70 distance measurements resulting in normalized average upper
18 distance 70 measurements and average lower 70 vertical distance measurements.

19 [44] Distance Range Output Step 218 provides output of vertical distance range 74,
20 such range comprising the differential vertical movement of target load 24 in relation to
21 boom tip 24.

22 [45] Referring to Figure 5, an exemplary method 202 of determination of relative
23 velocity of a crane boom tip 14 in relation to a target load 24 based on then-current
24 conditions comprises the following steps:

1 [46] Data Gathering Step 210 comprises a step of transmitting pulsed laser beam 30
2 vertically downward from rangefinder 32 to surface 48 proximate target load 24 and
3 sensing refracted laser beam 50.

4 [47] Velocity Determination Step 220 determines velocity of movement of boom tip 14
5 in relation to target load 24 from distance 70 measurements during specified time
6 intervals and velocity 72 measurements from signal processor 34 to data processor 44.

7 [48] Velocity Filtering Step 222 filters outlier velocity 72 measurements during a
8 specified period of time from average vertical velocity 72 measurements during a
9 specified period of time resulting in normalized average velocity 72 measurements during
10 a specified period of time.

11 [49] Velocity Output Step 224 provides output of relative velocity of target load 24 in
12 relation to boom tip 14.

13 Operation

14 [50] In operation, once an adjacent vessel 16 is in range, crane 10 is positioned over
15 load 24 such that mounted rangefinder 32 is directed towards a surface 48 proximate
16 target 24. Surface 48 may be a surface of target load 24, loading deck 20 or other surface
17 of the adjacent vessel 16. Beam 50 is refracted from surface 48. A portion of beam 50 is
18 received by photodiode 28.

19 [51] Signal processor 34 accumulates distance 70 data over time, processes the data
20 and transmits relative distance data 70 and relative vertical velocity data 72 electronically
21 to a data processor 44 in operator cab 42. Data processor 44 filters distance 70 data to
22 determine relative vertical distance range 74 of load 24 in relation to boom tip 14. Data
23 processor 44 filters velocity 72 data to determine relative vertical velocity 72 of load 24
24 in relation to boom tip 14.

1 [52] As depicted in Figure 3, data from rangefinder 32 and other sensors 60 may be
2 electronically transmitted to data processor 44. Data processor 44, with associated
3 software 200, determines rated capacity of the offshore crane 10 utilizing the real-time
4 direct measurements.

5 Second Exemplary Embodiment

6 [53] In an exemplary embodiment of the present invention, rated capacity of an
7 offshore crane is computed utilizing as-built crane parameters and then-existing
8 environmental conditions.

9 [54] Referring to Figs. 1 and 6, a lift and trim sensor 82 is provided on crane 10 to
10 measure and output to data processor 44 lift and trim of crane 10. Lift and trim sensors
11 are known in the art and are commercially available.

12 [55] A wind sensor 84 is provided on crane 10 to measure environmental wind
13 conditions and output to data processor 44 environmental wind conditions. Wind sensors
14 are known in the art and are commercially available.

15 [56] A boom angle sensor 86 is provided on crane 10 to measure the angle of boom 12
16 relative to vertical and output to data processor 44 environmental wind conditions. Boom
17 angle sensors are known in the art and are commercially available.

18 [57] A load cell 88 load sensor is provided on crane hook 15 to determine actual loads
19 encountered by crane hook 15. Load cells are known in the art and are commercially
20 available. Load cell 88 is not utilized to determine rated capacity of the crane, but is
21 instead used as a comparator of actual load on load hook 15 in relation to rated capacity
22 determinations.

23 [58] Referring to Fig. 7, an exemplary method 300 of determining rated capacity of a
24 crane under then-current environmental conditions comprises the following steps:

1 [59] As-built Input Step 302 comprises input of as-built crane parameters and
2 calculation parameters necessary to determine safe working limits of the subject crane 10
3 as part of software 200 thereby enabling calculation of crane safe working limits with
4 data processor 44.

5 [60] List and Trim Input Step 304 comprises a step of sensing and transmitting to data
6 processor 44 current crane 10 list and trim data.

7 [61] Wind Condition Input Step 306 comprises a step of sensing and transmitting to
8 data processor 44 current wind condition trim data.

9 [62] Boom Angle Input Step 308 comprises a step of sensing and transmitting to data
10 processor 44 current boom angle status.

11 [63] Velocity Step 310 comprises determination of relative velocity of boom tip 14 in
12 relation to target load 24 in accordance with the system and method previously described
13 herein and consistent with Steps 210, 220, 222 and 224 of Figure 5.

14 [64] Rated Capacity Calculation Step 312 comprises calculation of rated capacity of
15 crane 10 based on as-built crane parameters, crane list and trim, environmental wind
16 conditions, boom angle and relative velocity of movement of boom tip 14 in relation to
17 target load 24.

18 [65] Steps 302, 304, 306, 308 and 310 may occur in any order prior to Step 312.

19 [66] An exemplary embodiment further includes a Distance Range Step 314
20 comprising a step of determination of distance range 74 of boom tip 14 in relation to
21 target load 24 in accordance with the system and method previously described herein and
22 consistent with Steps 210, 212, 214 and 216 of Figure 4. Distance Range Step 314 may
23 occur prior to Step 312.

1 [67] An exemplary embodiment further includes a Load Cell Step 316 comprising a
2 step of determining actual load on crane hook 15 in relation to then-determined crane 10
3 rating capacity. Load Cell Step 316 may be ordered at any time before or after Step 312.

4 [68] All embodiments described herein contemplate continuous and/or intermittent
5 continuous applications of the method steps herein described to allow regular iterations of
6 the processes and methods herein described.

7 [69] On a continuous or intermittent basis determinations made may be output to an
8 operator interface device 40, to an internal storage device 62 and/or an external recording
9 device 46 with appropriate time and date indicia to provide a record of activity.

10 [70] The foregoing description of the invention illustrates a preferred embodiment
11 thereof together with various alternative embodiments. Various changes may be made in
12 the details of the illustrated construction and methods within the scope of the appended
13 claims without departing from the true spirit of the invention. The present invention
14 should only be limited by the claims and their equivalents.

1 Claims

2 I claim:

- 3 1. A system for an offshore crane operable to determine relative movement of a
4 target load in relation to a crane boom tip, the system comprising:
5 a rangefinder mounted on a crane boom proximate a crane boom tip;
6 said rangefinder having a signal transmitter and a signal receiver;
7 said rangefinder oriented to direct a signal downward;
8 said rangefinder oriented to receive a refracted signal from a refractive surface
9 proximate a target load;
10 said rangefinder including a signal processor;
11 a data processor on said crane operably connected to said signal processor; and
12 said range processor, said signal processor, and said data processor operable to
13 provide data output identifying relative vertical distance measurements of said
14 boom tip to said refractive surface.
- 15 2. A system according to claim 1 further comprising:
16 said system operable to determine velocity measurements of relative movement of
17 said refractive surface in relation to said boom tip.
- 18 3. A system according to claim 2 wherein:
19 said data processor operable to filter outlier velocity measurements.
- 20 4. A system according to claim 1 further comprising:
21 said data processor operable to determine a range of distance measurements; and
22 said data processor operable to filter outlier distance measurements.
- 23 5. A system according to claim 1 wherein
24 said system entirely contained on said crane.

1 6. A method of determining relative movement of a target load in relation to a crane
2 boom tip utilizing a rangefinder mounted proximate the boom tip, said method
3 comprising:

4 a data gathering step of transmitting a signal downward from said rangefinder to a
5 surface proximate said target load, sensing a refracted signal and determination of
6 multiple distance measurements; and

7 a distance averaging step of determining average distance measurements during
8 specified time intervals and transmitting said distance measurements to a data
9 processor.

10 7. A system according to claim 6 further comprising:

11 a filtering step of filtering outlier distance measurements from average distance
12 measurements; and

13 an output step of providing output of distance measurements.

14 8. A system according to claim 6 further comprising:

15 a distance range determination step of determining relatively high distance
16 measurements and relatively low distance measurements; and

17 an averaging step of averaging relatively high distance measurements and
18 relatively low distance measurements.

19 9. A system according to claim 6 further comprising:

20 a velocity determination step of determining distance measurements during
21 specified time intervals and transmitting said distance measurements to a data
22 processor;

23 a filtering step of filtering outlier velocity measurements; and

24 a velocity output step of providing output of velocity measurements.

1 10. A method of determining rated capacity of a crane under then-current
2 environmental conditions comprising:

3 an as-built input step of programming as-built crane parameters and calculation
4 parameters into software of a data processor on a subject crane to enable calculation
5 of said crane safe working limits;

6 a list and trim input step of sensing and transmitting to said data processor current
7 crane list and trim data;

8 a wind condition input step of sensing and transmitting to said data processor
9 current wind condition data;

10 a boom angle input step of sensing and transmitting to said data processor current
11 boom angle status;

12 a velocity step of determining and transmitting to said data processor relative
13 velocity data of movement of a target load in relation to a boom tip of said crane
14 utilizing a rangefinder mounted proximate said boom tip; and

15 a rated capacity calculation step of using said as-built crane parameters and
16 calculation parameters, said crane list and trim data, said current wind condition data,
17 said boom angle status and said relative velocity data, and calculating rated capacity
18 of said crane.

19 11. A method according to claim 9 further comprising:

20 a distance range step of determining distance range data of said boom tip in
21 relation to said target load utilizing a rangefinder mounted proximate said boom tip.

22 12. A method according to claim 10 further comprising:

23 a load cell step of determining actual load on a crane hook of said crane in relation
24 to said determined crane rating capacity.

AMENDED CLAIMS

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1

2 I claim:

3 1. A system for an offshore crane operable to determine relative movement of a
4 target load in relation to a crane boom tip, the system comprising:

5 a rangefinder mounted on a crane boom proximate a crane boom tip;

6 said rangefinder having a signal transmitter and a signal receiver;

7 said rangefinder oriented to direct a signal downward;

8 said rangefinder oriented to receive a refracted signal from a refractive surface
9 proximate a target load;

10 said rangefinder including a signal processor;

11 a data processor on said crane operably connected to said signal processor;

12 said range processor, said signal processor, and said data processor operable to
13 provide data output identifying relative vertical distance measurements of said boom
14 tip to said refractive surface; and

15 said system operable to determine velocity measurements of relative
16 movement of said refractive surface in relation to said boom tip.

17 2. (cancelled).

18 3. A system according to claim 1 wherein:

19 said data processor operable to filter outlier velocity measurements.

20 4. A system according to claim 1 further comprising:

21 said data processor operable to determine a range of distance measurements; and

22 said data processor operable to filter outlier distance measurements.

23 5. A system according to claim 1 wherein

24 said system entirely contained on said crane.

1 6. A method of determining relative movement of a target load in relation to a crane
2 boom tip utilizing a rangefinder mounted proximate the boom tip, said method
3 comprising:

4 a data gathering step of transmitting a signal downward from said rangefinder to a
5 surface proximate said target load, sensing a refracted signal and determination of
6 multiple distance measurements; and

7 a distance averaging step of determining average distance measurements during
8 specified time intervals and transmitting said distance measurements to a data
9 processor.

10 7. A method according to claim 6 further comprising:

11 a filtering step of filtering outlier distance measurements from average distance
12 measurements; and

13 an output step of providing output of distance measurements.

14 8. A method according to claim 6 further comprising:

15 a distance range determination step of determining relatively high distance
16 measurements and relatively low distance measurements; and

17 an averaging step of averaging relatively high distance measurements and
18 relatively low distance measurements.

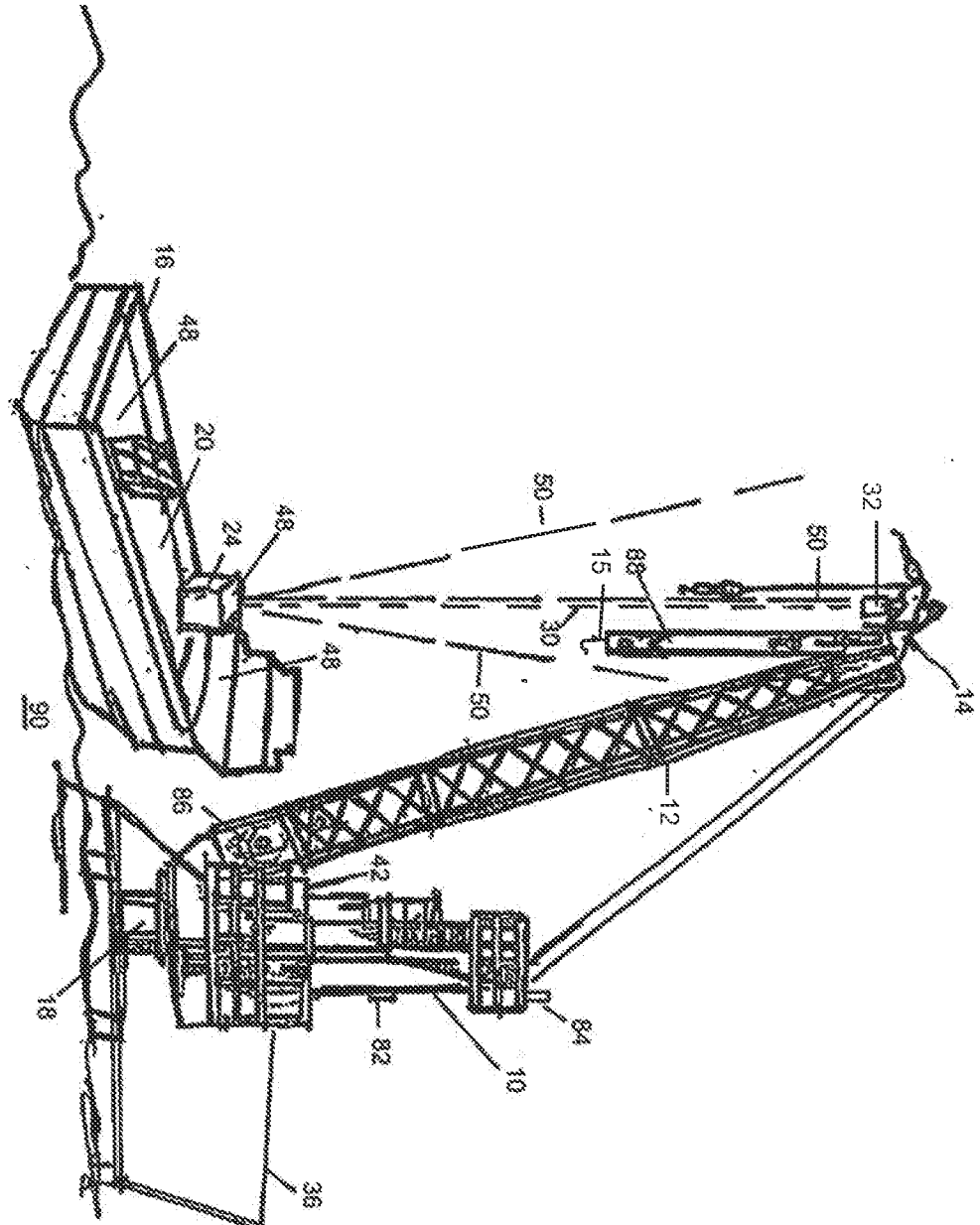
19 9. A method according to claim 6 further comprising:

20 a velocity determination step of determining distance measurements during
21 specified time intervals and transmitting said distance measurements to a data
22 processor;

 a filtering step of filtering outlier velocity measurements; and

 a velocity output step of providing output of velocity measurements.

- 1 10. A method of determining rated capacity of a crane under then-current
2 environmental conditions comprising:
- 3 an as-built input step of programming as-built crane parameters and calculation
4 parameters into software of a data processor on a subject crane to enable calculation
5 of said crane safe working limits;
- 6 a list and trim input step of sensing and transmitting to said data processor current
7 crane list and trim data;
- 8 a wind condition input step of sensing and transmitting to said data processor
9 current wind condition data;
- 10 a boom angle input step of sensing and transmitting to said data processor current
11 boom angle status;
- 12 a velocity step of determining and transmitting to said data processor relative
13 velocity data of movement of a target load in relation to a boom tip of said crane
14 utilizing a rangefinder mounted proximate said boom tip; and
- 15 a rated capacity calculation step of using said as-built crane parameters and
16 calculation parameters, said crane list and trim data, said current wind condition data,
17 said boom angle status and said relative velocity data, and calculating rated capacity
18 of said crane.
- 19 11. A method according to claim 10 further comprising:
- 20 a distance range step of determining distance range data of said boom tip in
21 relation to said target load utilizing a rangefinder mounted proximate said boom tip.
- 22 12. A method according to claim 10 further comprising:
- 23 a load cell step of determining actual load on a crane hook of said crane in relation
24 to said determined crane rating capacity.



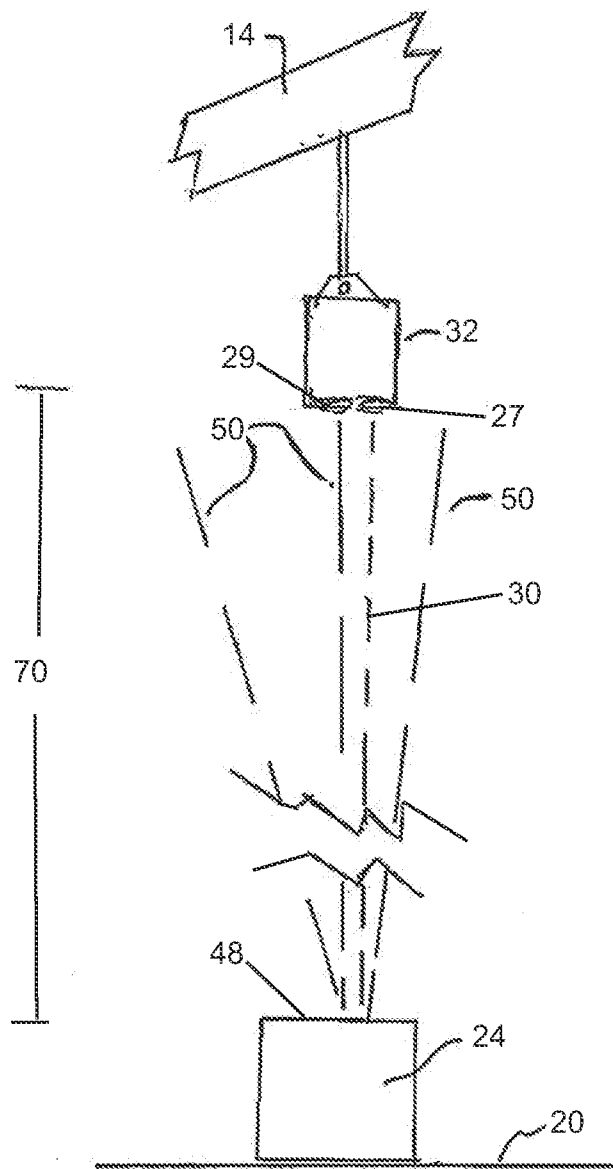


Fig. 2

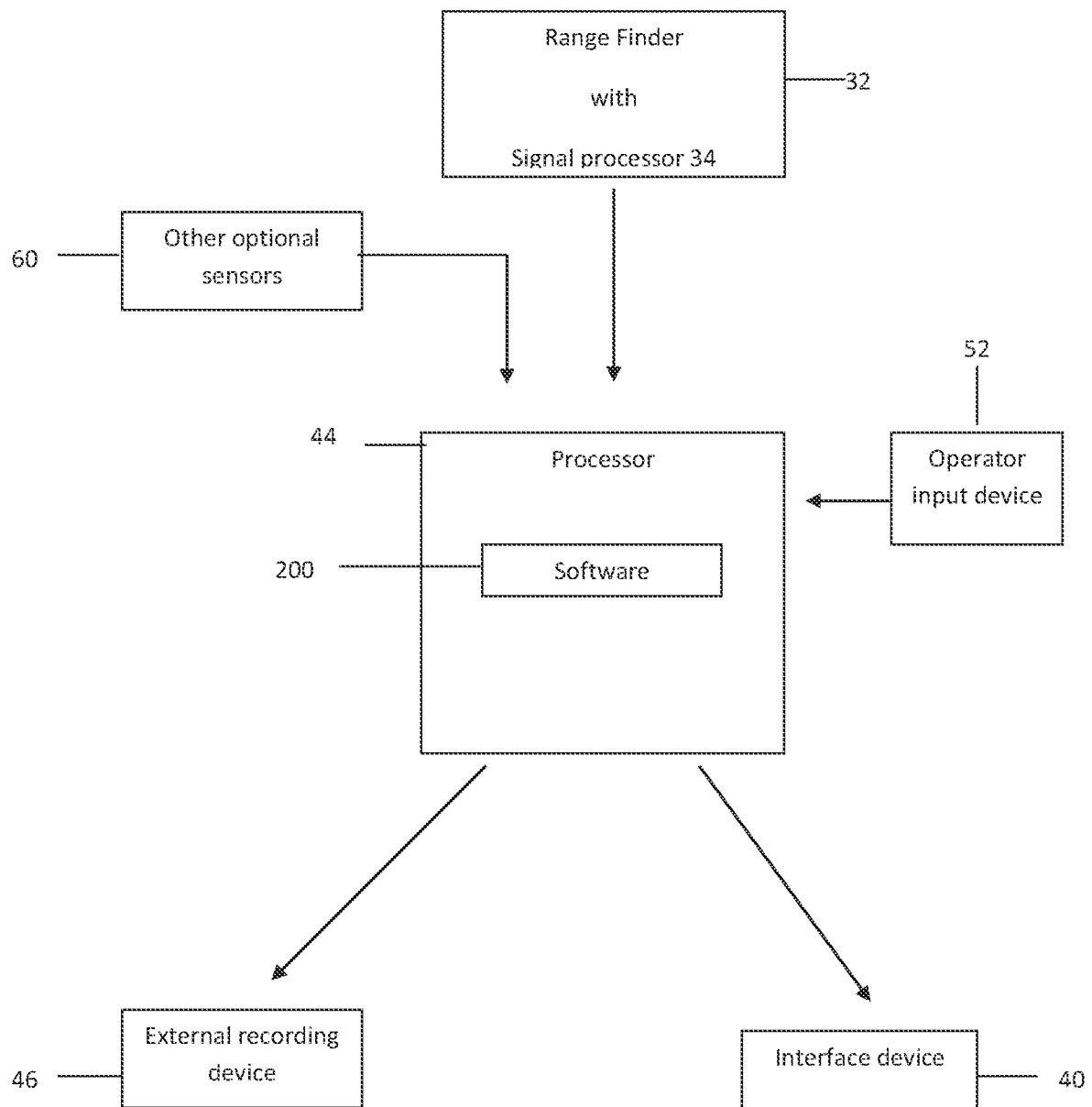


Fig. 3

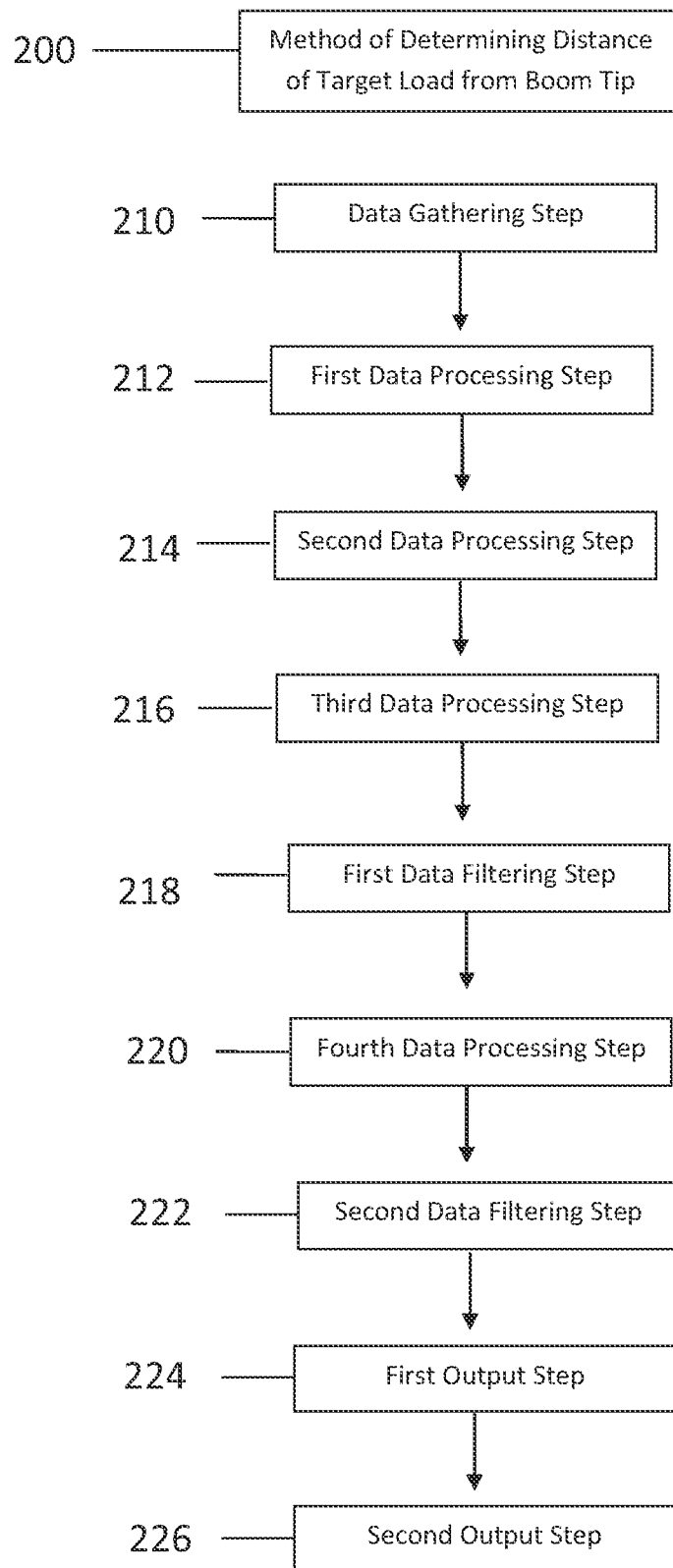


Fig. 4

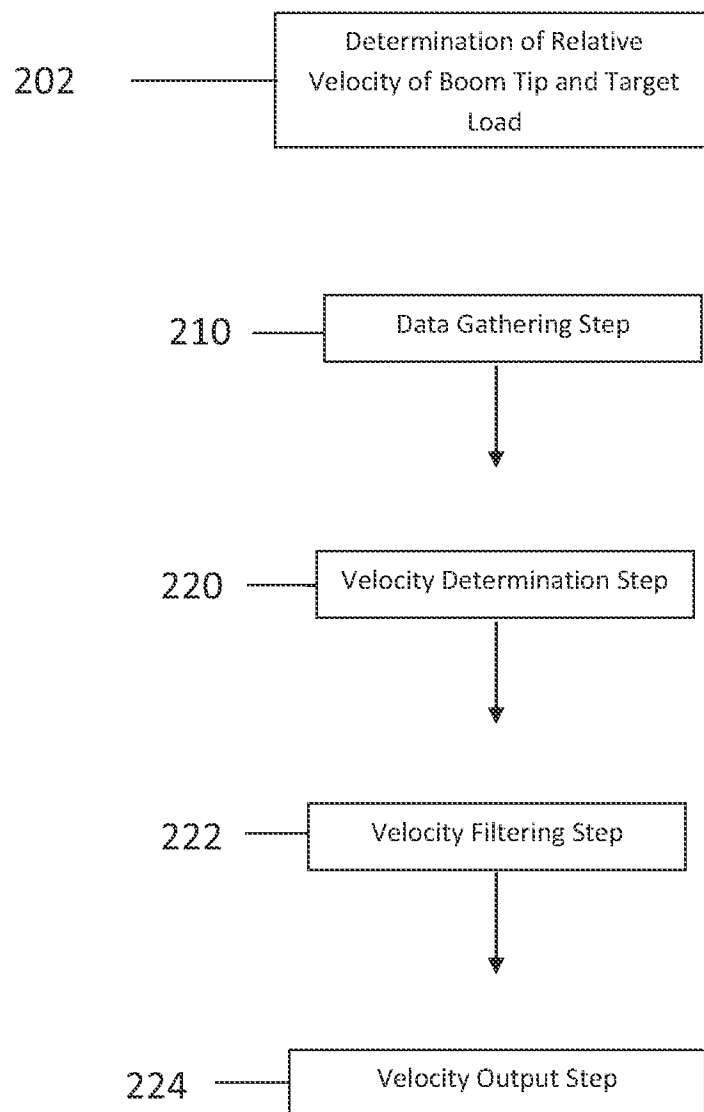


Fig. 5

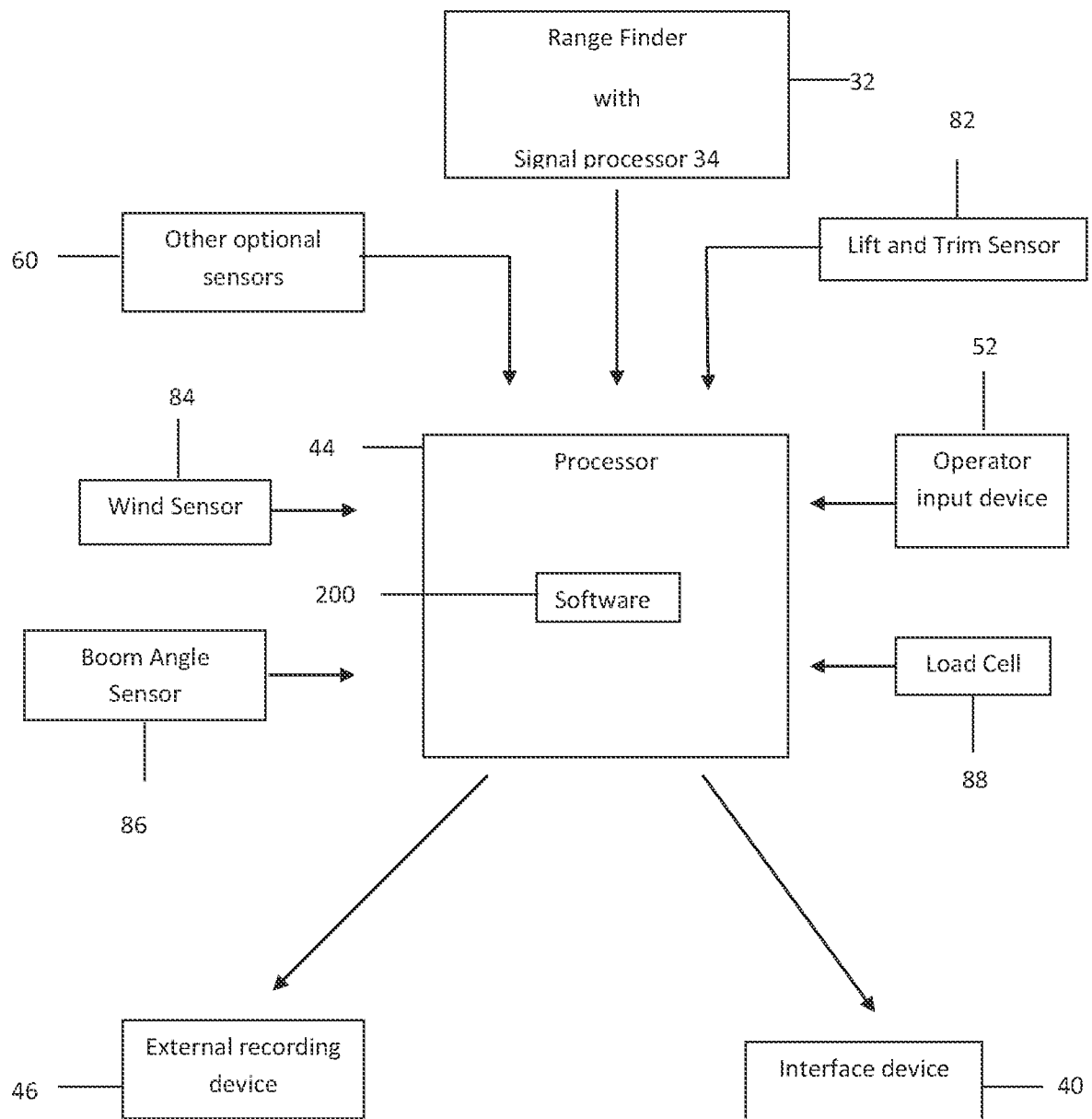


Fig. 6

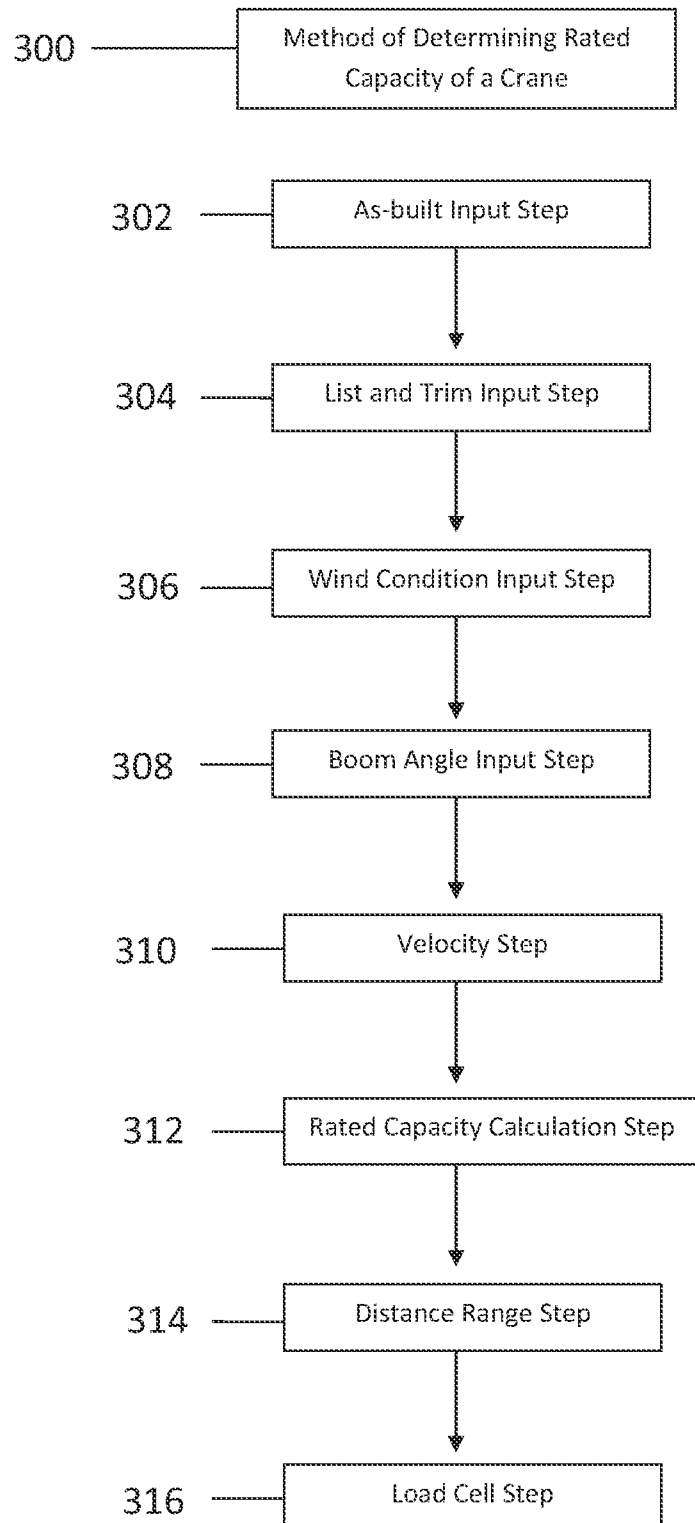


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/043746**A. CLASSIFICATION OF SUBJECT MATTER****B66C 13/18(2006.01)i, B66C 23/53(2006.01)i, B66C 13/46(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B66C 13/18; B66C 23/52; B66C 1/10; G03B 17/26; B66C 13/12; B63B 27/00; B66C 23/53; B66C 13/46

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: offshore crane, target load, crane boom tip, rangefinder, transmitter, receiver, and distance

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4753357 A (MIYOSHI et al.) 28 June 1988 See column 2, line 33 - column 4, line 53 and figures 4-5.	1,5
A		2-4,6-12
A	US 4354608 A (WUDTKE, DONALD J.) 19 October 1982 See column 2, line 1 - column 3, line 2 and figures 1-2.	1-12
A	KR 10-2011-0066764 A (J.L.C CO., LTD.) 17 June 2011 See paragraphs 27-34 and figures 1-3.	1-12
A	US 2005-0232626 A1 (SCHLTE et al.) 20 October 2005 See paragraph 32 and figure 4.	1-12
A	US 4932541 A (BELSTERLING CHARLES A.) 12 June 1990 See column 4, lines 2-37 and figures 3-5.	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

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11 September 2013 (11.09.2013)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/043746

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US 4932541 A	12/06/1990	None	