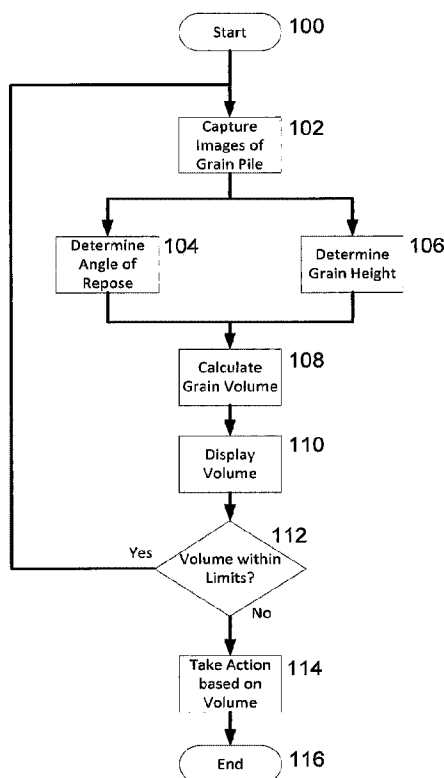




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(72) Inventeur/Inventor:
DUCROQUET, FREDERIC, IT
(73) Propriétaire/Owner:
AGCO CORPORATION, US
(74) Agent: GOWLING WLG (CANADA) LLP

(54) Titre : MOISSONNEUSE-BATTEUSE POURVUE D'UNE CELLULE A GRAIN
(54) Title: A COMBINE HARVESTER HAVING A GRAIN BIN



(57) Abrégé/Abstract:

There is described a combine harvester comprising a grain bin having a grain volume monitoring system. The grain volume monitoring system has at least one image capture device which monitors the level of grain in the grain bin, such that a calculation of the volume of grain in the grain bin can be determined. In particular, the image capture device monitors the height of sections of the grain pile, as well as the angle of repose of the grain pile, which are used to calculate the contained volume of grain. The calculated volume can be compared with pre-set volume limits to prevent spillage of grain when driving on an incline or over uneven terrain.

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(71) Applicant: AGCO CORPORATION [US/US]; 4205 River Green Parkway, Duluth, Georgia 30096 (US).

(72) Inventor: DUCROQUET, Frederic; c/o Laverda Spa, Via F Laverda 15/17, Breganze 36042 (IT).

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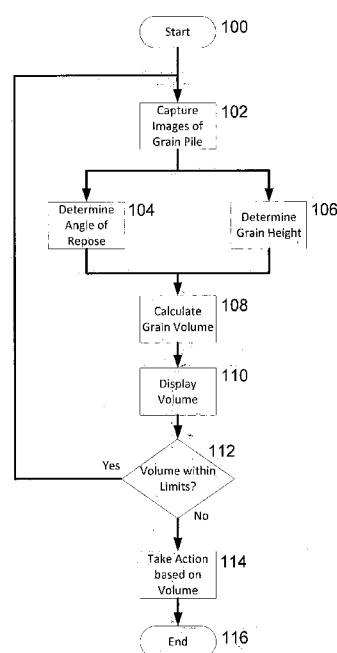


Fig. 4

(57) Abstract: There is described a combine harvester comprising a grain bin having a grain volume monitoring system. The grain volume monitoring system has at least one image capture device which monitors the level of grain in the grain bin, such that a calculation of the volume of grain in the grain bin can be determined. In particular, the image capture device monitors the height of sections of the grain pile, as well as the angle of repose of the grain pile, which are used to calculate the contained volume of grain. The calculated volume can be compared with pre-set volume limits to prevent spillage of grain when driving on an incline or over uneven terrain.

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A Combine Harvester having a Grain Bin

Field of the Invention

The present invention relates to a combine harvester comprising a grain bin having a
5 volume monitoring system.

Background of the Invention

Grain bins are used to hold harvested grain, and are often provided in combination with an
agricultural combine, to retain newly-harvested grain after initial harvesting and during
10 transport to a dedicated storage facility. An example of such a grain bin is provided in US
4,106,649.

When harvesting and transporting grain, an operator needs to be aware of the volume fill
level of a grain bin, to prevent grain spillage. It is known to provide simple level sensors
15 around the periphery of a grain bin, such that a warning can be generated when the level
of the contained grain approaches the top level of the grain bin. An operator can then take
action to prevent over-filling of the grain bin.

However, such level sensor systems only detect the height of the grain at the sides of the
20 grain bin, and do not provide any indication of the total volume of the contained grain, e.g.
if the middle of the accumulated grain is formed in a peak. As a result, an operator must
take additional care to visually monitor for the shape profile of the grain level in the bin, to
ensure that the volume of accumulated grain does not present increased risk of spillage
when traversing an incline, or at relatively high speed over uneven terrain.

25

It is an object of the invention to provide an improved grain volume sensing system, to
address the above problems.

Summary of the Invention

30 Accordingly, there is provided a combine harvester comprising a grain bin comprising
walls defining a grain storage space, the grain bin further comprising a grain volume
monitoring system having:

at least one image capture device positioned on said grain bin, the at least one
image capture device arranged to capture at least one image of a grain pile contained in
35 the grain storage space; and

a controller coupled to said at least one image capture device to receive said captured image, the controller arranged to determine an angle of repose of the grain pile and the height of the grain pile, based on the captured image,

5 wherein the controller calculates the volume of the contained grain pile based on the angle of repose and the height of the grain pile.

Through the use of at least one captured image of a grain pile contained in a grain bin, a controller can perform image processing of the captured data to derive the shape profile of the contained grain. Having knowledge of the dimensions and structure of the grain bin
10 itself, the volume of grain within the grain bin can then be calculated. This allows for a dynamic system for the monitoring of the harvested grain levels, and can provide for indications of remaining grain capacity of the grain bin, as well as grain volumes or shape profiles which may present increased risk of spillage. Preferably, the system comprises first and second image capture devices arranged to capture different images of the grain
15 pile.

Preferably, the grain volume monitoring system comprises:

a first image capture device provided on a first side of the grain bin, the first image capture device arranged to capture an image of a grain pile contained in the grain bin from
20 said first side of the grain bin, and

a second image capture device provided on a second side of the grain bin, opposite the first side, the second image capture device arranged to capture an image of a grain pile contained in the grain bin from said second side of the grain bin.

25 The use of two image capture devices located at opposite sides of the contained grain pile allows for an accurate calculation of the grain pile volume, as the distribution of grain in the grain bin may be uneven across the width of the contained grain pile. As a result, by capturing images on either side of any peak of the contained grain pile, an accurate shape profile of the contained grain pile can be derived.

30

Preferably, the grain volume monitoring system further comprises:

third and fourth image capture devices on the grain bin arranged to capture different images of a grain pile contained in the grain bin,

35 wherein the first and second image capture devices are arranged along a first plane, and wherein the third and fourth image capture devices are arranged along a

second plane, different to said first plane. Preferably, the second plane is transverse to said first plane.

An increase in the number of image capture devices used will result in a corresponding increase in the accurate profiling of the shape of the contained grain pile. Accordingly, the calculation of grain volume can be performed with increased accuracy. Positioning the various image capture devices at cardinal points about the contained grain pile will ensure an even coverage of all aspects of the contained grain pile, with a 360 degree image profile.

Additionally or alternatively, the system comprises:

at least first and second image capture devices, wherein the first image capture device has a wider capture angle relative to the second image capture device.

Providing different capture angles for the image capture devices allows for an increase in capture accuracy. Different image capture devices can be directed to capture different aspects of the grain pile, e.g. a relatively narrow capture angle may be used to focus on the height of the contained grain pile against one of the walls of the grain bin, while a relatively wide capture angle may be used to capture the general profile of the grain pile, including the peak height of the grain pile. In addition, depending on the dimensions of the grain bin, wide capture angle devices may be required at certain locations to accurately record the entire visible profile of the contained grain.

Preferably, the image capture devices are arranged adjacent to an upper rim of the grain bin. Preferably, the image capture devices are arranged on the walls of the grain bin. Alternatively, the image capture devices are provided on brackets projecting from walls of the grain bin

The image capture devices may further be provided on grain bin extension panels, arranged at the upper end of a grain bin.

The image capture devices may comprise a video camera or still image camera. The image capture devices may also comprise a 3D camera.

Preferably, the controller is arranged to compare the calculated volume of grain to a pre-set volume limit, and to generate a warning signal if the calculated volume exceeds the pre-set volume limit.

- 5 The pre-set volume limit can comprise a threshold volume, above which there is an increased risk of grain spillage. The pre-set volume limit may be based on a number of different factors, which may comprise one or more of the following: the type of crop, the speed at which the grain bin is travelling or expected to travel, the field contour in which the grain bin is operating.

10

Preferably, the controller is arranged to communicate the calculated volume data to an operator. Preferably, the controller is coupled with a display terminal, wherein the calculated volume data is displayed on the display terminal.

- 15 Preferably, the combine comprises a drive control device having a force feedback module, wherein the force feedback module of the drive control device is controlled based on the calculated volume data.

- Through use of an appropriate force feedback control of the combine, the controller can
20 increase the force required to accelerate or decelerate the combine, based on the calculated volume data. This can be useful in case the volume is such that sudden acceleration or decelerations may result in grain spillage.

- There is further provided a grain volume monitoring system as described above, for
25 installation on a grain bin or on a combine harvester having a grain bin.

The sensor system may be provided as a kit of parts, for installation or retrofitting on a new or existing combine harvester or grain bin.

30 **Detailed Description of the Invention**

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

- Fig. 1 is an illustration of a combine harvester having a grain bin with a grain
35 volume monitoring system according to the invention;

Fig. 2 is a cross-sectional illustrative view of a grain bin with a grain volume monitoring system according to a first embodiment of the invention;

Fig. 3 is a top plan view of the grain bin of Fig. 2;

Fig. 4 is a process diagram for the operation of the grain volume monitoring system of the invention;

Fig. 5 is a cross-sectional illustrative view of a grain bin with a grain volume monitoring system according to a second embodiment of the invention;

Fig. 6 is a top plan view of the grain bin of Fig. 4;

Fig. 7 is a cross-sectional illustrative view of a grain bin with a grain volume monitoring system according to a third embodiment of the invention; and

Fig. 8 is an illustrative view of the variables determined by the grain volume monitoring system of the invention.

It will be understood that the drawings are provided as illustrative examples, and are not provided to scale.

With reference to Fig. 1, a combine harvester is indicated at 10. The combine harvester 10 is provided with an integrated grain bin 12, which is used for the storage of harvested grain. The combine 10 comprises a driver station 14 which is used to control the operation of the combine 10. It will be understood that the driver station 14 comprises various input devices, e.g. steering wheels, acceleration and brake pedals, ground drive joysticks, etc., which may be used to control the combine systems and drive. In addition, the driver station 14 comprises information display devices, e.g. instrument dials, display terminals, touchscreen panels, etc., for the display and manipulation of data relating to combine operation.

The system of the invention comprises a controller 16 as part of a grain volume monitoring system, which is arranged to communicate with the driver station 14. It will be understood that the controller 16 may be a stand-alone device, specific to the grain volume monitoring system, or the controller 16 may be provided as a processor routine which is performed by a general-purpose electronic control unit (ECU) of the combine 10.

In Figs. 2 and 3, an illustration is provided of an embodiment of grain bin 12 according to the invention. The grain bin 12 is defined by side walls 18 which extend from a bottom wall 20 towards an open end 22. The open end 22 of the grain bin 12 may be provided with adjustable doors or extension panels (shown in the embodiments of Fig. 5 and 6), which

may be opened to provide access to the interior of the grain bin 12 or to provide for extended capacity of the bin 12.

5 A pair of image capture devices in the form of first and second cameras 24a,24b are provided on the grain bin 12, the cameras 24a,24b forming part of the grain volume monitoring system. The cameras 24a,24b are mounted on opposed side walls 18 of the grain bin 12, at the open end 22 of the grain bin 12. The cameras 24a,24b are directed towards the interior of the grain bin 12, to monitor the level of grain contained within the grain bin 12, indicated at 26. The images captured by the cameras 24a,24b are provided
10 to the controller 16 for further image processing. While the illustrated embodiment uses two separate cameras 24a,24b, it will be understood that a single image capture device or camera may be used in alternative embodiments, where such a single camera is positioned to provide an overview of the entire grain pile for the purpose of determining the contained volume of grain.

15

With reference to Fig. 4, an outline of the process used by the grain volume monitoring system of the invention is now described, starting at step 100.

The cameras 24a,24b are controlled to capture images of the contained grain pile 26, step
20 102. The captured images are communicated to the controller 16, which analyses the images to determine the angle of repose of the grain pile, step 104, and the height of at least a portion of the grain pile, step 106. The height of the grain pile 26 may be the peak height of the grain pile, and/or the height of the grain pile adjacent the side walls 18 of the grain bin 12. The controller 16 is configured to perform image recognition techniques in
25 order to determine the characteristics of the grain pile. In some embodiments, the controller 16 is arranged to stitch together a series of captured images, to provide a geometrical profile of the level of grain in the bin 12.

Using the determined data of the shape of the contained grain 26, the controller 16 is
30 arranged to determine the volume of grain contained in the bin 12, using geometrical calculations and based on prior knowledge of the dimensions of the grain bin 12 itself, step 108. Once the volume is calculated, the controller 16 is configured to display the calculated volume to an operator, for example using a display terminal provided at the operator station 14, step 110.

In a further aspect of the invention, the controller 16 is arranged to compare the calculated volume of grain with at least one pre-set volume limit, step 112. The pre-set volume limit may comprise a threshold grain volume, above which there is an increased risk of grain spillage from the grain bin 12. The pre-set volume limit may be based on a number of
5 different factors, which may comprise one or more of the following: the type of crop, the capacity of the grain bin, the speed at which the grain bin is travelling or expected to travel, the field contour or terrain profile for the area in which the grain bin is operating.

If the grain volume is within the defined limits, the controller 16 continues to monitor the
10 grain volume in the bin 12. If the grain volume exceeds a pre-set limit, the controller 16 is arranged to perform an action in response to the high grain level, step 114. The action may comprise simply displaying a warning notification to an operator, e.g. via a display terminal provided at the operator station 14. In particular, if the volume of the contained grain is relatively high, the system can be configured to provide a warning to the combine
15 operator that the contained grain may be in danger of spillage, in the event of driving over an inclined surface, driving at a relatively high speed, and/or sudden braking. When such a warning is issued, the operator may be prompted to take precautionary measures, e.g. ceasing further filling of the grain bin, reducing speed, changing route to avoid excessive inclines, smoothing the contained grain level to reduce the angle of repose of the grain,
20 etc.

In a further aspect, the action may comprise an adjustment of the drive control of the combine 10. For example, the controller 16 may activate a speed limiter to restrict the maximum speed of the combine 10. Alternatively, if the combine 10 comprises a drive
25 control device at the operator station 14 having a force feedback module, the controller 16 may adjust the force feedback response of the control device based on the calculated volume data. Such adjustment may comprise increasing the force required by the drive control device to accelerate or decelerate the combine 10, based on the calculated volume data. As a result, sudden acceleration or decelerations, which may result in grain
30 spillage, are prevented.

In a further option, the controller 16 may be provided with information relating to a predicted route of the combine 10, in particular relating to predicted slopes to be traversed and/or expected speeds of the combine 10. In this instance, the controller can determine if
35 the predicted route may result in grain spillage, based on the calculated grain volume level. If the risk of grain spillage exceeds a threshold, the controller can display a warning

to the operator, either to adjust the predicted route, or to take further actions to prevent spillage.

5 Dependent on the calculated volume data, the volume monitoring method may continue to capture images of the grain pile for further analysis, step 102, or the method may be ceased, step 116. Providing a grain volume monitoring system utilising cameras allows for an efficient and dynamic system for the calculation of harvested grain volumes.

10 Preferably, the cameras 24a,24b comprise still image cameras, but video cameras may also be used. In addition, 3D image cameras may be provided, to generate a more accurate profile of the contained grain. The cameras 24a,24b are preferably provided within an insulating housing, e.g. formed of plastics or rubber, to reduce the risk of current arcing when passing under overhead power lines.

15 Further embodiments of the invention are illustrated in Figs. 5-7. Features common to the various embodiments are provided with the same reference numerals.

In Figs. 5 and 6, the grain bin 12 is provided with additional grain bin extension panels 28, to provide for increased capacity of the grain bin 12. The panels 28 are arranged at the
20 open end 22 of the bin 12, at the upper end of the side walls 18. The panels 28 act to define a new open end 30, and may be hingedly connected to the side walls 18 to allow for different dimensions of the open end 30.

In the embodiment of Figs. 5 and 6, the image capture devices 24a,24b are provided at
25 the upper end of the panels 28, at opposite sides of the new open end 30 of the bin 12.

In a further enhancement, Fig. 6 shows that the embodiment of grain volume monitoring system comprises additional image capture devices in the form of third and fourth cameras 24c,24d, which are provided at opposite sides of the open end 30 of the bin 12.
30 As can be seen from the embodiment of Fig. 6, the first and second cameras 24a,24b are arranged along a first plane A, while the third and fourth cameras 24c,24d are arranged along a second plane B, which is orthogonal or transverse to the first plane A. By arranging the cameras 24a,24b,24c,24d at the cardinal points around the interior of the grain bin 12, an accurate profile of a contained grain pile 26 can be monitored, accounting
35 for all variations in the shape profile of the grain pile 26 to be captured by the cameras. It

will be understood that any number of cameras may be used to provide an accurate profile of the shape of the contained grain pile 26.

5 In a further aspect of the invention, image capture devices may be used having different capture angles. For example, a first camera may be used having a wider capture angle relative to a second camera. Providing different capture angles for the image capture devices allows for an increase in capture accuracy. Different image capture devices can be directed to capture different aspects of the grain pile, e.g. a relatively narrow capture angle may be used to focus on the height of the contained grain pile against one of the
10 walls of the grain bin, while a relatively wide capture angle may be used to capture the general profile of the grain pile, including the peak height of the grain pile. In addition, depending on the dimensions of the grain bin, wide capture angle devices may be required at certain locations to accurately record the entire visible profile of the contained grain.

15 In Fig. 7, a further embodiment of the grain volume monitoring system is illustrated, wherein the cameras 24a,24b are provided on brackets 32 extending from the upper end of the grain bin extension panels 28. The use of such brackets allows for a better overall viewing angle of the contained grain pile 26 by the cameras 24a,24b. It will be understood
20 that the brackets 32 may be hingedly or pivotally mounted to the panels 28 or alternatively to the side walls 18 of the grain bin 12, such that the cameras can be easily adjusted into a position to provide the best view of the contained grain pile 26. In addition, it will be understood that the brackets 32 are preferably provided from an insulating or non-conductive material, to reduce the risk of current arcing when passing under overhead
25 power lines.

With reference to Fig. 8, it will be understood that the image capture devices of the invention are used to record a number of different variables of a contained grain pile 26. In one aspect, the angle of repose of the grain pile is measured as the angle ϕ formed by the
30 surface of the accumulated grain pile 26. In the event of uneven filling of the grain bin 12, the angle of repose may vary about the grain pile, wherein the system is arranged to record such variations in angle. The absolute peak height H of the grain pile 26 may be measured by the system. Additionally or alternatively, the height of the grain pile is measured against the side walls 18 or the extension panels 28, to determine the distance
35 h between the top of the grain pile and the upper end of the grain bin 12. Based on this data, and on pre-existing knowledge of the overall dimensions of the grain bin 12 and the

type of grain being harvested, the controller 16 is arranged to calculate the volume of grain contained in the grain bin 12.

5 In some embodiments, it will be understood that the grain bin 12 may be provided with additional load cells to provide a measurement of the weight of the grain bin plus the contained grain. Such a weight measurement may be used as a comparison to the calculated volume of the contained grain, as a confirmation of the accuracy of the calculations used.

10 It will be understood that the grain volume monitoring system may be provided as a kit of parts for installation on or retrofitting to an existing grain bin or combine harvester.

It will be understood that the invention may be used for level detection of other particulate material, and is not limited to use for measuring the volume of harvested grain.

15

The invention is not limited to the embodiments described herein, and may be modified or adapted without departing from the scope of the present invention.

CLAIMS

1. A combine harvester comprising a grain bin comprising walls defining a grain storage space, the grain bin further comprising a grain volume monitoring system having:
 - at least one image capture device positioned on said grain bin, the at least one
 - 5 image capture device arranged to capture an image of a grain pile contained in the grain storage space; and
 - a controller coupled to said at least one image capture device to receive said captured image, the controller arranged to determine an angle of repose of the grain pile and a height of the grain pile, based on the captured image,
 - 10 wherein the controller calculates a volume of the contained grain pile based on the angle of repose and the height of the grain pile.
2. The combine harvester of claim 1, wherein the grain volume monitoring system comprises:
 - 15 a first image capture device provided on a first side of the grain bin, the first image capture device arranged to capture an image of the grain pile contained in the grain bin from said first side of the grain bin, and
 - a second image capture device provided on a second side of the grain bin, opposite the first side, the second image capture device arranged to capture an image of the grain
 - 20 pile contained in the grain bin from said second side of the grain bin.
3. The combine harvester of claim 2, wherein the grain volume monitoring system further comprises:
 - third and fourth image capture devices on the grain bin arranged to capture different
 - 25 images of a grain pile contained in the grain bin,
 - wherein the first and second image capture devices are arranged along a first plane, and wherein the third and fourth image capture devices are arranged along a second plane, different to said first plane.
- 30 4. The combine harvester of claim 3, wherein the second plane is transverse to said first plane.
5. The combine harvester of claim 1, wherein the grain volume monitoring system comprises:
 - 35 at least first and second image capture devices, wherein the first image capture device has a wider capture angle relative to the second image capture device.

6. The combine harvester of claim 1, wherein the at least one image capture device is arranged adjacent to an upper rim of the grain bin.
- 5 7. The combine harvester of claim 1, wherein the at least one image capture device is provided on at least one bracket projecting from the grain bin
8. The combine harvester of claim 1, wherein the at least one image capture device is provided on a grain bin extension panel, arranged at an upper end of the grain bin.
- 10 9. The combine harvester of any one of claims 1-8, wherein the at least one image capture device comprises at least one of the following: a video camera, a still image camera, a 3D camera.
- 15 10. The combine harvester of any one of claims 1-9, wherein the controller is arranged to compare the calculated volume of grain to a pre-set volume limit, and to generate a warning signal if the calculated volume exceeds the pre-set volume limit.
11. The combine harvester of any one of claims 1-10, wherein the controller is arranged to
20 communicate the calculated volume data to an operator.
12. The combine harvester of claim 11, wherein the calculated volume data is displayed on a display terminal.
- 25 13. The combine harvester of any one of claims 1-12, wherein the combine comprises a drive control device having a force feedback module, wherein the force feedback module of the drive control device is controlled based on the calculated volume data.
14. A grain volume monitoring system provided as a kit for installation on a combine
30 harvester having a grain bin, the system comprising:
at least one image capture device positioned on said grain bin, the at least one image capture device arranged to capture an image of a grain pile contained in a grain storage space of the grain bin; and
a controller coupled to said at least one image capture device to receive said
35 captured image, the controller arranged to determine an angle of repose of the grain pile and a height of the grain pile, based on the captured image,

wherein the controller calculates a volume of the contained grain pile based on the angle of repose and the height of the grain pile.

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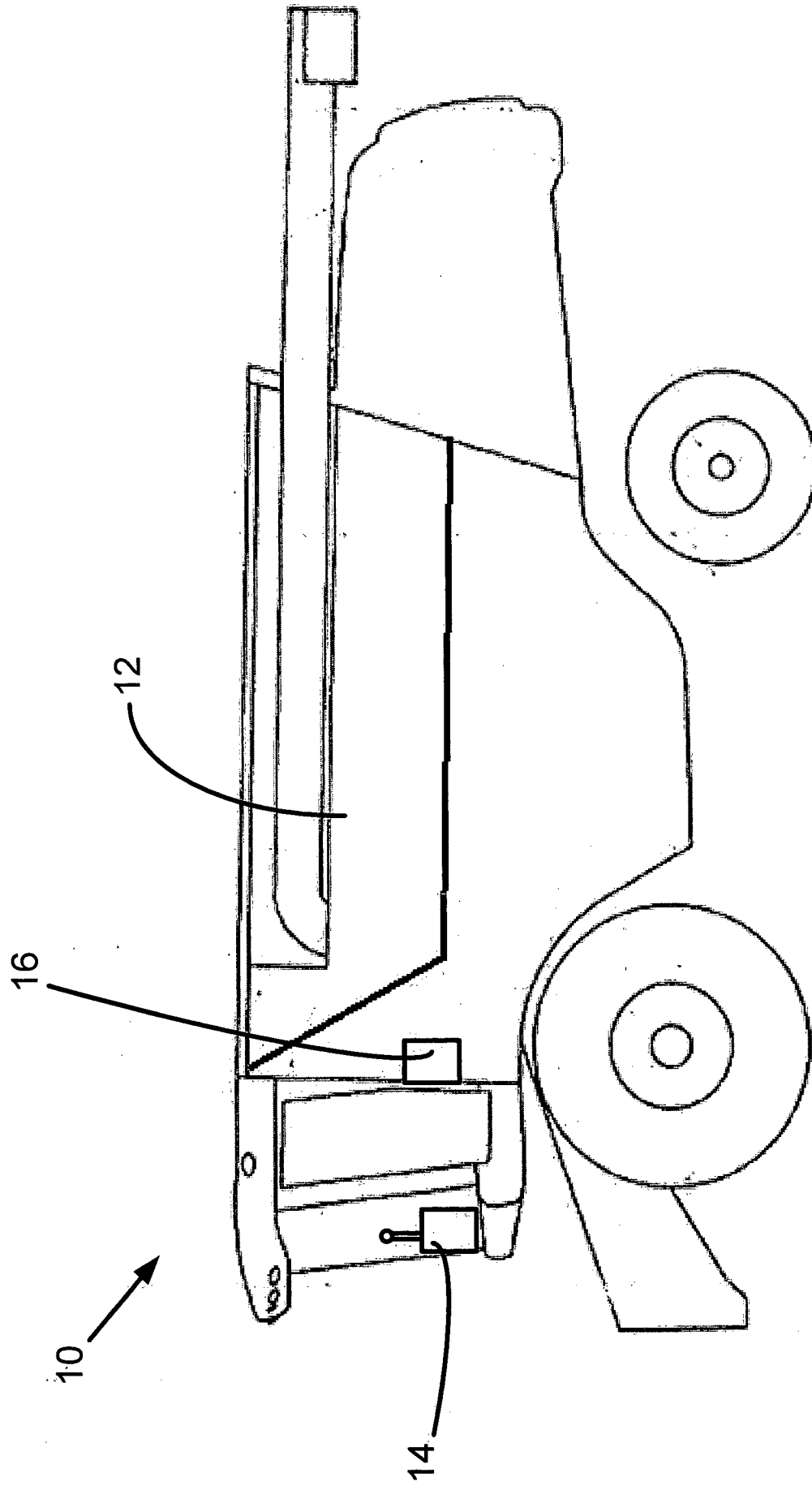


Fig. 1

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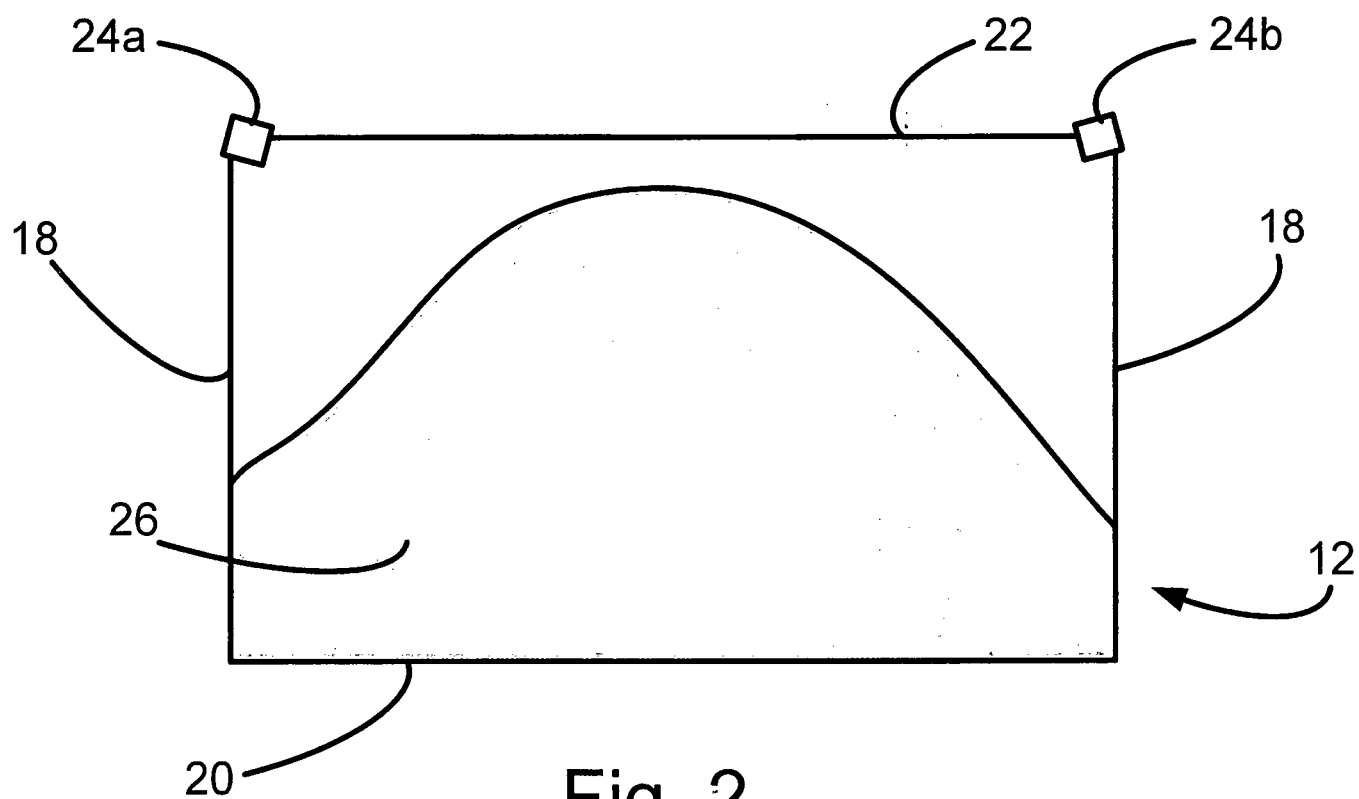


Fig. 2

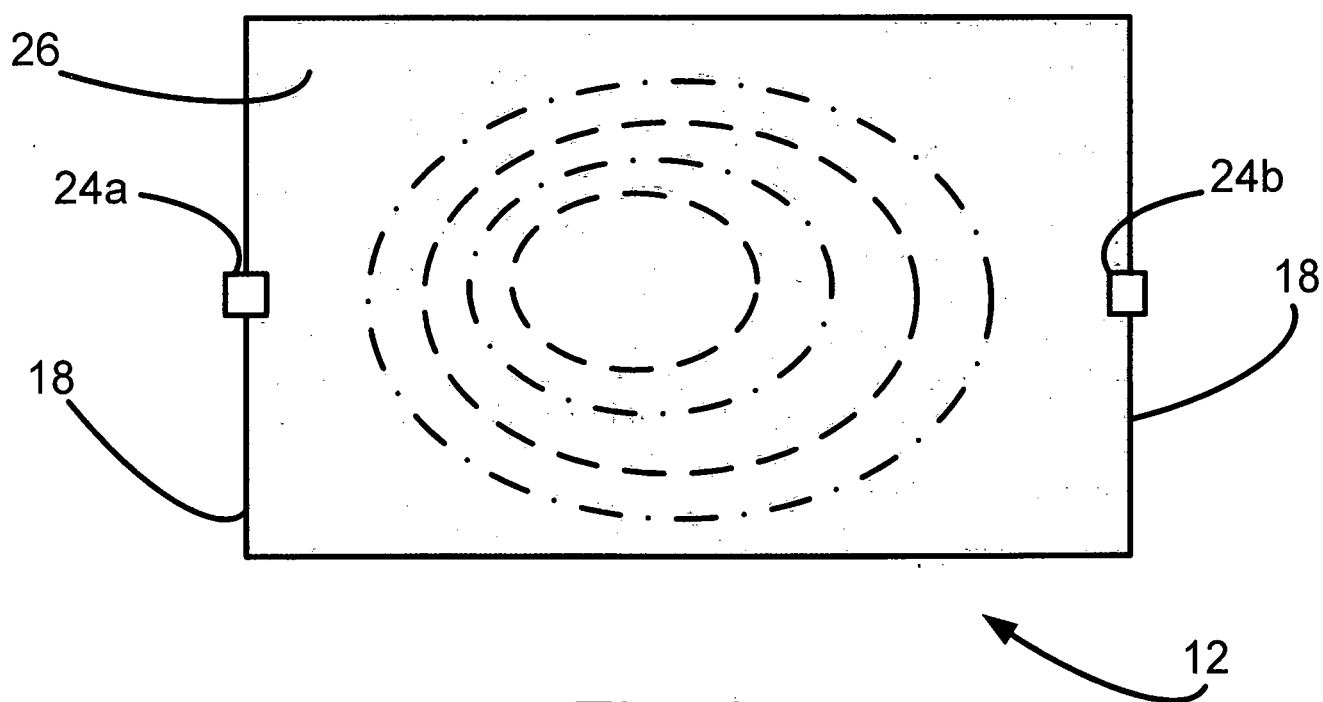


Fig. 3

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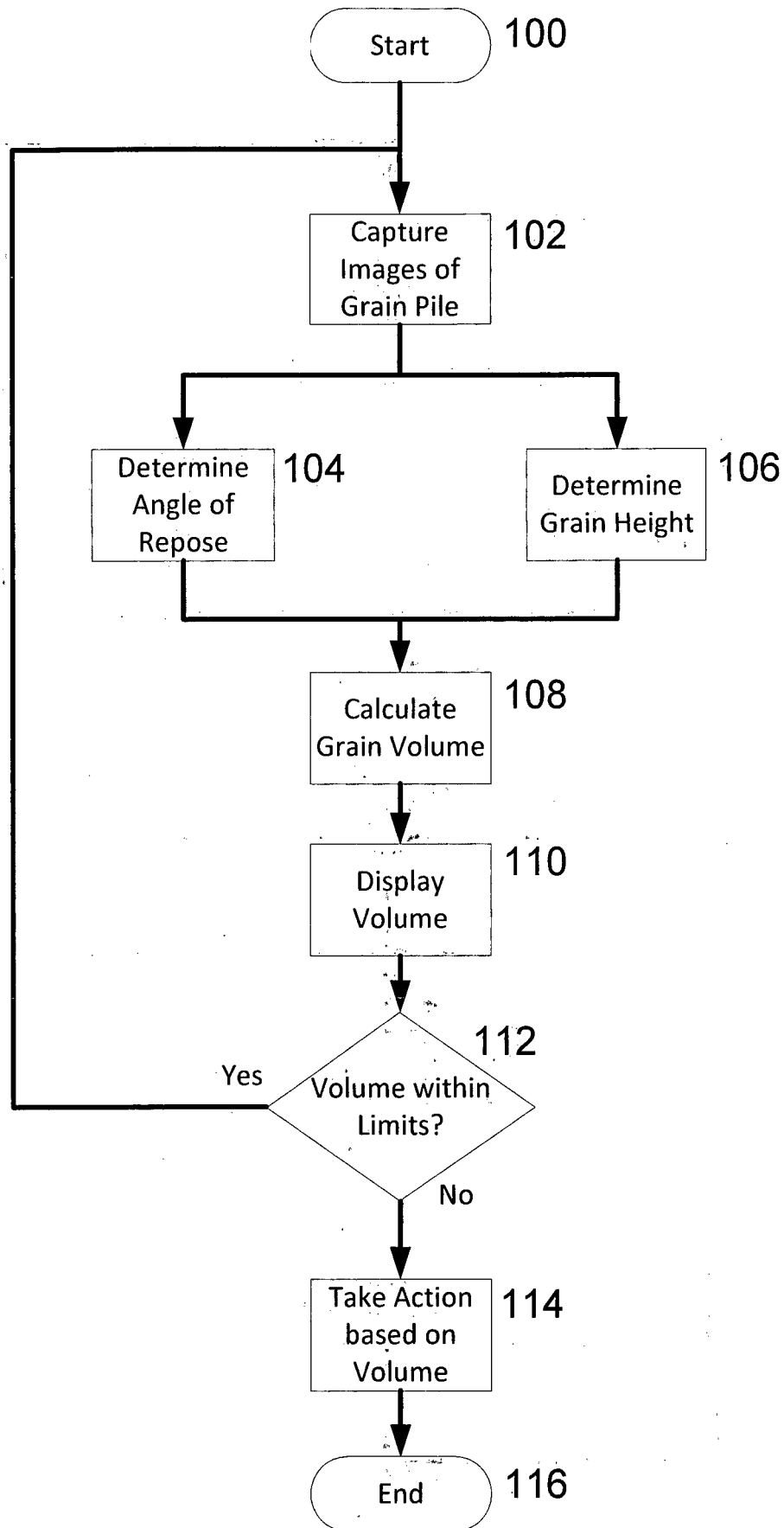


Fig. 4

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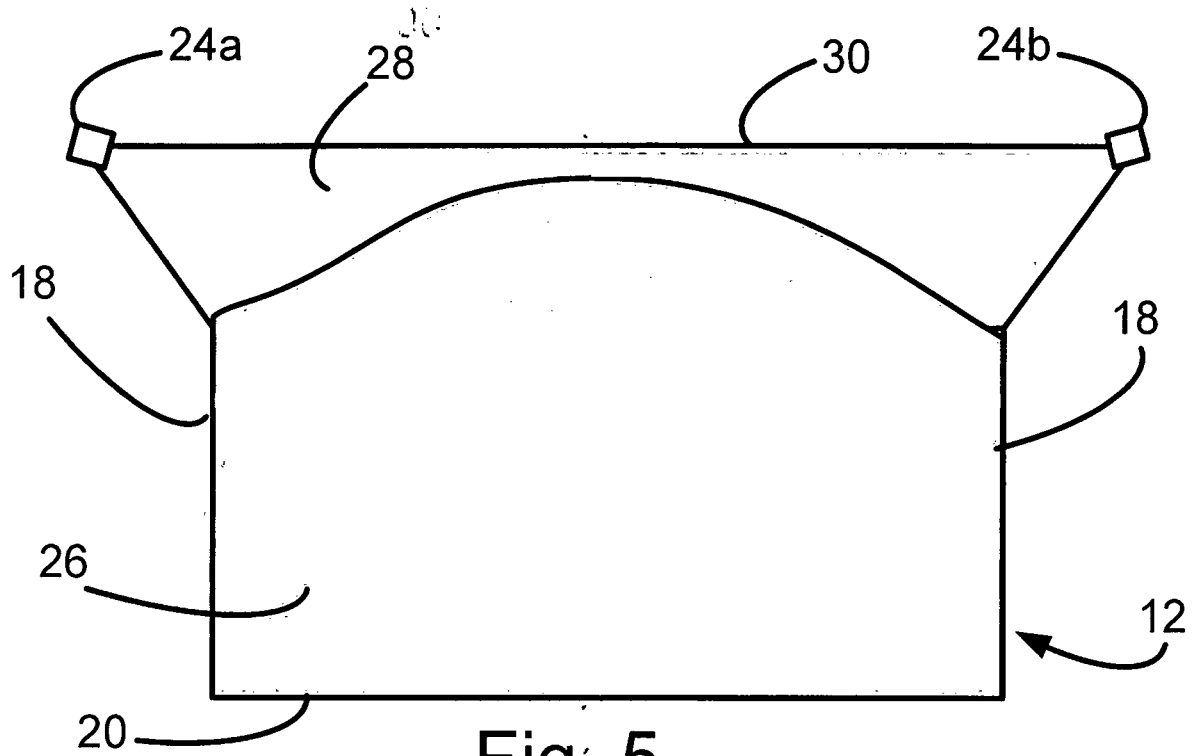


Fig. 5

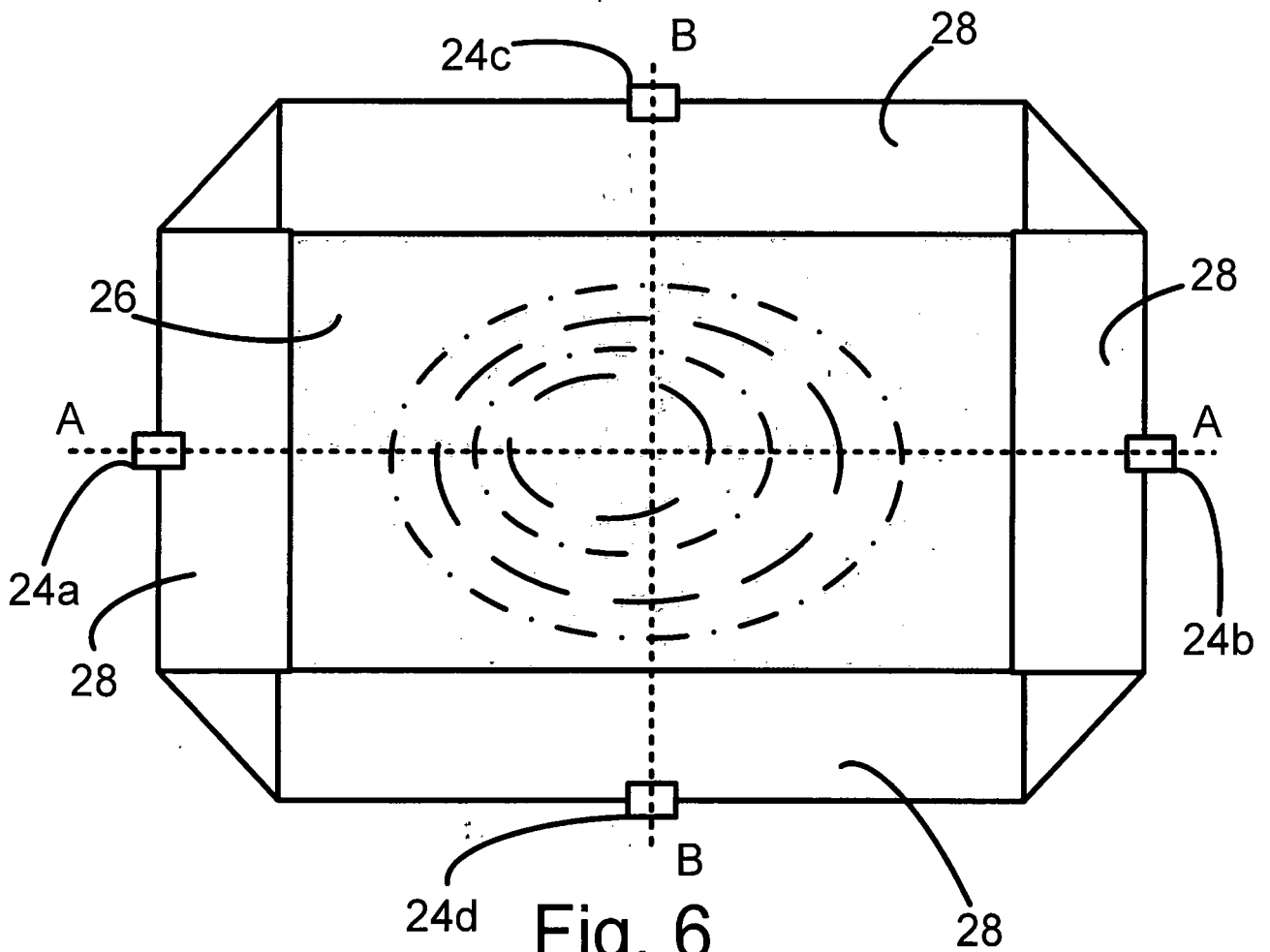


Fig. 6

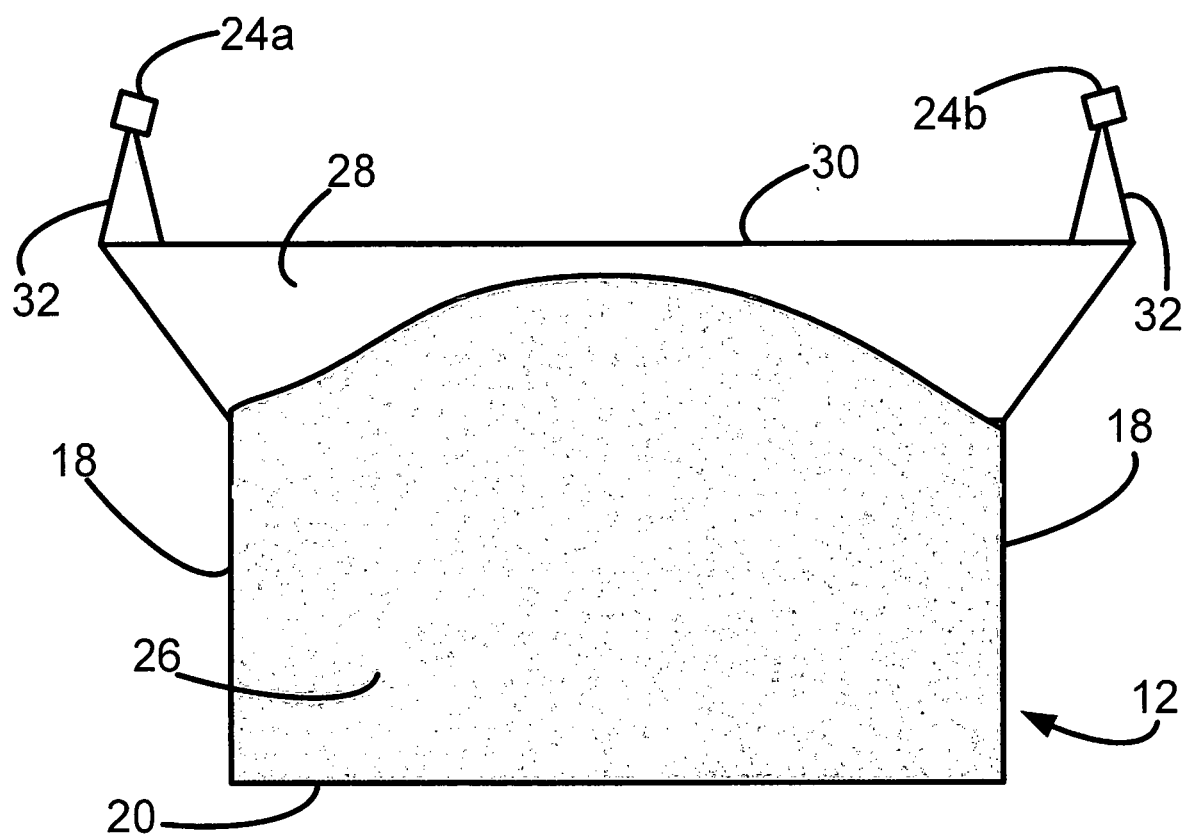


Fig. 7

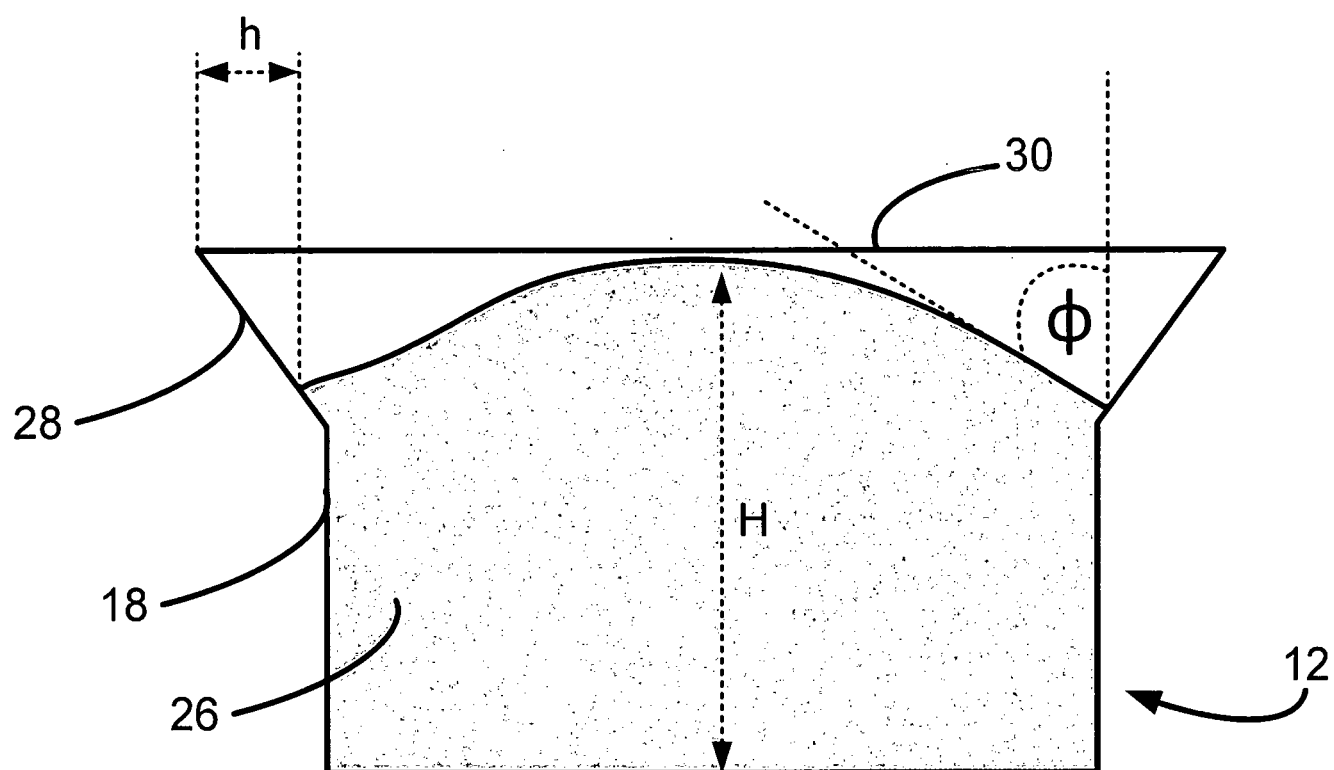


Fig. 8

