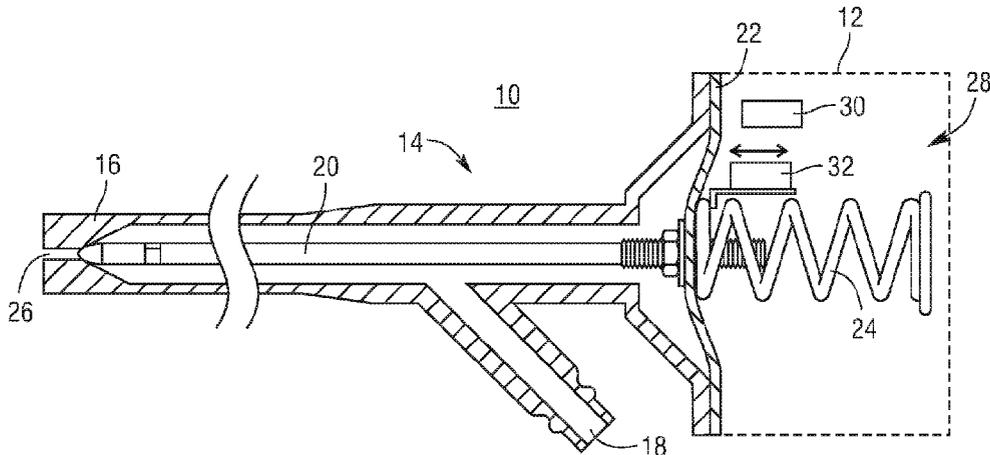




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(57) Abrégé/Abstract:

A sparger for injection of bubbles into a flotation system comprises a housing, a movable rod assembly, and a sensor system that comprises a sensor and a target that move relative to each other. One of the sensor and the target is located in the housing and the other is located on or attached to the movable rod assembly. The sensor for measuring motion, including position and vibration, relative to the target based on the movement of the movable rod assembly. The sensor system for determining operating parameters of the sparger based on the analysis of the measurement of the motion of the sensor relative to the target.

## **Abstract**

A sparger for injection of bubbles into a flotation system comprises a housing, a movable rod assembly, and a sensor system that comprises a sensor and a target that move relative to each other. One of the sensor and the target is located in the housing and the other is located on or attached to the movable rod assembly. The sensor for measuring motion, including position and vibration, relative to the target based on the movement of the movable rod assembly. The sensor system for determining operating parameters of the sparger based on the analysis of the measurement of the motion of the sensor relative to the target.

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## **Sparger Status Sensor System**

### **Background**

In mineral flotation applications, sparging systems are used to promote the attachment and recovery of hydrophobic particles through the generation of a fine bubble dispersion. This is accomplished by arranging a series of spargers in the periphery of flotation tanks. The spargers generate a large amount of bubbles at the optimum size for the given application. Specifically, they are designed to generate high rates of bubble surface area which guarantees a high probability of attachment and improved recoveries of hydrophobic particles. Smaller mineral processing plants could have as few as a single flotation tank while larger plants could have several dozen flotation tanks. Each flotation tank could have thirty spargers or more. This means that larger processing plants could easily have hundreds of spargers that represent a significant investment in equipment, maintenances, and repair.

Prior art spargers were essentially left to their own devices as it was difficult to monitor real time performance and provide feedback and troubleshooting for spargers that were operating inefficiently or not at all. It was only in routine maintenance that problems were uncovered, if at all.

What is presented is a sparger for the injection of bubbles into flotation systems which incorporates sensors and mechanisms that provide status indicators on the functioning of an individual sparger as well as systems for providing networked communications between a collection of spargers on a single flotation system or in a facility that has multiple flotation systems.

### **Summary**

What is presented is a sparger and a sensor system for a sparger that comprises a housing and a movable rod assembly for injection of bubbles into a flotation system. The sensor system comprises a sensor and a target that move relative to each other. One of the sensor and the target is located in the

housing and the other is located on or attached to the movable rod assembly. The sensor is for measuring motion, including position and vibration, relative to the target based on the movement of the movable rod assembly. The sensor system for determining operating parameters of the sparger based on the analysis of the measurement of the movement of the sensor relative to the target. The sensor is one of a Hall Effect sensor, an inductive proximity sensor, or an optical proximity sensor. The sensor system measures the motion of the movable rod assembly, the position of the movable rod assembly, and the vibration of the movable rod assembly. The sensor system the presence of failure modes of the sparger that is any of a plugged nozzle, a torn diaphragm, loss of pressure, or loss of fluid.

The sensor from the sensor system outputs a signal to a signal processor. The signal processor comprises a sensor signal conditioner, an analog to digital converter, and a sensor signal analyzer. The signal processor generates a signal output to indicators located on the housing and/or to a central control unit via wired or wireless remote communication.

In some embodiments, a network of sensor systems for spargers for injection of bubbles into a flotation system comprises a plurality of spargers that each comprise a housing, a movable rod assembly and a sensor system. Each sensor system further comprises a sensor and a target that move relative to each other, wherein one of the sensor and the target is located in the housing and the other is located in or attached to the movable rod assembly. The sensor is for measuring motion, including position and vibration, relative to the target based on the movement of the movable rod assembly. The sensor system for determining operating parameters of the sparger based on the analysis of the measurement of the movement of said sensor relative to said target. Each sensor outputs a signal to a signal processor that generates a signal output to a central control unit. The central control unit aggregates and analyzes each signal to display operating parameters of each corresponding sparger and provide overall system performance data.

In some embodiments, the plurality of spargers is mounted to a single flotation separation system. In other systems the said plurality of spargers is mounted to multiple flotation separation systems. The signal output to said central control unit is transmitted wirelessly.

Those skilled in the art will realize that this invention is capable of embodiments that are different from those shown and that details of the apparatus and methods can be changed in various manners without departing from the scope of this invention. Accordingly, the drawings and descriptions are to be regarded as including such equivalent embodiments as do not depart from the spirit and scope of this invention.

### **Brief Description of Drawings**

For a more complete understanding and appreciation of this invention, and its many advantages, reference will be made to the following detailed description taken in conjunction with the accompanying drawings.

FIG. 1 is a cut out view of a sparger operating at low pressure with the sparger in the closed position;

FIG. 2 is a cut out view of a sparger operating at high pressure with the sparger in the open position;

FIG. 3 is a flow chart outlining the process steps from the sensor system through the signal processor and its output; and

FIG. 4 shows a series of spargers installed on a flotation tank networked wirelessly to a central control unit.

## Detailed Description

Referring to the drawings, some of the reference numerals are used to designate the same or corresponding parts through several of the embodiments and figures shown and described. Corresponding parts are denoted in different embodiments with the addition of lowercase letters. Variations of corresponding parts in form or function that are depicted in the figures are described. It will be understood that variations in the embodiments can generally be interchanged without deviating from the invention.

As shown in FIGs. 1 and 2, spargers **10** comprise a housing **12** and a movable rod assembly **14**. The movable rod assembly **14** further comprises a nozzle **16** that is inserted into the liquid medium inside a flotation tank (not shown). A source compressed gas is connected to the inlet **18**. A rod **20** is connected to a diaphragm **22** that is further connected to a spring **24**. As shown in FIG. 1 when pressure is low, the spring **24** pushes the diaphragm **22** and the rod **20** into the nozzle **16** thereby sealing the nozzle tip **26** and preventing liquid from the flotation tank from flowing back into the sparger. As shown in FIG. 2, when higher pressure is applied by the introduction compressed gas from the inlet **18**, the pressure acts on the diaphragm **22** to compress the spring **24**, retracting the rod **20**, and opening the nozzle tip **26** which allows the gas to be released through the nozzle tip **26** to create bubbles in the liquid medium in the flotation tank. In some embodiments, liquid may be added to the compressed gas stream at the inlet **18** to enhance bubble formation.

A sensor system **28** is mounted within the housing **12**. The sensor system **28** comprises a sensor **30** and a target **32**. In the embodiment shown in FIGs. 1 and 2 it is preferred that the sensor **30** is mounted in a stationary position within the housing **12** while the target **32** is linked with the movable rod assembly **14** such that the target **32** moves in concert with the movable rod assembly **14**. The figures show that the target **32** is connected to the spring **24** but it should be understood that the actual mounting location of the target **32** to the movable rod assembly **14** is immaterial so long as the

movement of target **32** is an accurate reflection of the movement of the movable rod assembly **14**. It is understood that the position of the target **32** and the sensor **30** could be switched such that the target **32** is stationary while the sensor **30** moves with the movable rod assembly **14**. The sensor system **28** will operate identically in either configuration.

The sensor system **28** could be any type of system that has a sensor **30** that measures the motion, including position and vibration, of a target **32** based on the movement of the movable rod assembly **14**. Examples include Hall Effect sensors and other magnetic sensors, optical sensors for visual recognition of a reflective target, and inductive sensors with a metallic target. Depending on the type of sensor used, the target **32** does not have to be a separate element from the movable rod assembly **14** as is depicted in FIGs. 1 and 2. Components of the movable rod assembly **14** itself could be the target **32**. So long as the sensor is able to detect and measure motion, including position and vibration, of the movable rod assembly **14**, then the purpose of the target **32** is met without any additional element being present. The target **32** could be the spring **24**, a nut or washer on the movable rod assembly **14**, or even the rod **20**.

With the sparger **10** in the closed position as shown in FIG. 1, the sensor **30** determines the motion of the target **32** relative to it. With no movement the sensor system **28** is able to determine that no gas is passing through the sparger **10** and that the sparger **10** is not in operation. When higher pressure is applied by the introduction of compressed gas from the inlet **18**, as shown in FIG. 2, the rod **20** moves and vibrates as fluid flows through the sparger **10** and the nature of these vibrations provides an indication of the functioning of the sparger **10**. The output from the sensor **30** is an indirect measure of the pressure at which compressed gas is introduced through the inlet **18** and provides operating parameters and failure modes of the sparger **10**. The measured motion of the target **32** relative to the sensor **30** indicates the position and motion of the rod **20** and is a measure of the opening of the nozzle tip **26**. Minimum useful indication would be “fully open” vs. “not fully open”. More nuanced sensors

could measure continuous position changes in the rod **20** or percentage opening of the nozzle tip **26** from fully closed to fully open. If the sparger **10** is plugged, the sensor **30** would record that the rod **20** will move but that it doesn't vibrate. If the diaphragm **22** tears, pressure drops and a partial position change of the rod **20** will be recorded as the rod **20** would not be able to move as far because the compressed gas has another outlet to escape.

Measurements from the sensor system **28** could be combined with measurements of other sparger **10** parameters to get a more accurate reading on system performance. For example, the interpretations of the readings from the sensor system **28** could be correlated with direct measurement of the compressed gas flow from the inlet **18** using, for example, a vane flow sensor, a hot wire flow sensor, differential pressure measurement across an orifice, differential temperature measurement across an orifice, or a microphone to sense flow noise. So, for example, a determination that a nozzle **16** is plugged based on a reading from the sensor system **28** can be correlated with a reading from the compressed gas flow to confirm whether and to what extent compressed gas is flowing into the sparger **10**.

Whatever the readings of the sensor system **28**, FIG. 3 shows how those readings are communicated to an operator for analysis and to determine operation status. Signals from the sensor **30** are transmitted to a signal processor **34** where they are conditioned **36** and converted to a digital signal **38** for further analysis **40**. The signal is scaled based on stored calibration values and compared to threshold setpoints to determine whether the sparger **10** is in the expected operating conditions. The results of the analysis can be output to local indicators **42** at the sparger **10** by, for example, LED indicators on the housing or some other display or output. The results can also be transmitted via remote communications **44** to a central control unit by radio communications, along with the raw sensor data, if desired. Various embodiments of the sensor system may have only local indicators **42**,

only remote communications **44**, or both. In various embodiments, the remote communications **44** may be wireless, wired, or both as needed for the particular application.

FIG. 4 shows an embodiment of how the remote communications **44a** systems of a sensor system housed within a system of spargers **10a** can be configured to form a network of sensor systems. In this example, a series of spargers **10a** is installed in a flotation tank **46a**. The remote communications **44a** from each sparger **10a** may be wired or wirelessly connected to a central control unit **48a** which receives, aggregates, and analyzes the information from all spargers and displays the overall system status to the operator. The central control unit **48a** may display and/or store the data locally, forward the data to another control system, or both.

The central control unit **48a** aggregates the status information from multiple spargers and may perform additional analysis on the data. This includes comparing data from one sparger (or group of spargers) with another sparger (or group of spargers). The central control unit **48a** could also correlate sparger data with data from other types of sensors or status indicators that may be available in the plant. For example, if all of the spargers in the plant are closed, the central control unit **48a** could be directed to check the status of the air compressor rather than indicating that all of the spargers are faulty. In addition, the central control unit **48a** could compare data from one or more spargers over time, looking at trends and variations.

The central control unit **48a** could also display status indications in some aggregate form to clearly inform the operator how many spargers are not operating correctly and where the offenders are located in the plant. The status could be presented in a graphical display, possibly with a touchscreen for user interaction, discrete indicators, or integrated into a larger (e.g. plant-wide) control/indication system.

The central control unit **48a** could communicate status remotely to plant operators, supervisors, and/or others if desired. This could include, but is not limited to, fault alerts, horns, beacons,

loudspeaker annunciator, email, text message, real-time status information, remote PC, or a smartphone application.

This invention has been described with reference to several preferred embodiments. Many modifications and alterations will occur to others upon reading and understanding the preceding specification. It is intended that the invention be construed as including all such alterations and modifications in so far as they come within the scope of the appended claims or the equivalents of these claims.

## Claims

What is claimed is:

1. A sensor system for a sparger that comprises a housing and a movable rod assembly for injection of bubbles into a flotation system, the sensor system comprising:
  - a sensor and a target that move relative to each other, wherein one of said sensor and said target is located in the housing the other is located on or attached to the movable rod assembly;
  - said sensor for measuring parameters of motion, position and vibration, relative to said target based on the movement of said movable rod assembly;
  - said sensor system for determining operating parameters of the sparger based on analysis of the measured motion, position and vibration of said sensor relative to said target.
2. The sensor system of claim 1 in which the sensor is one of a Hall Effect sensor, an inductive proximity sensor, and an optical proximity sensor.
3. The sensor system of claim 1 in which said target is a component of the movable rod assembly.
4. The sensor system of claim 1 in which said sensor is configured to measure the motion of the movable rod assembly, the position of the movable rod assembly, and the vibration of the movable rod assembly.
5. The sensor system of claim 1 in which said sensor system is configured to determine the presence of failure modes of the sparger that is any of a plugged nozzle, a torn diaphragm, loss of pressure, or loss of fluid.
6. The sensor system of claim 1 in which said sensor is configured to output a signal to a signal processor.
7. The sensor system of claim 1 further comprising a signal processor and in which said sensor outputs a signal to said signal processor and said signal processor comprises a sensor signal conditioner, an analog to digital converter, and a sensor signal analyzer.

8. The sensor system of claim 1 further comprising a signal processor and in which said sensor outputs a signal to said signal processor and said signal processor generates a signal output to indicators located on the housing.

9. The sensor system of claim 1 further comprising a signal processor and in which said sensor outputs a signal to said signal processor and said signal processor generates a signal output to a central control unit via wired or wireless remote communication.

10. A sparger for injection of bubbles into a flotation system comprising:

a housing;

a movable rod assembly;

a sensor system that comprises a sensor and a target that move relative to each other, wherein one of said sensor and said target is located in said housing the other is located on or attached to said movable rod assembly

said sensor system for measuring parameters of motion, position and vibration, relative to said target based on the movement of said movable rod assembly; and

said sensor system for determining operating parameters of the sparger based on analysis of the measured motion, position and vibration of said sensor relative to said target.

11. The sparger of claim 10 in which said sensor system is one of a Hall Effect sensor, an inductive proximity sensor, and an optical proximity sensor.

12. The sparger of claim 10 in which said target is a component of said movable rod assembly.

13. The sparger of claim 10 in which said sensor is configured to measure the motion of said movable rod assembly, the position of said movable rod assembly, and the vibration of said movable rod assembly.

14. The sparger of claim 10 in which said the sensor system is configured to determine the presence of failure modes of the sparger that is any of a plugged nozzle, a torn diaphragm, loss of pressure, or loss of fluid.

15. The sparger of claim 10 in which said sensor is configured to output a signal to a signal processor.

16. The sparger of claim 10 further comprising a signal processor and in which said sensor outputs a signal to said signal processor and said signal processor comprises a sensor signal conditioner, an analog to digital converter, and a sensor signal analyzer.

17. The sparger of claim 10 further comprising a signal processor and in which said sensor outputs a signal to said signal processor and said signal processor generates a signal output to indicators located on the housing.

18. The sparger of claim 10 further comprising a signal processor and in which said sensor outputs a signal to said signal processor and said signal processor generates a signal output to a central control unit.

19. A network of sensor systems for spargers for injection of bubbles into a flotation system, comprising:

a plurality of spargers that each comprise a housing and a movable rod assembly;

each said sparger comprising a sensor system, wherein each said sensor system further comprises a sensor and a target that move relative to each other, wherein one of said sensor and said target is located in said housing the other is located or attached to said movable rod assembly, said sensor for measuring motion, including position and vibration, relative to said target based on the movement of said movable rod assembly, and said sensor system for determining operating parameters of the sparger based on the analysis of the measurement of the motion of said sensor relative to said target; and

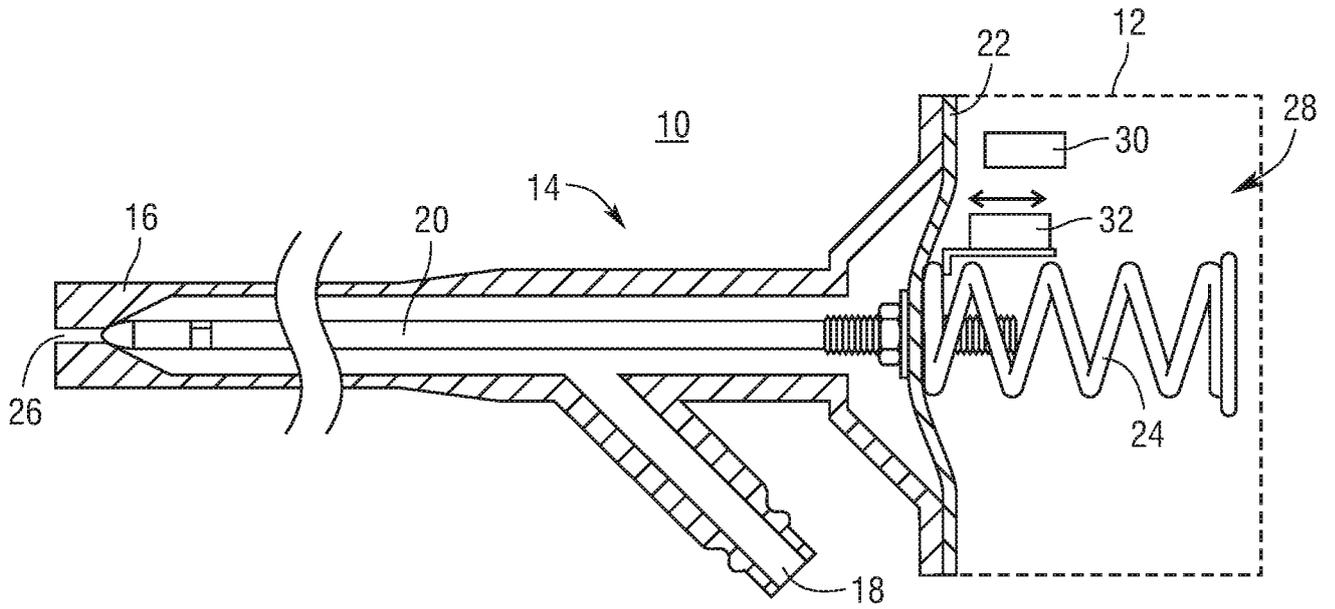
a signal processor wherein each sensor outputs a signal to said signal processor and said signal processor generates a signal output to a central control unit, wherein said central control unit aggregates and analyzes each said signal to display operating parameters of each corresponding said sparger and provide overall system performance data.

20. The network of sensor systems of claim 19 in which said plurality of spargers is mounted to a single flotation separation system.

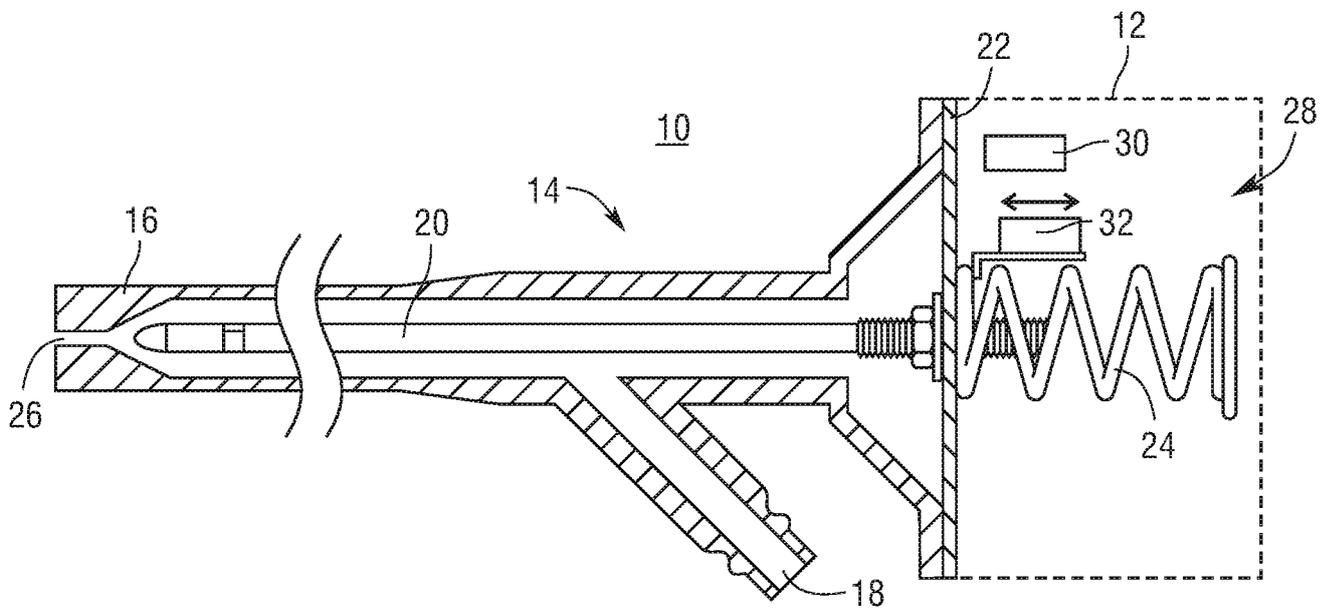
21. The network of sensor systems of claim 19 in which said plurality of spargers is mounted to multiple flotation separation systems.

22. The network of sensor systems of claim 19 in which said signal is output to said central control unit wirelessly.

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*Fig. 1*



*Fig. 2*

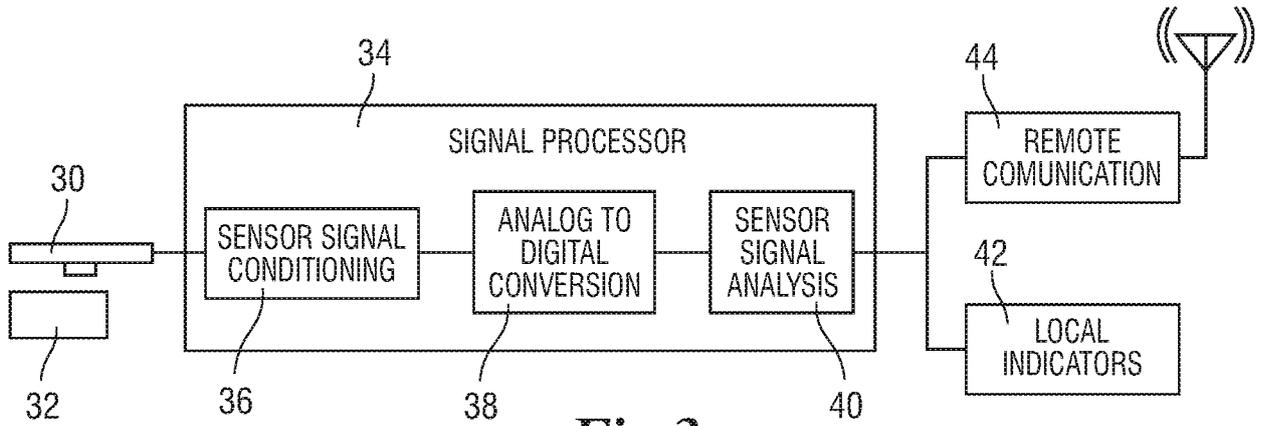


Fig.3

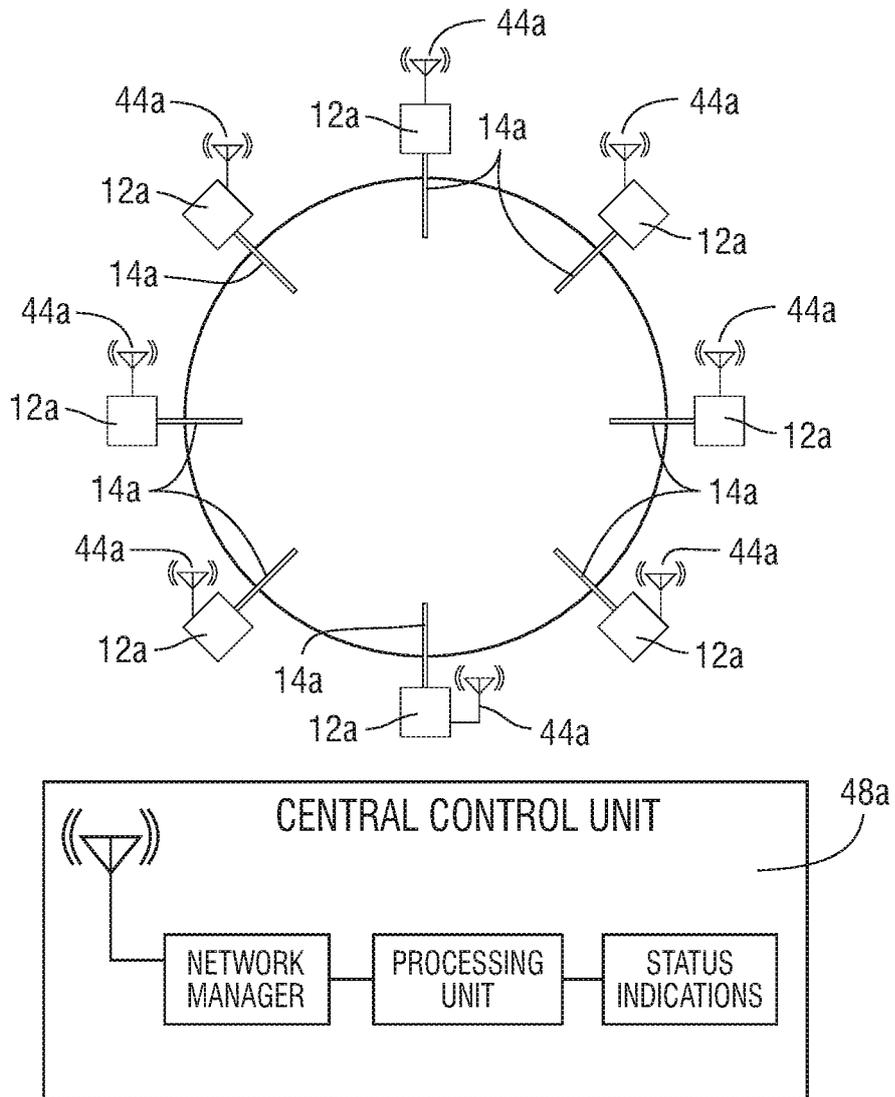


Fig.4

