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(54) **SYSTEM AND METHODS TO DETERMINE AND MONITOR CHANGES IN RAIL CONDITIONS OVER TIME**

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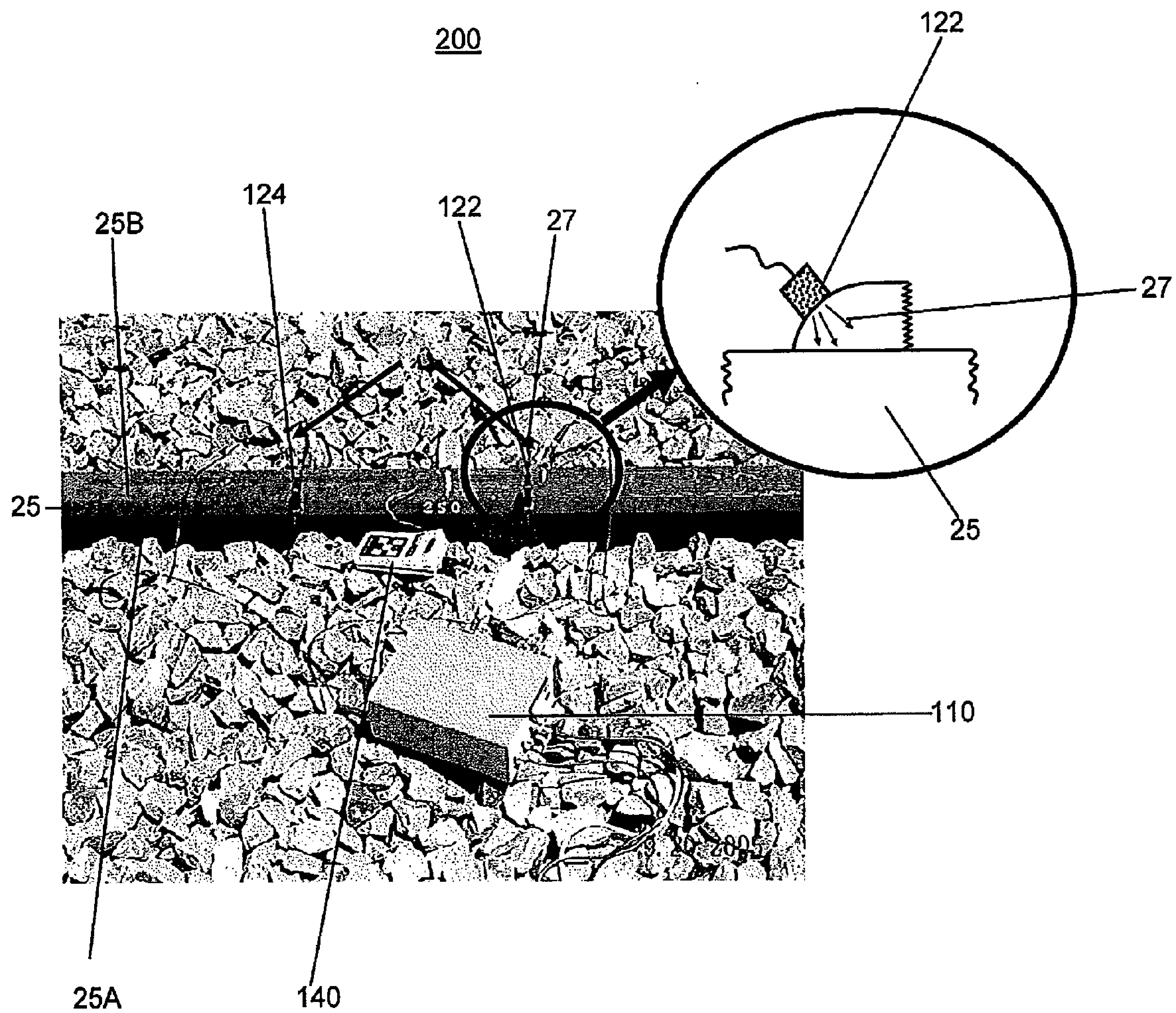
(57) **ABSTRACT**

The present invention is directed to a system and methods with which changes in rail conditions can be determined and monitored over time. The present invention includes a database of data, wherein a first set of data is used for comparison with a second set of data to determine the stress state of rail.



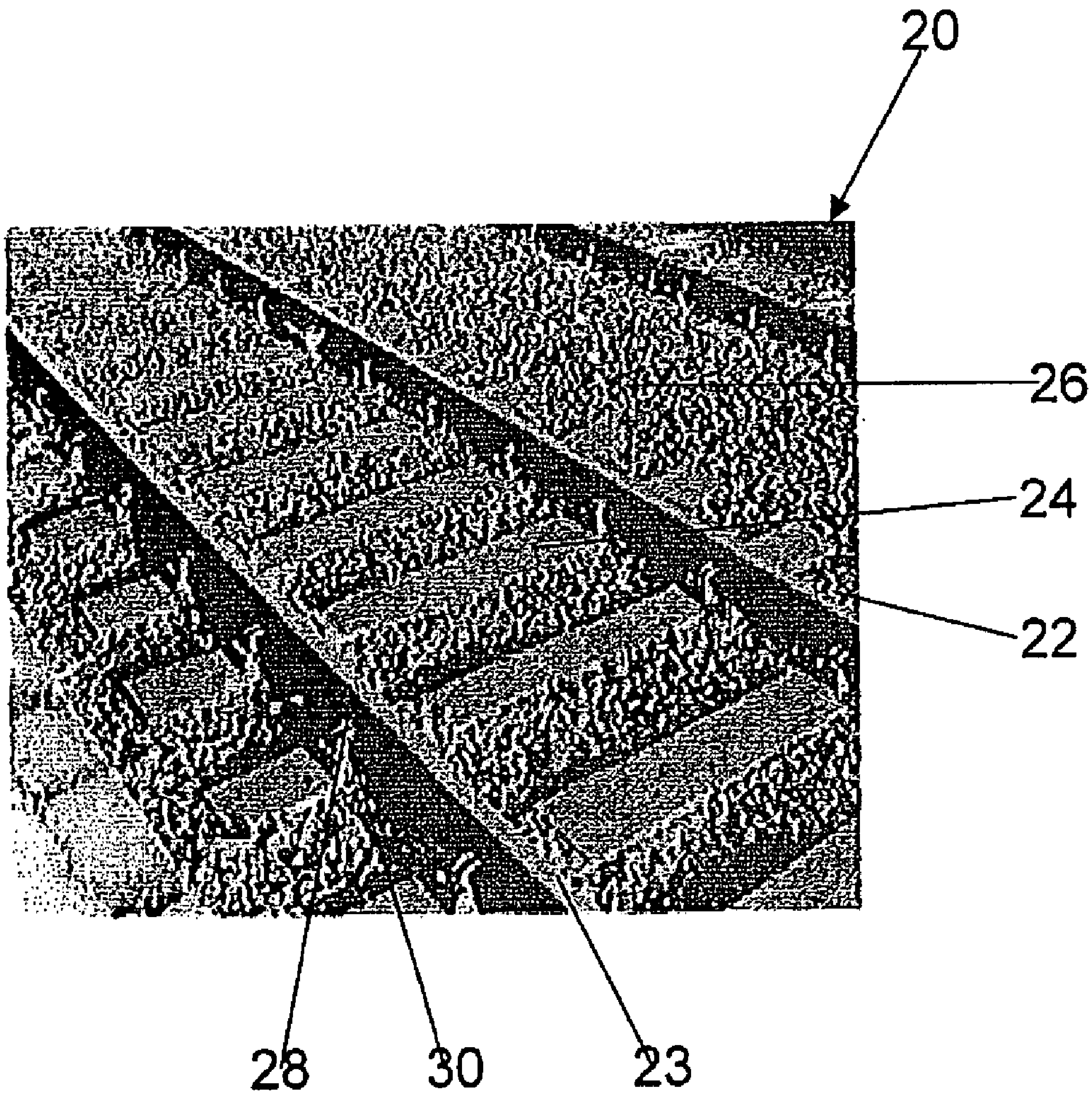


FIG. 1

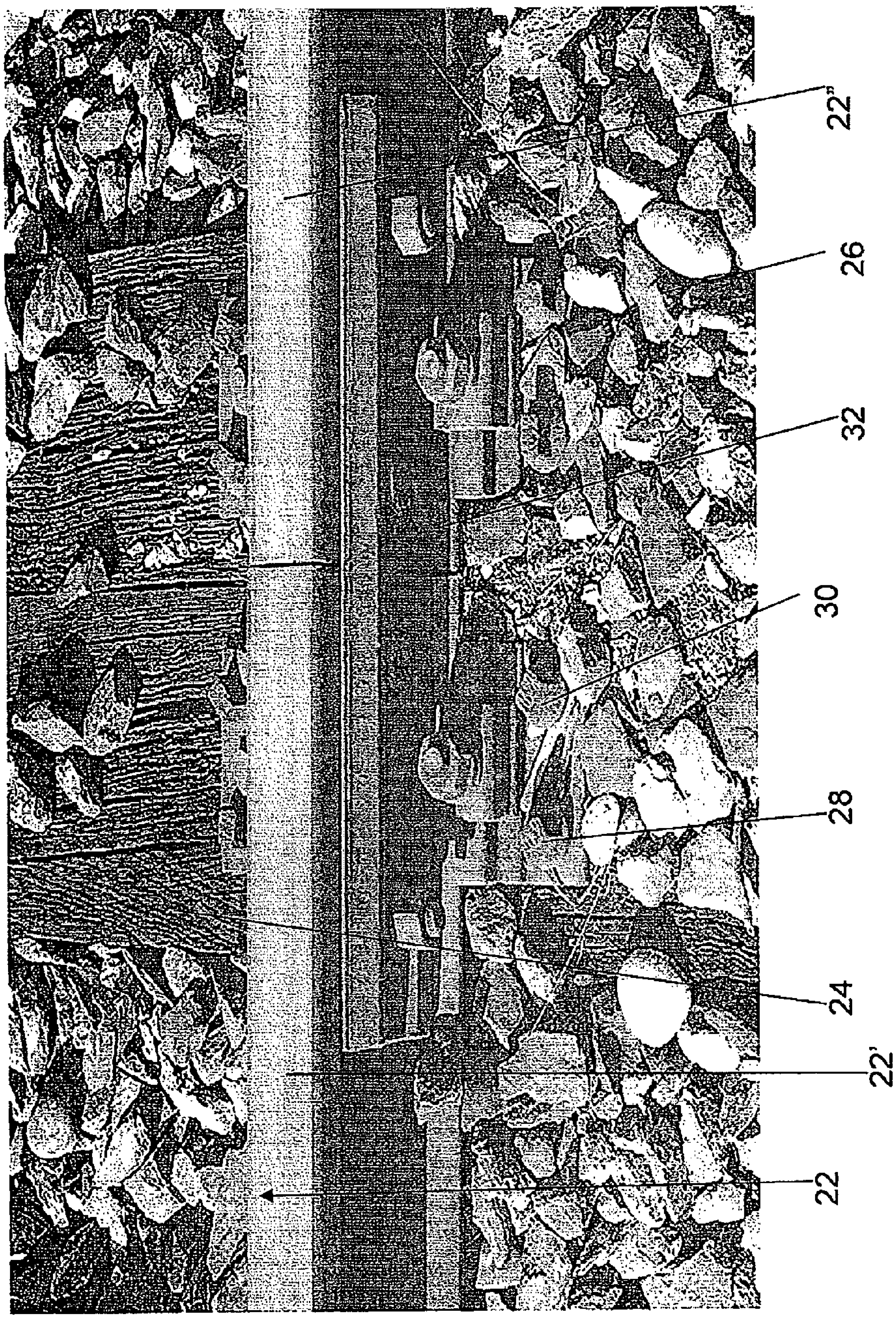


FIG. 2

PRIOR ART

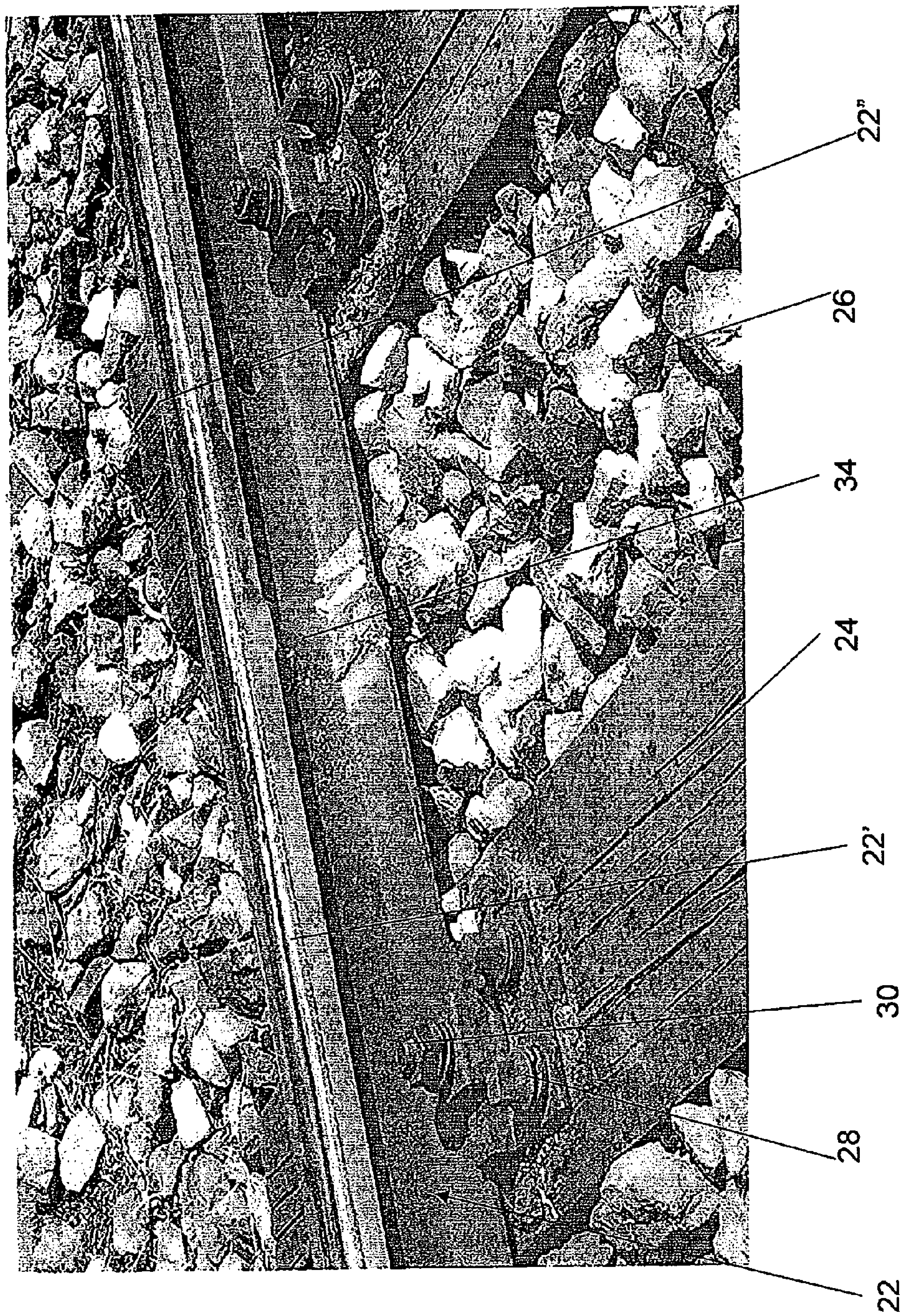
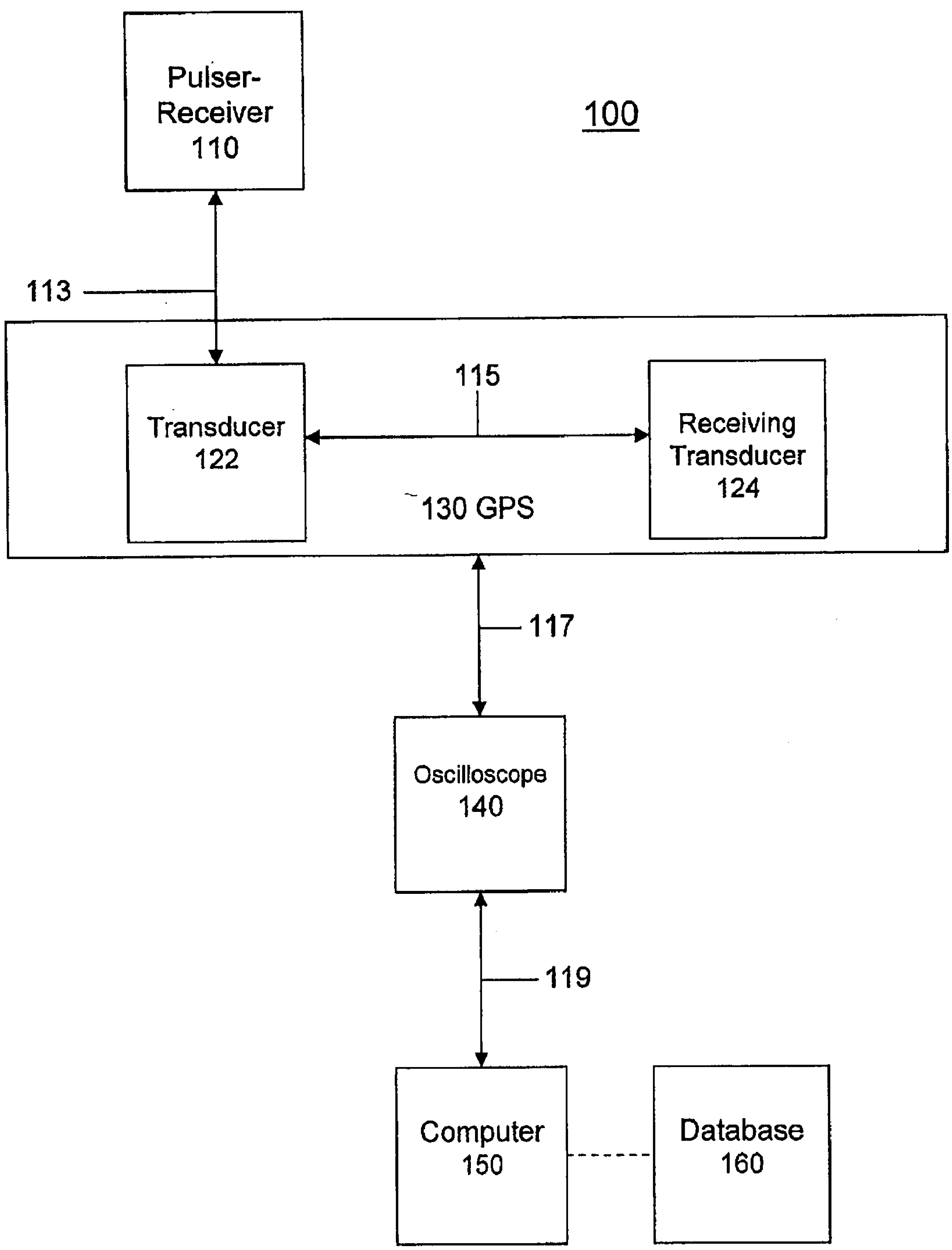


FIG. 3

PRIOR ART

FIG. 4


Pulser-
Receiver
110
100
113
Transducer
122
115
Receiving
Transducer
124
130 GPS
117
Oscilloscope
140
119
Computer
150
Database
160

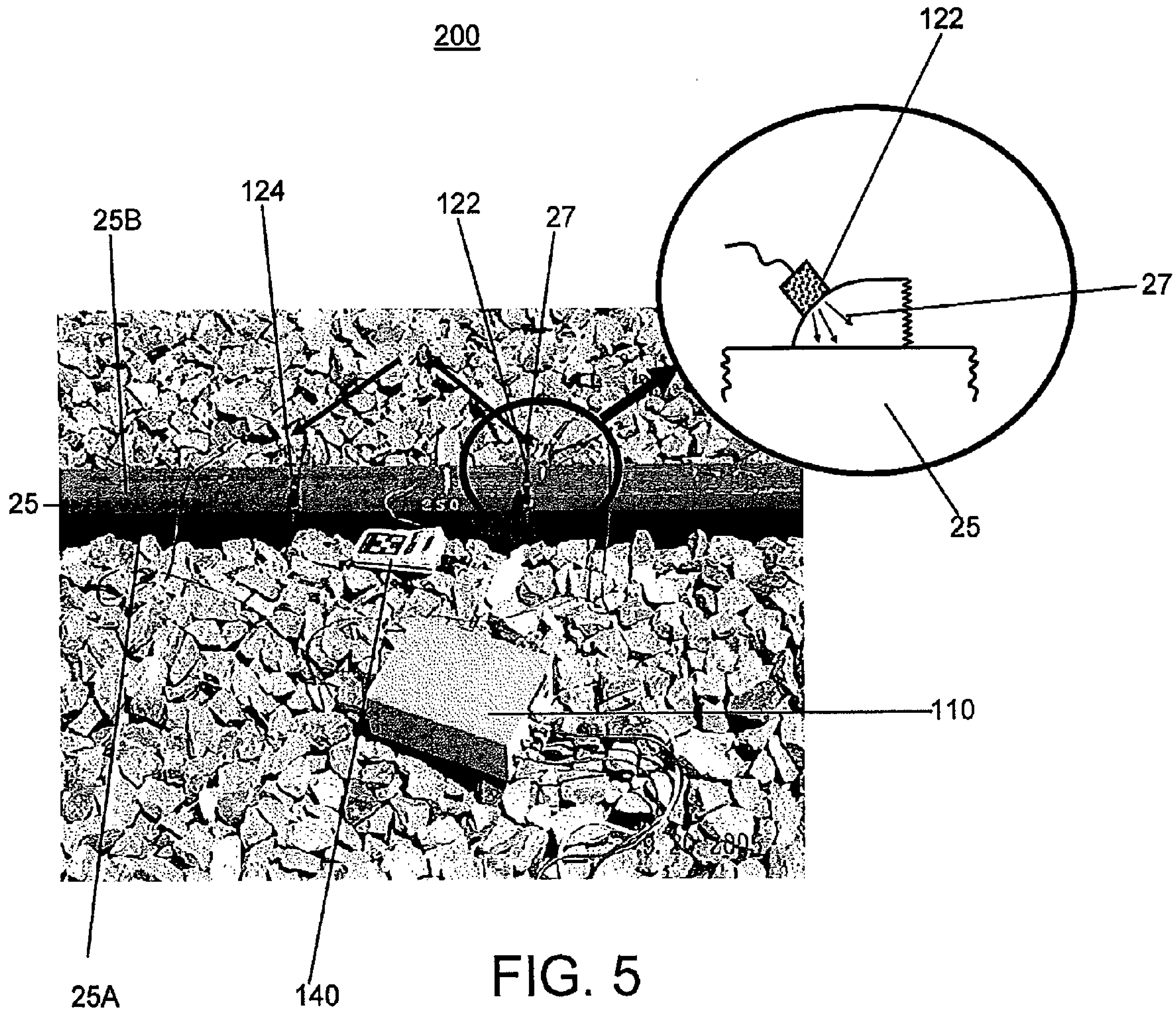


FIG. 5

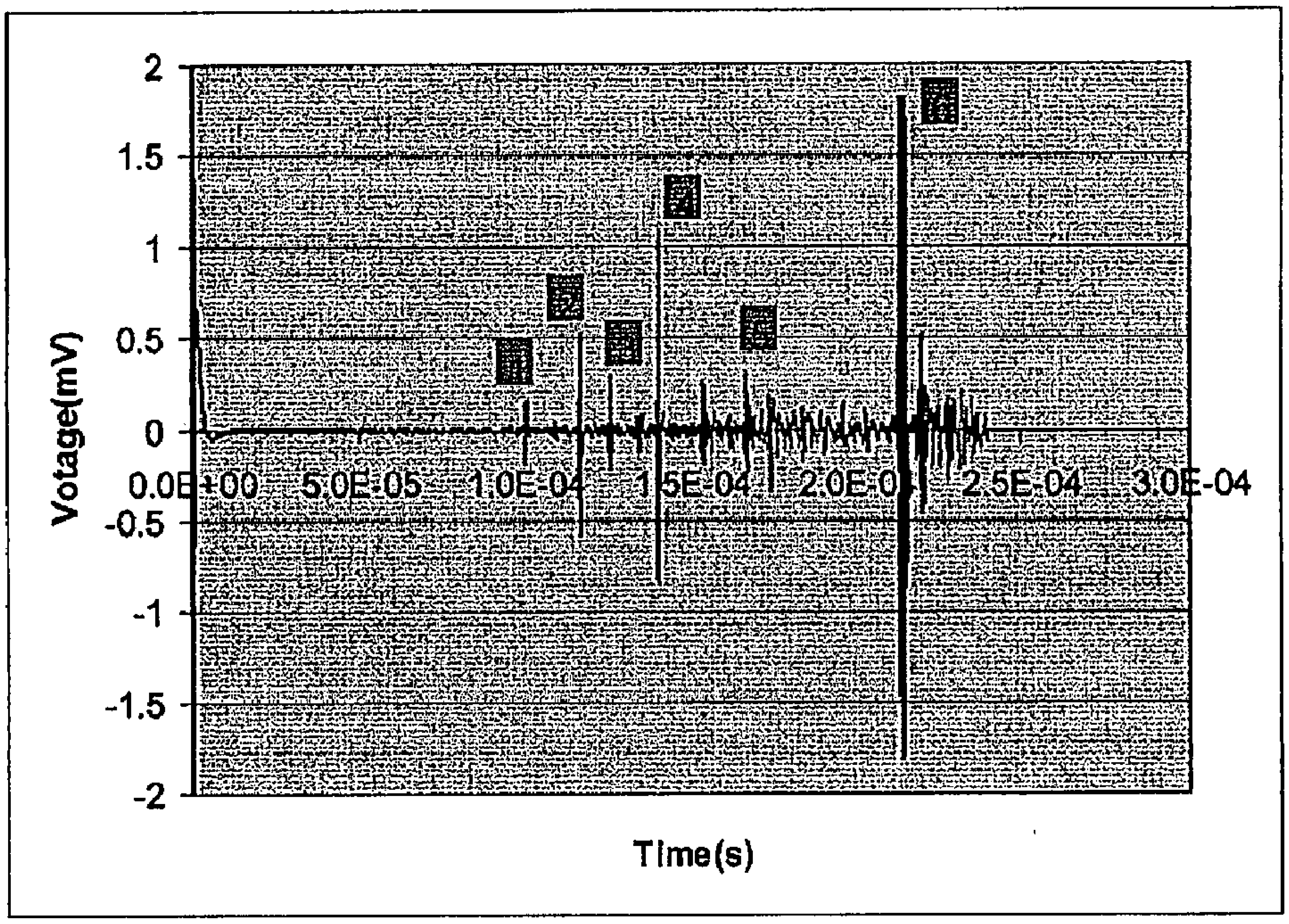

2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Votage(mV)
0.0E+00
5.0E-05
1.0E-04
1.5E-04
2.0E-04
2.5E-04
3.0E-04
Time(s)

FIG. 6

SYSTEM AND METHODS TO DETERMINE AND MONITOR CHANGES IN RAIL CONDITIONS OVER TIME

[0001] This application claims priority of U.S. Provisional Application No. 60/782,608 filed Mar. 15, 2006.

FIELD OF THE INVENTION

[0002] The present invention relates generally to a system and methods with which changes in rail conditions, including conditions related to stress, can be determined and monitored over time. In particular, the present invention relates to a system and methods for measuring rail stress over large regions of rail track to mitigate stress-related issues, such as rail breaks and rail buckling.

BACKGROUND OF THE INVENTION

[0003] Rail tracks are used on railways, otherwise known as railroads, which guide trains without the need for steering. As shown in FIG. **1** rail tracks **20** typically consist of two parallel rails, **22**, **23**. Rails are typically made from steel, which can carry heavier loads than other materials. Rails **22**, **23** are laid upon cross ties **24** that are embedded in ballast **26**. Cross ties **24**, also known as sleepers, ensure the proper distance, or gauge, between the rails **22**, **23**. Cross ties **24** also distribute the load, or force, on the rails **22**, **23** over the ballast **26**. Plates **28** are positioned on top of cross ties **24** to receive rails **22**, **23**. The rails **22**, **23** are then fastened to the cross ties **24** by a fastener **30**, for example with rail spikes, lag screws, bolts or clips. The fastener **30** is driven through the plate **28** and into the cross tie **24**.

[0004] Shown in FIGS. **2** and **3** is a representative rail. Rail **22** consists of rail sections **22'**, **22"** Rail sections **22'**, **22"** can be aligned and secured together by joint bars **32** (FIG. **2**) or welding **34** (FIG. **3**). Most modern railways use welding to align a secure rail sections, known as continuous welded rail ("CWR"), to form one continuous rail that may be several miles long. In this form of track, the rails are welded together such as by thermite reaction or flash butt welding.

[0005] Longitudinal stress is a problem over large regions of rail track. Stress is a measure of force per unit area, typically expressed in pound-force per square inch (psi). The term, longitudinal means "along the major (or long) axis" as opposed to latitudinal which means "along the width", transverse, or across.

[0006] Longitudinal rail stress ("LRS") is usually related to rail contractions and expansions, due to changes in temperature. Longitudinal rail stress leads to failure, which is loss of load-carrying capacity. Examples of failure include, for example, buckling and fracture. Rail experiences tensile stress in cold temperatures, which can lead to fracture or separation of a rail into two or more pieces. In hot temperatures, rail experiences compression stress, which can lead to buckling or warping. Tensile stress is stress state causing expansion (increase in volume) where as compression stress is stress state causing compaction (decrease in volume). It should be noted that a zero stress state is when the material does not experience any stress. Failures, among other things, cause derailments and service disruption.

[0007] The ability to measure longitudinal rail stress is a primary challenge in the railway industry. The presence of large regions of rail track reduces the ability of rail to expand and contract easily due to daily and seasonal temperature changes. Thus, high longitudinal stresses can develop, which in turn leads to possible failure.

[0008] In the United States, from years 2001-2003, there were over 98 derailments associated with track buckling. Damage estimates for these derailments exceed $37 million. In addition, over 900 additional incidents associated with rail stress were reported. LRS is an on-going major difficulty for railroads.

[0009] There has been extensive research to develop a non-destructive method to measure LRS. Current techniques include strain gauges (e.g., available from Salient Systems) and rail uplift (e.g., the VERSE system by Vortok, Inc.). There are downfalls to these current techniques. Strain gauges only provide measurements related to stress in a local, or confined, area. Additionally, strain gauges present difficulty in determining the zero stress state. Measurement by rail uplift is costly and requires a section of rail to be detached from the ties. Techniques such as these are single-point measurements making it difficult to obtain measurements on large regions of rail track.

[0010] There is a demand therefore, for reliable, practical and cost effective system and methods with which changes in rail conditions can be determined and monitored over time, including conditions related to longitudinal rail stress. The present invention satisfies that demand.

SUMMARY OF THE INVENTION

[0011] For purposes of this application, the present invention is discussed in reference to rail tracks on railways, but the present invention is applicable to any structure, including geological structures. For example, the present invention can determine and monitor changes in conditions of buildings, bridges, fault lines for predicting earthquakes and land mass for prospecting oil.

[0012] The present invention is directed to a system and methods with which changes in rail conditions can be determined and monitored over time. In the broadest form, the present invention includes a signal generator device, an energy conversion device, an electronic test device, a database, a computing device, and a navigation device.

[0013] The present invention includes a signal generator device that is useful to non-destructively assess material conditions in rail. One embodiment of a signal generator device is a pulser-receiver. A pulser-receiver includes a pulser that generates electrical signals, and thereby ultrasonic sound waves, and a receiver to receive them. Another signal generator device includes a laser, which generates heat creating an ultrasonic sound wave.

[0014] An energy conversion device converts signals from one form to another. One such type of energy conversion device is a transducer, which includes such types as electromagnetic, electrochemical, electromechanical, electroacoustic, photoelectric, electrostatic, or thermoelectric. Transducers typically communicate from a transducer to a receiving transducer.

[0015] One embodiment of the invention includes a system and methods wherein the energy conversion device is securable to the rail track of a railway.

[0016] Another embodiment of the invention includes a system and methods in which the energy conversion device is securable to the wheels of a railway car to implement a "rolling" system. A "rolling" system allows the present invention to become mobile, thereby allowing rail conditions to be determined and monitored over large regions of rail track. It is further contemplated that a "rolling" system can be integrated with other rail measurement techniques, such as the rail deflection system developed by Shane Farritor, or defect detection vehicles, such as those used by Sperry Rail Service or Herzog Services, for example.

[0017] An electronic test device captures data, such as voltage, current, ultrasonic wave information, temperature, date, time, position, or any measurement to name a few. Such equipment may include a voltmeter, ohmmeter, ammeter, power supply, signal generator, pulse generator, oscilloscope and frequency counter, for example. Ultrasonic wave information can include speed, amplitude, and wavelength

[0018] The present invention also includes a database for the storage of a grouping of data. A grouping of data can include one or more sets of data. One or more sets of data can be compared with one or more sets of data, as well as utilized for various calculations. For example, a first set of data can be compared with a second set of data. Likewise, data can be computed and analyzed, for example to determine the stress state of rail. The database can be retained on the computer used to conduct much of the analyses or on a separate computer or on a computing device.

[0019] A computing device is a machine for manipulating data according to a list of instructions. For example, a computer can be a laptop computer, handheld device, or personal digital assistant.

[0020] A navigation device is a device with position, or location, capability, such as a Global Positioning System ("GPS").

[0021] The improved system and methods of the present invention permit changes in rail conditions, most specifically longitudinal rail stress to be assessed and monitored over time dynamically and non-destructively. One embodiment of the system includes a signal generator device that generates a signal that is transmitted to an energy conversion device. The energy conversion device converts the signal to a sound wave that propagates through the rail to a receiving energy conversion device. The navigation device determines position of the sound wave at specific time intervals. An electronic test device captures this data, and stores the data to a database. The computing device processes the data pertaining to position of the sound wave at specific time intervals to compute wave speed. The wave speed at specific intervals of time as a function of position is also stored in the database for comparison to previous or subsequent data to determine and monitor changes in rail conditions.

[0022] According to the present invention, increasing wave speeds indicates an increase in longitudinal rail stress potentially leading to rail breaks while decreasing wave speeds indicates a decrease in longitudinal rail stress potentially leading to rail buckling.

[0023] The present invention has an objective of providing a system and methods to determine and monitor changes in rail conditions, including conditions related to stress.

[0024] Another object of the present invention is to measure rail stress over large regions of rail track to mitigate stress-related issues, such as fractures and buckling.

[0025] The present invention increases rail track safety by predicting failures before they occur.

[0026] Another object of the present invention is to provide a system and method for rail track maintenance.

[0027] While current technology is focused on single-position measurements; the present invention provides multiple position measurements of stress in rail.

[0028] Another object of the present invention is to provide a database for mass storage of data. The database can be accessed for analysis of the data including various calculations to determine and monitor changes in rail conditions over time.

[0029] Another object of the present invention is to utilize a navigation system to accurately determine position of the failure.

[0030] These and other advantages, as well as the invention itself, will become apparent in the details of construction and operation as more fully described and claimed below. Moreover, it should be appreciated that several aspects of the invention can be used in other applications where monitoring of stress would be desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. **1** illustrates rail tracks;

[0032] FIG. **2** illustrates rail tracks aligned and secured together by joint bars;

[0033] FIG. **3** illustrates rail tracks aligned and secured together by welding;

[0034] FIG. **4** is a flow chart for determining and monitoring stress in rail according to the present invention;

[0035] FIG. **5** illustrates a system for determining and monitoring stress in rail according to the present invention; and

[0036] FIG. **6** illustrates the measurements taken from the system of FIG. **5**.

DETAILED DESCRIPTION OF A PRESENTLY PREFERRED EMBODIMENT

[0037] The present invention will now be described in detail with reference to certain embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention and how it may be applied. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well-known process steps and/or structures have not been described in detail to prevent unnecessarily obscuring the present invention.

[0038] An embodiment of the system and methods of the present invention are illustrated as a flow chart **100** in FIG. **4**. In this embodiment, a pulser-receiver **110** generates an electrical signal that is transmitted **113** to a transducer **122**. The transducer **122** converts the electrical signal to an ultrasonic wave **115** that propagates through the rail to a receiving transducer **124**. Ultrasonic refers to sound with a frequency greater than 20 kilohertz. The GPS **130** determines position of the sound wave **115** at specific time intervals. An oscilloscope **140** captures measurements of data transmitted **117**, such as ultrasonic wave information, temperature, date, time, and position, and provides the data via transmission **119** to the computer **150** for processing. The computer **150** can further include a database **160** for storage of the data.

[0039] In another embodiment, a laser is used to generate a signal by firing the laser at a rail, thereby generating heat and an ultrasonic wave which may be picked up by a receiving transducer **124**.

[0040] The computer **150** includes an autocorrelation component **152** by which the travel time of the ultrasonic wave may be calculated. The travel time is then used to calculate the ultrasonic wave speed, which is then correlated to longitudinal rail stress. If the initial electrical signal generated from the transducer **122** includes a set of voltages V_i at times t_i, then the autocorrelation formula is defined as:

$$r_k = \frac{\sum_{i=1}^{N-k} (V_i - \overline{V})(V_{i+k} - \overline{V})}{\sum_{i=1}^{N} (V_i - \overline{V})^2},$$

where

$$\overline{V} = \frac{1}{N}\sum_{i=1}^{N} V_i.$$

[0041] Maxima in the vector r determines the travel times, otherwise referred to herein as the speed, of the ultrasonic wave. The travel times are dictated by the peak(s) of the ultrasonic wave (see FIG. **6**). These travel times are stored in the database **160** and used for comparison with other measurements (past or subsequent).

[0042] The computer utilizes the autocorrelation formula to calculate the wave speed of the ultrasonic sound wave. The wave speed is calculated by dividing transducer separation distance by the travel time of the sound wave. This wave speed data, along with other data such as temperature, date, time, and position of the sound wave at specific intervals determined by the navigation device, are stored onto a database **160**.

[0043] The data stored within the database **160** includes wave speed at specific intervals of time as a function of position. This data is compared to a grouping of data stored within the database **160** to determine and monitor changes in rail conditions. Changes in wave speed can be attributed to changes in LRS.

[0044] FIG. **5** illustrates an embodiment of a system **200** for determining and monitoring stress in rails according to the present invention. A transducer **122** and receiving transducer **124** are sized and shaped such that each may be positioned on a surface of the rail **25** such as a side surface **25**A, or top surface **25**B of a rail **25** through an applicator **27**. The applicator **27** may be in the form of a wedge **27** or other shape to permit easy adherence to the rail surface **25**A, **25**B. The applicator **27** is preferably formed of a material to facilitate the transmission of the ultrasonic wave by the transducer **122** and the receptor of the ultrasonic wave by the receiving transducer **124**. Acrylic is one of the many materials that may be sued for this purpose. Other embodiments of the system and methods utilize the positioning of the transducers **122**, **124** on the wheels of a railway car.

[0045] An ultrasonic pulser-receiver **110** sends a voltage signal to the transducer **122**. The transducer **122** converts the voltage signal to an ultrasonic sound wave that propagates through the rail **25** to the receiving transducer **124**. The receiving transducer **124** and amplifies and digitizes the sound wave into signals. The signals from the receiving transducer **124** may be acquired such as with an oscilloscope **140**, and conveyed to a database, for example within a laptop or equivalent computer (not shown). The database is used for data analysis of the signals. The computer utilizes an autocorrelation formula to calculate the travel time of the sound wave. The wave speed is then calculated by dividing transducer separation distance by the travel time of the sound wave.

[0046] This wave speed data, along with other data such as temperature, date, time, and position of the sound wave at specific intervals determined by the navigation device, are stored onto a database. Data such as temperature can be taken by the transducers **122**, **124** on the rail **25**. Likewise, the navigation device (not shown) can take the position data where the temperature data is taken.

[0047] The database **160** stores the data, including wave speed at specific intervals of time as a function of position. The database **160** can be on the computer **150** or on a separate computer.

[0048] The computer **150** compares data of the database **160**. A first set of data can be compared to other sets of data. The first set of data can be one data point, a plurality of data points, a base line or control data points. A second set of data points can be one data point or a plurality of data points for comparison with the first set of data points. The comparison between data points determines abnormalities or changes, if any, between the data over time.

[0049] According to the present invention, a first set of data points, such as wave information, is compared to a second set of data points. A comparison resulting in an increase in wave speeds indicates an increase in longitudinal rail stress potentially leading to rail breaks while a comparison resulting in a decrease in wave speeds indicates a decrease in longitudinal rail stress potentially leading to rail buckling.

[0050] Ultrasonic wave speed at specific time intervals as a function of position in graphically illustrated in FIG. **6**.

[0051] While endeavoring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicants claim protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon. While the apparatus and method herein disclosed forms a preferred embodiment of this invention, this invention is not limited to that specific apparatus and method, and changes can be made therein without departing from the scope of this invention, which is defined in the appended claims.

[0052] Therefore, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

We claim:

1. A system for determining and monitoring stress in rail, comprising:

a signal generator device for generating a signal;

a first energy conversion device coupled to said signal generator device, said first energy conversion device in response to said signal generates ultrasonic waves for propagation through the rail;

a second energy conversion device for receiving the ultrasonic waves propagated trough the rail;

a navigation device to determine position information of the ultrasonic waves at specific time intervals;

an electronic test device for capturing data including the position information; and

a computing device for analyzing the data in order to calculate ultrasonic wave information and for comparison to a grouping of ultrasonic wave information to determine the stress in the rail.

2. The system of claim 1 wherein said signal generator device is a pulser-receiver.

3. The system of claim 1, wherein said signal generator device is a laser.

4. The system of claim 1, wherein said first energy conversion device is a transducer.

5. The system of claim 1, wherein said second energy conversion device is a receiving transducer.

6. The system of claim 1, wherein said navigation device is a Global Positioning System.

7. The system of claim 1, wherein said electronic test device is an oscilloscope.

8. The system of claim 1, wherein said computer device is a laptop computer.

9. A method for determining and monitoring stress in rail, comprising:

generating a signal;

converting the signal to an ultrasonic sound wave;

propagating the ultrasonic sound wave through the rail;

receiving the ultrasonic sound wave;

resolving position information at specific time intervals of the ultrasonic sound wave;

capturing data including the position information at specific time intervals;

storing the data in a database;

computing the data to produce wave speed data;

comparing the wave speed data to a grouping of wave speed data; and

detecting longitudinal rail stress.

10. The method of claim 9, wherein said generating step includes producing the signal with a signal generator device.

11. The method of claim 9, wherein said converting step includes producing the ultrasonic sound wave with a first energy conversion device.

12. The method of claim 9, wherein said receiving step includes configuring the ultrasonic sound wave with a second energy conversion device.

13. The method of claim 9, wherein said resolving step includes determining the position information with the use of a navigation device.

14. The method of claim 9, wherein said capturing step uses an electronic test device.

15. The method of claim 9, wherein said computing step uses a handheld device.

16. The method of claim 9, wherein said comparing step includes an increase in value of the wave speed data indicating an increase in longitudinal rail stress.

17. The method of claim 9, wherein said comparing step includes a decrease in value of the wave speed data indicating a decrease in longitudinal rail stress.

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