Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2366030 A1 2003/06/20

(21) 2 366 030

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(22) Date de dépôt/Filing Date: 2001/12/20

(41) Mise à la disp. pub./Open to Public Insp.: 2003/06/20

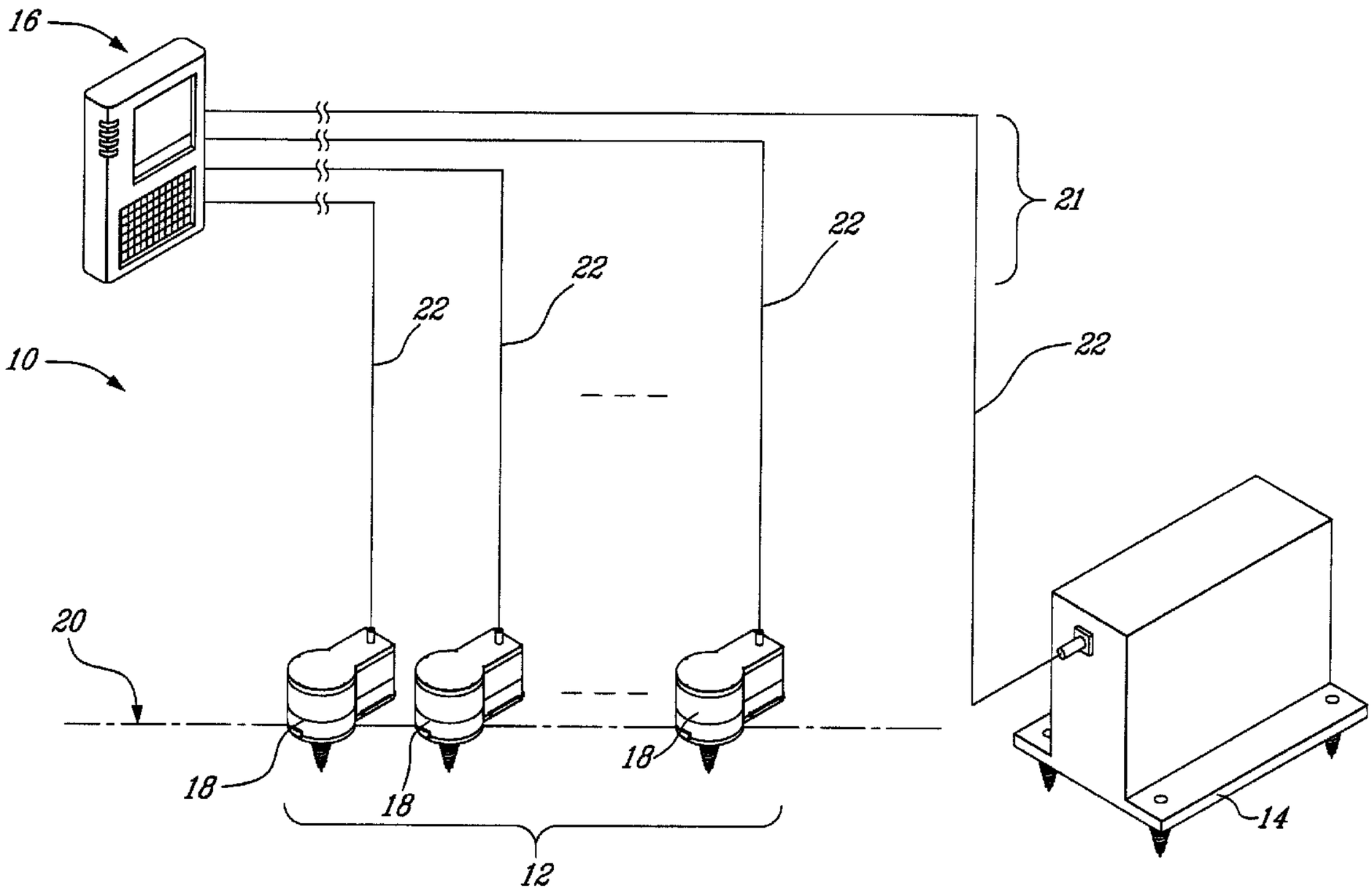
(51) Cl.Int.^{7}/Int.Cl.^{7} G01B 7/00, G01V 3/00, G01N 27/00, G06F 17/00

(71) Demandeur/Applicant:
GLOBAL E-BANG INC., CA

(72) Inventeur/Inventor:
RIOUX, DANIEL, CA

(74) Agent: GOUDREAU GAGE DUBUC

(54) Titre : SYSTEME DE PROFILAGE
(54) Title: PROFILING SYSTEM



(57) Abrégé/Abstract:
An all-inclusive system for the non-intrusive physical analysis of a medium under a surface, and a display of the results thereof is described herein. The system detects the velocity of shear waves, analyses them and displays the results. The system comprises three units: a sensing assembly, an energy impulse generator and a user-computing interface.

ABSTRACT OF THE DISCLOSURE

An all-inclusive system for the non-intrusive physical analysis of a medium under a surface, and a display of the results thereof is described herein. The system detects the velocity of shear waves, analyses them and displays the results. The system comprises three units: a sensing assembly, an energy impulse generator and a user-computing interface.

TITLE OF THE INVENTION

Profiling system

FIELD OF THE INVENTION

[0001] The present invention relates to the field of non-intrusive testing of a medium located under a surface. More specifically, the present invention is concerned with an intelligent profiling system permitting the mechanical characterization of a medium under a surface.

BACKGROUND OF THE INVENTION

[0002] In the field of geophysical exploration for example, non-intrusive techniques have been sought and developed as a supplement or an alternative to conventional in-situ testing techniques involving borings because these techniques are non-destructive. In some cases where boring is not feasible, for example in granular soils, such non-intrusive techniques are the only way to explore the underground. Also, they generally are more cost-effective.

[0003] Non-intrusive techniques are also used for exploring a medium situated under a surface in various other fields, for example, for assessing the wear conditions of roads, of bridges, of bar joints in buildings, of concrete walls, etc...., or for detecting subsurface pockets in mining or military applications.

[0004] Interestingly, surface waves, and especially Rayleigh waves, are very useful in the field of non-intrusive testing. One of the well known method in the art is Spectral Analysis of Surface Wave ("SASW"), for instance,

which makes use of surface waves for determining shear velocity profiles of the underground without intrusion. This method involves a pair of sensors, at least one source of impulses, and a signal processing system.

[0005] Although such a technique using surface waves permits to explore a broad range of thickness of soils, by changing the distance between the two sensors and by using different sources of impulses, in the case of SASW discussed hereinabove for instance, its operation generally requires actions from a highly skilled worker expert in the field in order to obtain useful information on the subsurface medium under investigation.

[0006] Therefore, in spite of the efforts in the field, there is still a need for a system allowing profiling of a medium under a surface, comprising sensors, a generator of impulses and a user-computing interface, and permitting collecting, analyzing, and processing the data for display and use by a non-expert.

OBJECTS OF THE INVENTION

[0007] An object of the present invention is therefore to provide an improved profiling system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] In the appended drawings:

[0009] Figure 1 is a schematic representation of a profiling system according to an embodiment of the present invention;

[0010] Figure 2 is a perspective view of a displacement sensor used in the profiling system of Figure 1;

[0011] Figure 3 is a top plan view of the displacement sensor of Figure 2;

[0012] Figure 4 is a sectional view taken along the line 4-4 of Figure 3;

[0013] Figure 5 is a top view of the substrate of the displacement sensor of Figure 2;

[0014] Figure 6 is a diagram of a circuit equivalent to the displacement sensor of Figure 5; and

[0015] Figure 7 is a schematic sectional view of an energy impulsion generator used in the profiling system of Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] Generally stated, the system of the present invention enables a non-intrusive physical analysis of mechanical characteristics of a medium located under a surface, and a display of the results thereof.

[0017] Such a medium separated from direct exploration by a surface can be the underground, the thickness of a concrete wall, the thickness of a joint bar and the like. For illustration purposes, the present invention will be described using an embodiment dealing with geophysical testing. Therefore, in

the following, the medium to be studied is a subsurface region of the underground, through the surface thereof.

[0018] More precisely, the system of the present invention makes use of sensors that detect the velocity of shear waves induced in the subsurface region under test by means of an excitation generated by a generator of impulses.

[0019] Turning now to Figure 1 of the appended drawings, the system according to an embodiment of the present invention will be described.

[0020] Basically speaking, the system 10 comprises three units: a sensing assembly 12; an energy impulse generator 14, (referred to in the following as EIG); and a user-computing interface 16, (referred to in the following as UCI).

[0021] As can be seen in Figure 1, the sensing assembly 12 comprises displacement sensors 18 placed at various locations on a surface 20. The sensing assembly 12 may comprise a number of sensors 18 comprised between one sensor 18, which is located successively at various locations, and a plurality of sensors 18. In a specific embodiment of a system 10 according to the present invention, the sensing assembly 12 comprises four sensors 18. The role of the sensors 18 is to detect a movement in response to bursts of impacts generated by the energy impulse generator 14 on the surface 20.

[0022] Each one of the displacement sensors 18 of the sensing assembly 12, and the energy impulse generator 14, are connected to the user-computing interface 16 by means of an interface of communication 21. Many different techniques may be used to interconnect the sensors 18 to the user-

computing interface 16. For example, the interface of communication 21 may include fiber optics cables, coaxial cables, multi-conductor cables, an optical link, a RF link, shown in Figure 1 under label 22. Alternatively, multiplexing means may be considered for the interface of communication 21.

[0023] As displayed in Figures 2 to 4, the sensor 18 is protected within a casing 24 closed by a top cover 25. Provided the surface 20 is not too hard, the displacement sensor 18 is attached to the surface 20 by means of a thread attachment 26 mounted on a plate 27 on which the casing 24 can be inserted and secured by edges 28 of the plate 27 (see Figure 2a). Alternatively, in the case where the surface 20 is too hard, the plate 27 can be fixed thereto by means of an adhesive 29 (see Figure 2b), or even simply deposited on the surface 20.

[0024] The casing 24 is provided with a communication connector 30 (see Figure 3) for connection to the user-computing interface 16 by means of a connection 22 of the interface of communication 21 (see Figure 1).

[0025] It is to be noted that the top cover 25 also supports a shock absorbing element 32 and a damping element 34, which are symmetrically located relative to a shock absorbing element 32' and a damping element 34' attached to the casing 24, and may support an optional communication antenna 36 or an optical diffuser (not shown).

[0026] A semiconductor substrate 42 is protected within the casing 24, as shown in the cross section of Figure 4. A mass 38 is supported within an opening 40 of the semiconductor substrate 42 supporting strain gauges 44 and resistors 46 and 48 (shown in Figure 5). The mass 38 is allowed to move in response to acceleration. As will easily be understood by one skilled in the art,

movements of the mass 38 induced by shear waves generated in the subsurface region under surface 20 cause strains on the semiconductor substrate 42.

[0027] As shown in Figure 6, the circuit equivalent to the displacement sensor 18 comprises four strain gauges 44 and two resistors 46 forming a Wheatstone bridge. One diagonal of the bridge is connected to a DC voltage source 50, while the other diagonal of the bridge serves as an output of the strain sensitive circuit and is connected to an amplification unit 52. As will be explained hereinbelow, the strain gauges 44 are used as transducers for transforming a mechanical deformation on the semiconductor substrate 42 into an electric signal. The resistor 48 is used for calibration purposes, as will be described hereinbelow.

[0028] The strain gauges 44 are used to record the movement of the subsurface region under test, transmitted to the displacement sensor 18 by the mass 38. They are temperature-compensated by means of the matched resistors 46. It is to be noted that the high symmetry of the sensing circuit of Figure 5 also contributes to the temperature compensation by allowing balancing of the Wheatstone bridge over a range of temperature.

[0029] The strain gauges 44 can be glued on top of the semiconductor substrate 42, or directly etched thereto. The direct etching of the semiconductor substrate 42, by techniques known in the art using X-rays or photons for instance, ensures a perfect location of the strain gauges 44 together with a minimized temperature mismatch, therefore a minimized stress concentration, thus enabling the manufacture of a highly sensitive displacement sensor 18.

[0030] The displacement sensor 18 further comprises an interface board 53, shown in Figure 4, which supports the required communication circuitry attached to the communication connector 30. As seen in Figure 6, it may further include an analog to digital converter 47, a transmitting circuit 49 and a control circuit 57. The control circuit 57 is used for power management, to adjust the level of amplification of the amplification unit 52 and its offset, during calibration to a prefixed value. Frequency filtering means (not shown) may be added. The control circuit 57 also allows setting the dynamic range of the analog to digital converter 47.

[0031] Of course, the type of circuitry depends in part on the type of communication 22 of the interface of communication 21 between the displacement sensors 18 and the user-computing interface 16.

[0032] The displacement sensor 18 can either be externally powered or internally powered by means of an integrated power source 54 such as batteries located underneath the semiconductor substrate 42 (see Figure 4). Such batteries can be located inside the casing wherever convenient, or even in an extra casing outside the casing 24.

[0033] As explained hereinabove in relation to Figures 2a and 2b, each displacement sensor 18 may be simply deposited on the surface 20, or secured thereto by means of an adhesive 29 (figure 2b), or fastened thereto by means of a thread attachment 26 (figure 2a).

[0034] The damping element 34 attached to the top cover 25, and the corresponding damping element 34' attached to the casing 24, are made of a gel material. By ensuring a constant absorption of energy over a range of temperature, and provided they are made of a material having resistance to

fatigue such as neoprene or silicone for example, they optimize the damping factor and contribute in maximizing the quality of the signal.

[0035] Indeed, the performance of the displacement sensor 18, as assessed in terms of amplitude and phase distortion, depends primarily on the magnification factor and the damping factor of the device. In order to minimize the amplitude and phase distortion of the sensor 18 over a range of performance thereof, the magnification factor is advantageously as close as possible to unity (1), so that the natural frequency of the sensor 18 be as high as possible and the damping factor be optimized.

[0036] The shock absorbing pads 32 and 32' are efficient in protecting the displacement sensor 18 from excessive shock, for example during handling.

[0037] Thermoplastic or rubber joints 55 are provided between the cover 25 and the casing 24 for sealing the displacement sensor 18 and protection against adverse environment (see Figure 4).

[0038] It is to be pointed out that the fact that the displacement sensor 18 of the present invention comprises a semiconductor substrate 42 that has integrated strain gauges 44, amplification means 52 and regulation circuitry 57, permits reducing the noise to signal ratio and therefore the contamination of the signal during transmission to the UIC 16. The possibility for the displacement sensor 18 to include an analog to digital inverter 47 in case one such item is needed also contributes to the reduction of the noise to signal ratio during transmission.

[0039] Furthermore, people in the art will be aware that the use of semiconductor strain gauges 44 enables achieving a gain superior to that obtained by using conventional foil strain gauges.

[0040] It is also to be underlined that the use of a mass 38 contributes to increase the responsiveness, and therefore, the measurement capability, of the strain gauges assembly. The mass 38 is clamped by means of polymer clamps above the opening 40 of the semiconductor substrate 42 between the top cover 25 and the casing 24, so as to achieve enhanced stiffness of the substrate 42 and increase the natural frequency of the structure so as to reduce the amplitude and phase distortion.

[0041] As is generally known in the art, the displacement sensor 18 according to the present disclosure operates as follows: when power is fed to the circuit in absence of acceleration, the substrate 42 is not strained and the resistance of the strain gauges 44 is maintained at its original level so that the output signal of the circuit is zero. As an acceleration occurs, an external force is applied on the mass 38, which causes deformation of the substrate 42 resulting in a change of the electric resistance values of the resistance elements since the substrate 42 bends and deforms the gauges 44. This deformation changes the nominal resistance of the gauges 44, causing the equilibrium conditions of the Wheatstone bridge to be broken, giving rise to a voltage output of the circuit. One skilled in the art will understand that an of this output voltage enables to obtain the characteristics of the subsurface region under test.

[0042] Turning to Figure 7 of the appended drawings, the energy pulse generator 14 will now be described.

[0043] The energy pulse generator 14 comprises a spring 60 that is set into compression by a motor assembly 62 so as to store energy and to pull on an impact head 64 through a latch 66. The impact head 64 is released by activating a solenoid 68 that pulls the latch 66, thus unlocking the impact head 64, allowing the extension of the spring 60.

[0044] Obviously, the power source for the spring 60, here exemplified as the motor assembly 62, could be a pneumatic, a hydraulic or a mechanical source.

[0045] The spring 60 is used against the inertia of the impact head 64 and gives impulsion at the time of an impact, and also as a means for holding back the impact head 64 so as to prevent it from bouncing back after an impact.

[0046] A strain gauge circuitry 63, located on the latch 66 for example, is used to monitor the energy, which is stored into the spring 60, by comparing it with the energy command transmitted by the UCI 16 to the EIG 14 control circuit.

[0047] A damper 72 is provided to absorb the shock produced on the assembly, while the energy pulse generator 14 thus transmits a burst of energy by the impact of the impact head 64 on an element to be analyzed.

[0048] A control circuit (not shown) permits to monitor the amount of energy release and the overall operation of the EIG 14.

[0049] A power pack 65 is provided for holding a battery. It also adds weight to the overall structure of the EIG 14.

[0050] The EIG 14 is fastened to the surface 20 using threaded attachment 26 or other attachment essentially similar to those used for the displacement sensor 18 and described hereinabove.

[0051] The energy for activating the above described process of impact generation is released by means of a command issued from the user computing interface 16 (UCI) and transmitted to the EIG 14 through a cable, an optical signal or a radio frequency signal. This command triggers the loading and unloading of the mechanism and thus the delivery of an energy pulse by the EIG 14.

[0052] The user-computing interface (UCI) 16, exemplified in Figure 1, comprises a number of subsystems: a user interface system, comprising a keyboard, power and function keys, a display screen and/or a touch screen; an equipment interface, which allows connection to other output devices such as printers (not shown); an interface system with the IEG; a signal collecting system for collecting data from the displacement sensors 18 of the sensing assembly 12; a processing system, which performs the computations and manages the various interfaces together; and a computer interface system that permits connection to other computers.

[0053] Of course, the UCI 16 stores a program or algorithm that, for example, can control the energy impulse generator 14 and the displacement sensors 18, and collects and stores data from the displacement sensors 18 of the sensing assembly 12. Furthermore, this program may analyze the

collected data to calculate some underground properties or features and display them.

[0054] It is to be noticed that each one of the different assemblies can operate in an autonomous fashion, or powered by a central unit.

[0055] Most interestingly, provided the program and software stored in the UCI 16 is adequate, the system of the present invention can be used in a variety of applications.

[0056] For example, in the field of geotechnical testing, the system of the present invention can be used to detect pockets or faults in the underground, in the mining industry. As a further example, in the military field, the system of the present invention can be used in order to study the geological structure of a terrain for the purpose of effective explosive positioning or hideouts uncovering. The present system could be used to supply data to systems such as the so-called JTIDS ("Joint Tactical Information Distribution System").

[0057] Additionally, people in the art will foresee the possibility of adding GPS systems to locate each displacement sensor 18 of the sensing assembly 12, and the EIG 14. One possible application is related to the identification of an underground cavity and the determination of its spatial coordinates. An algorithm can be introduced into the UCI 16 that maps, through the use of a global positioning system (GPS), volumes that can be used for underground concealed hideouts, facilities, etc. In military applications in particular, such an algorithm may also enable to detect any structural fault so as to allow planning accordingly strategic delivery of payload in order to maximize the damage to cavities or underground-concealed areas.

[0058] Another field of possible applications where the system 10 of the present invention can be used, providing the adequate algorithm is included into the UCI 16, is the communication field, taking advantage of the property of low frequency shear waves to propagate over long distances or great depths. Such a specific user-computing interface 16 may perform unidirectional or bi-directional communication, detect, identify and locate movements on the ground surface. In this kind of application, the system 10 uses as a transmitter an electromechanical device that induces energy at various frequencies in the ground, resulting in ground waves. As low frequency shear waves propagate deep into the ground and over long distances, while high frequency waves can travel only short distances, a communication signal consists of an energy signature modulated in frequency and relative amplitude that initiates, delivers, and ends a predetermined communication protocol. Due to various reflections caused by the complex geophysical environment, the transmitted signal is scrambled in time and frequency domain during its way therethrough. The sensing assembly 12, used at the receiving end, in conjunction with the UCI 16, unscrambled this signal so as to reconstruct the frequency domain and its variation over time. The high frequency content thereof is used as a mean to securely position the source of the signal.

[0059] Additionally, the distribution of displacement sensors 18 enables position triangulation of an emitter or of any signal sources generated by troops, moving vehicles or impacts on the ground. Reconstructing incoming signals, the UCI 16 may process pattern recognition database to match signatures and identify an emitting source.

[0060] Although the present invention has been described hereinabove by way of preferred embodiments thereof, it can be modified,

without departing from the spirit and nature of the subject invention as defined in the appended claims.

WHAT IS CLAIMED IS:

1. A profiling system comprising displacement sensors, a pulse generator and a user-computing interface, wherein said profiling system enables collecting, processing, analyzing and displaying data in an integrated fashion for used by an unskilled worker.

2. A displacement sensor comprising semiconductor strain gauges directly etched on a semiconductor substrate, with integrated amplification means and numerical conversion, and possibility of transmission by means of one transmission line (bidirectional communication).

3. An energy impulse generator, wherein said energy impulse generator delivers a pre-set amount of energy.

4. A user-computing interface said user-computing interface permitting a 2D or a 3D-representation display of analyzed data.

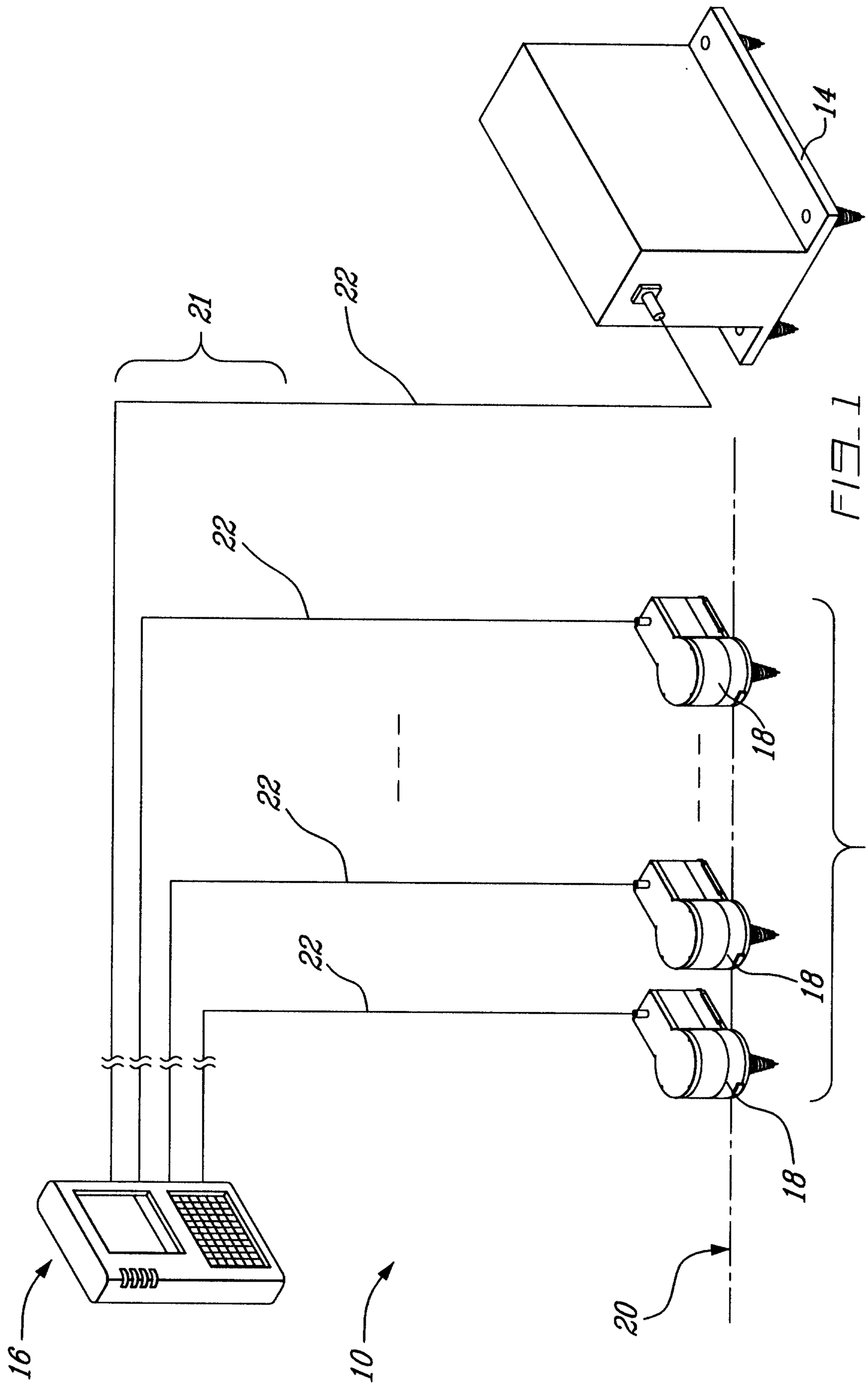


FIG. 1

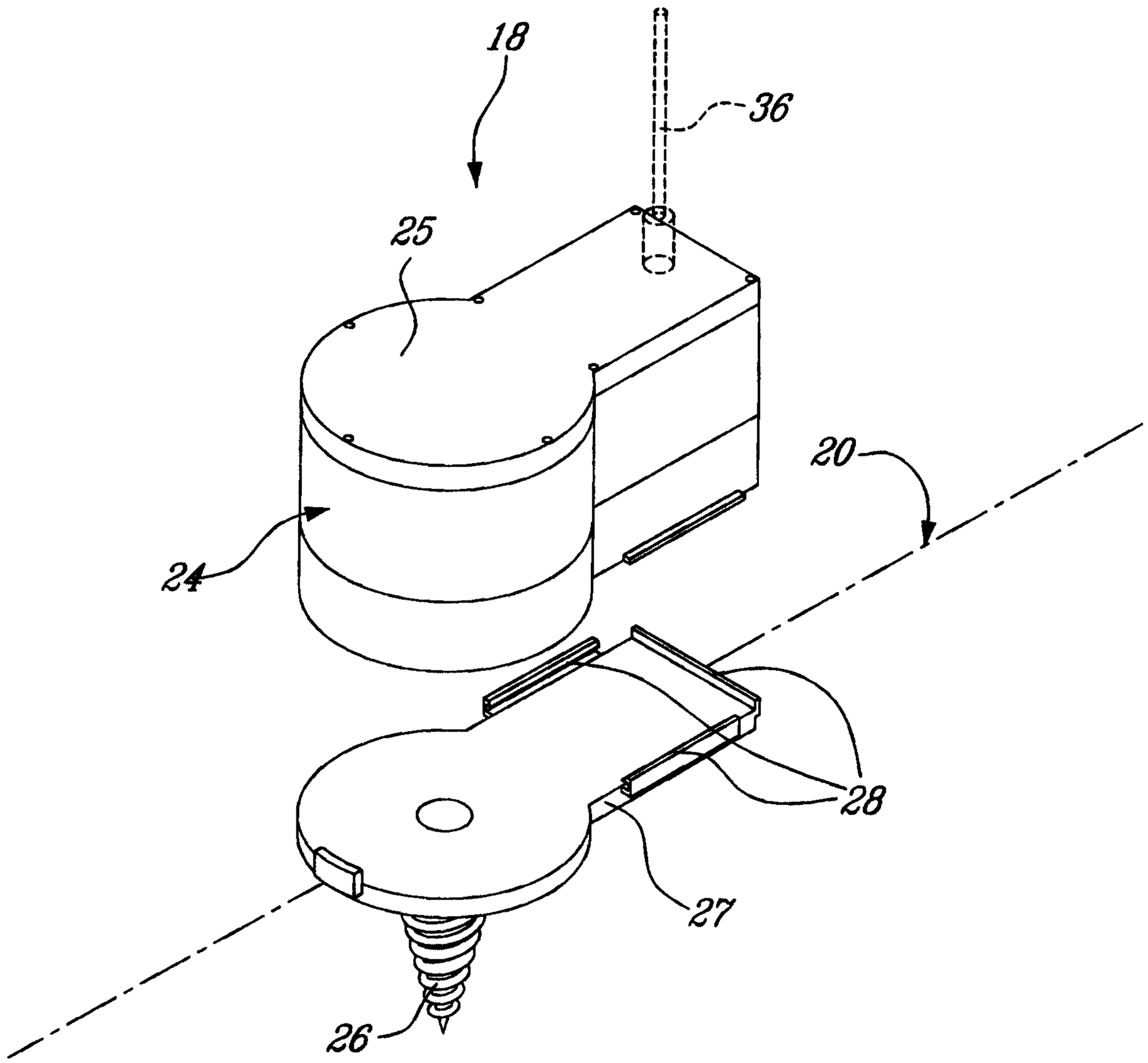


FIG_2A

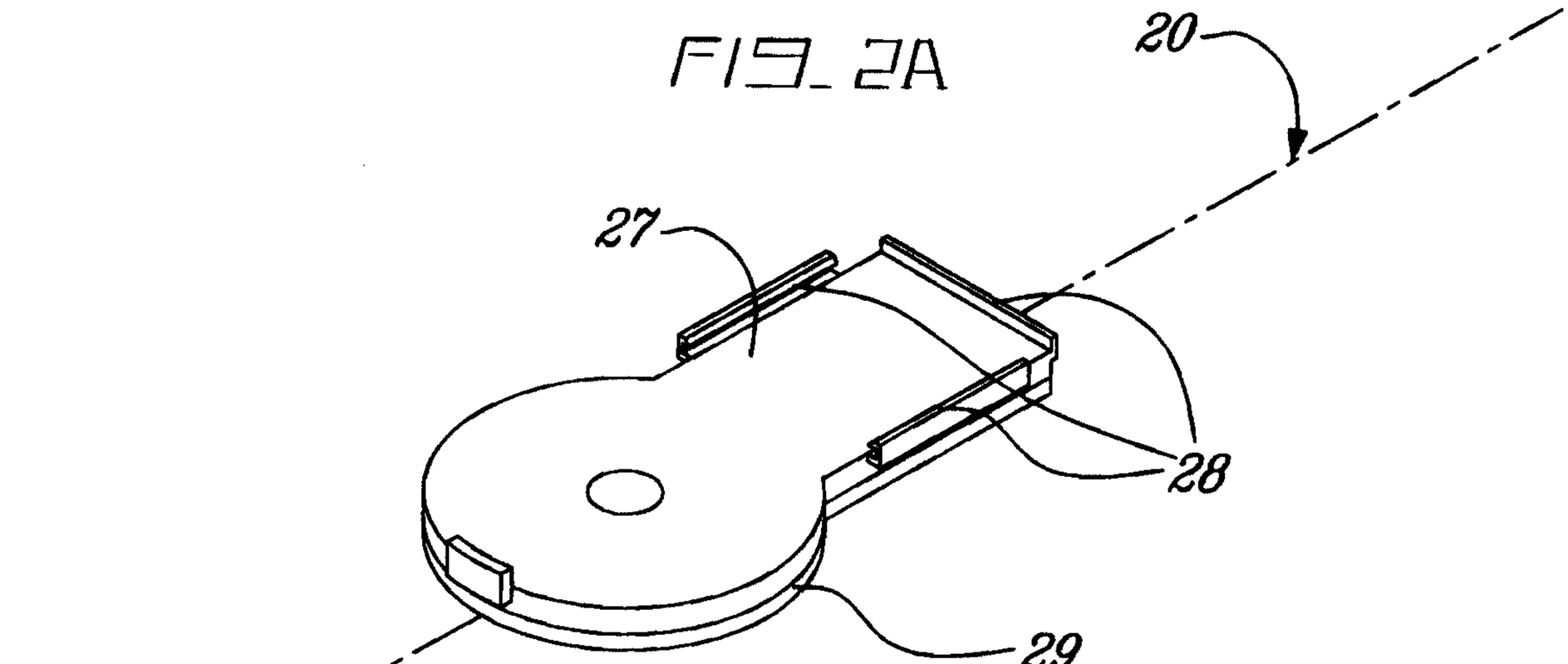


FIG_2B

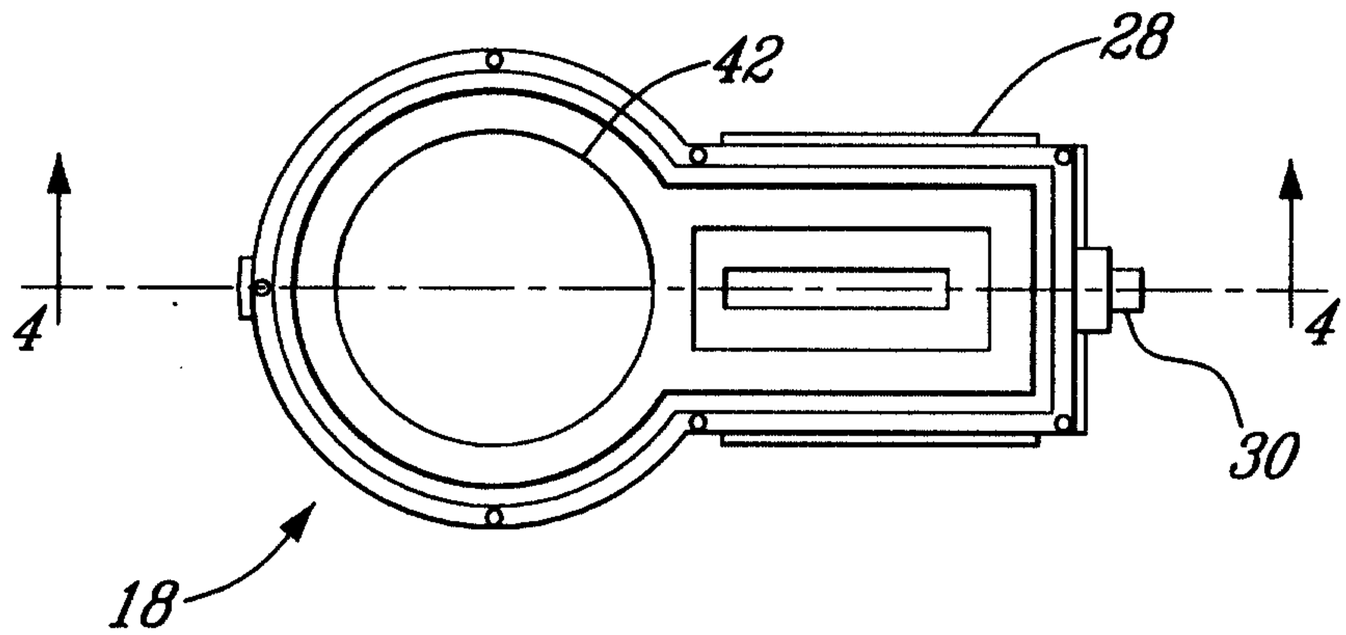

42
28
4
4
30
18

FIG_3

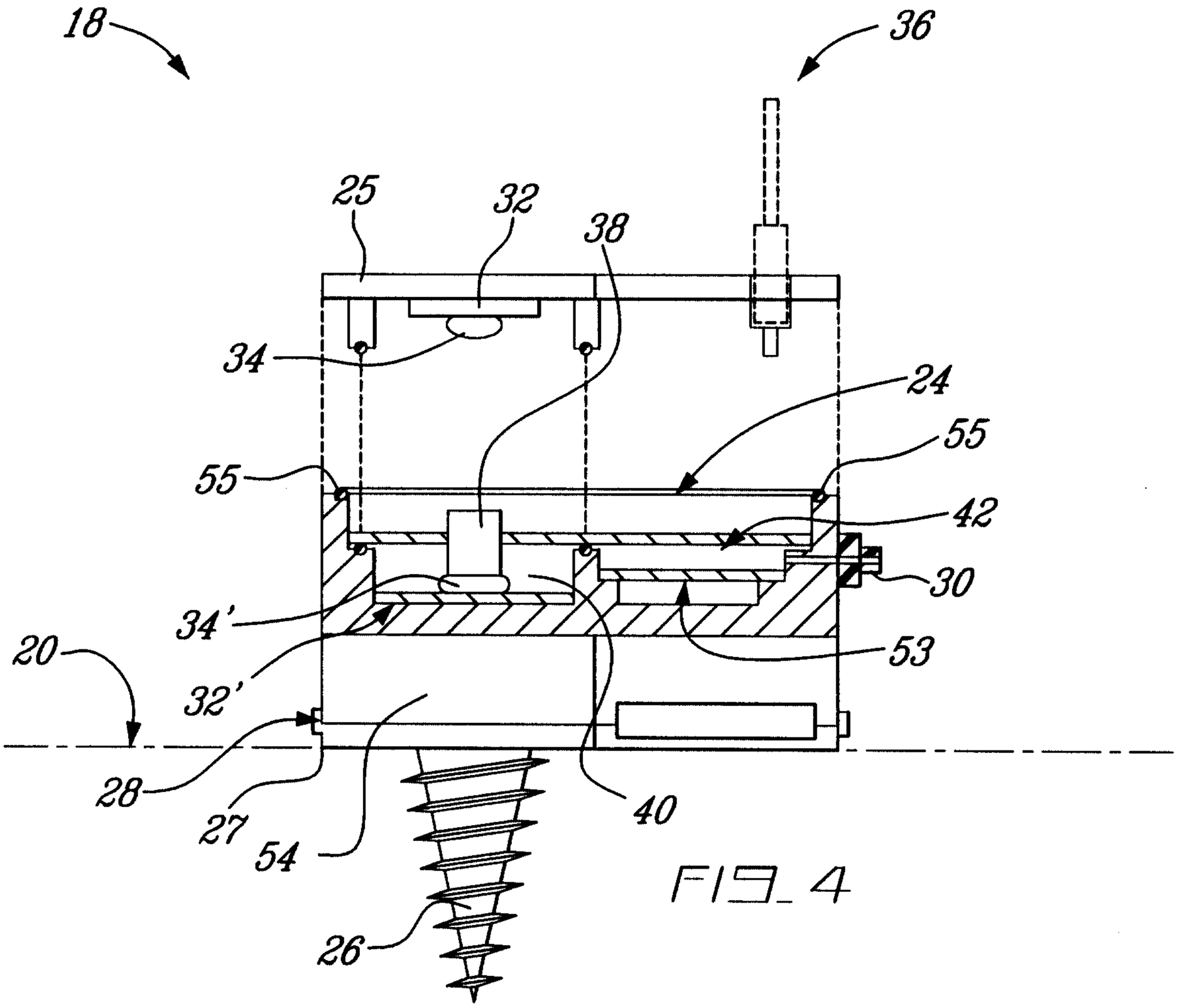

18
36
25
32
38
34
24
55
55
42
30
34'
20
53
32'
28
27
54
40
26

FIG_4

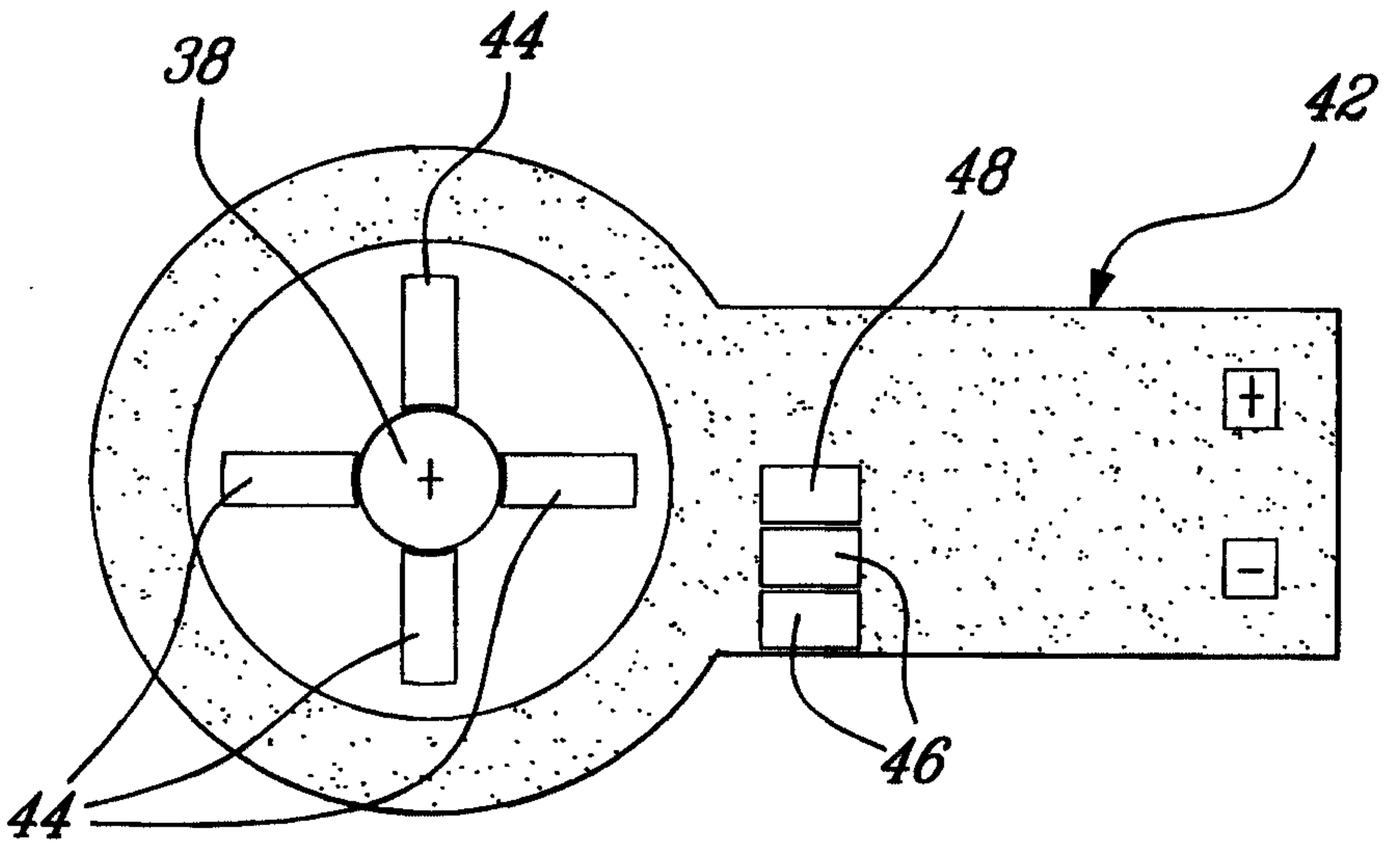

38
44
42
48
+
-
44
46

FIG_5

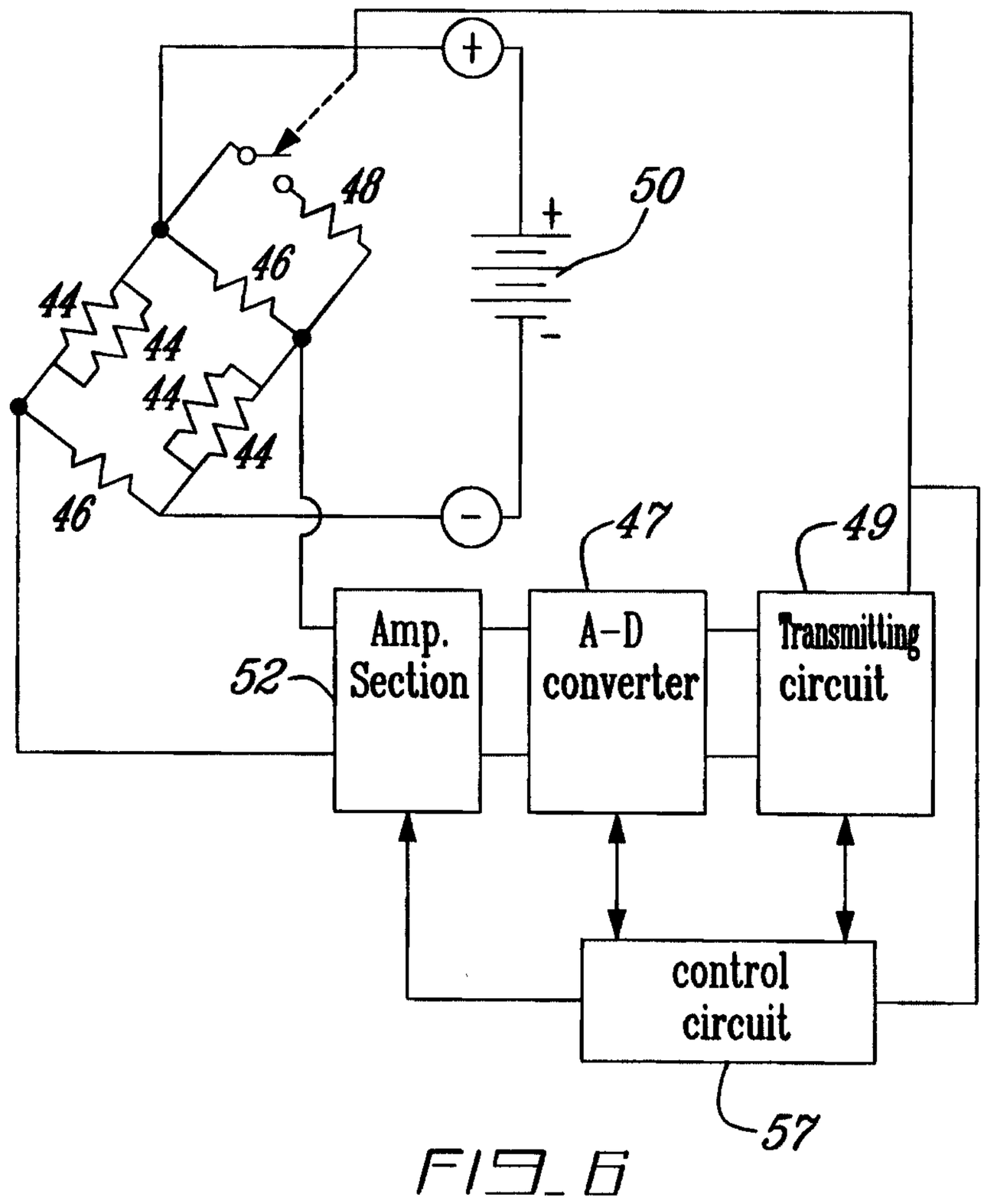

+
48
50
+
46
44
44
44
44
-
46
47
49
52
Amp.
Section
A-D
converter
Transmitting
circuit
control
circuit
57

FIG_6

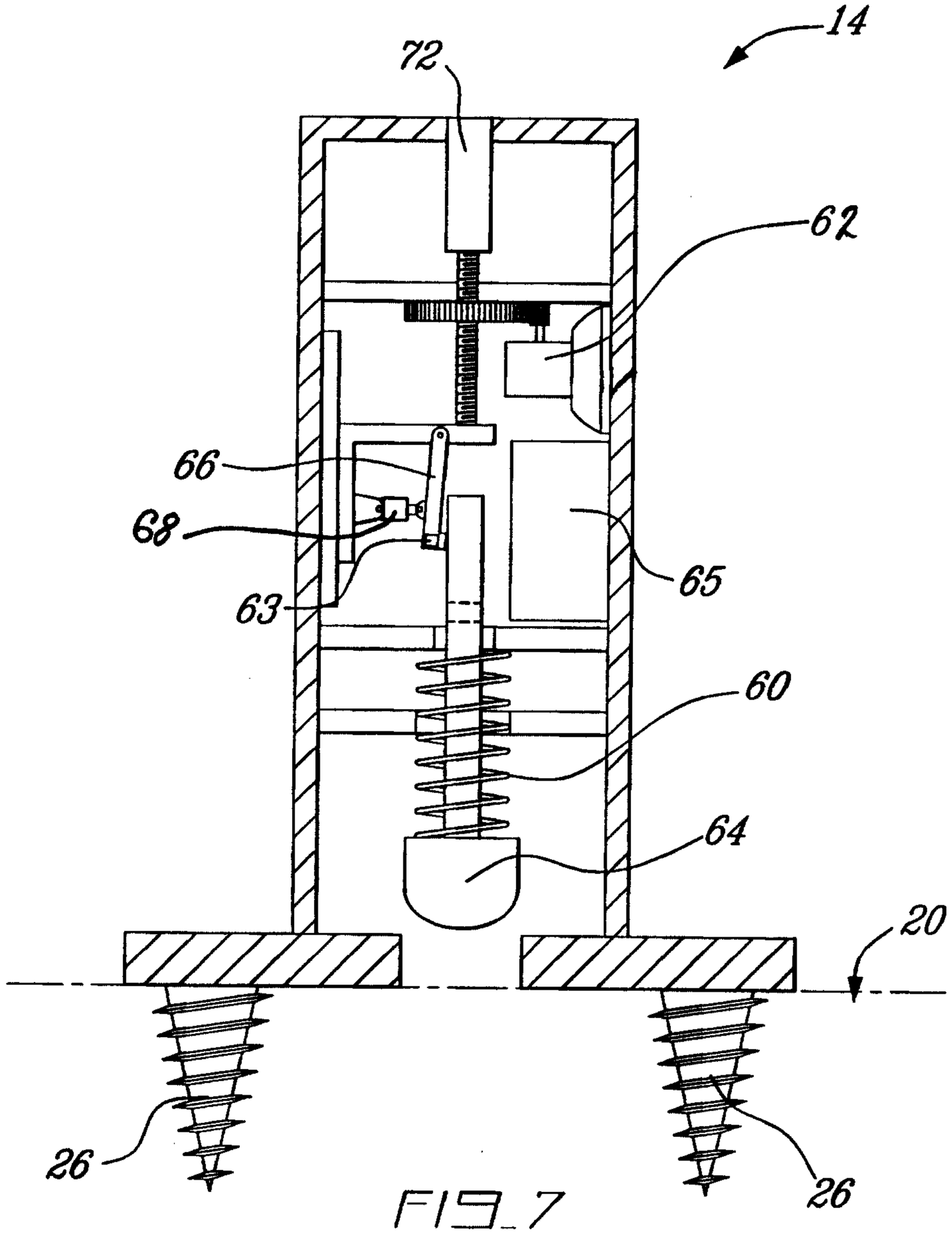
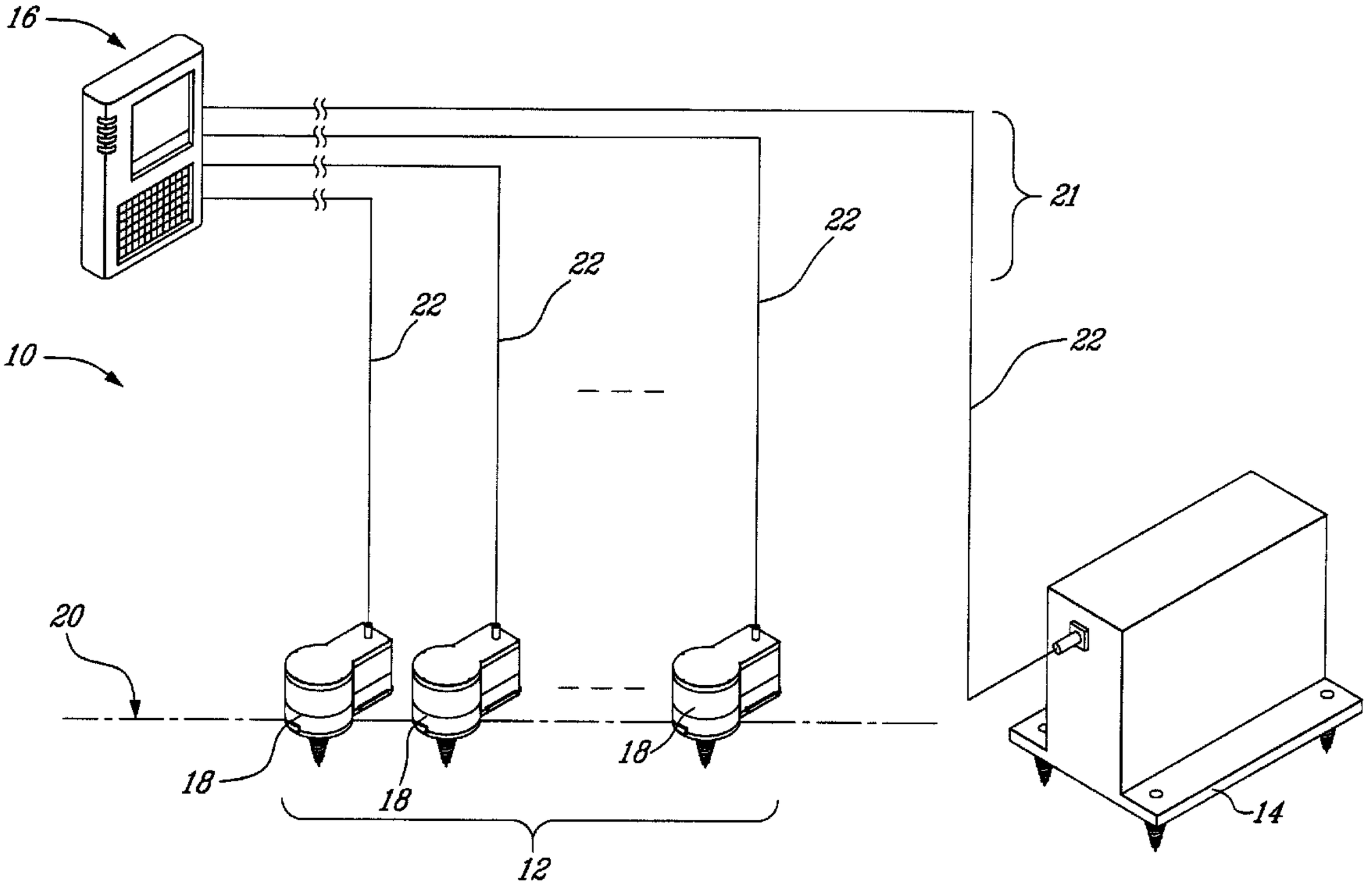


FIG. 7


16
10
22
22
22
22
21
20
18
18
18
12
14