

Jan. 28, 1947.

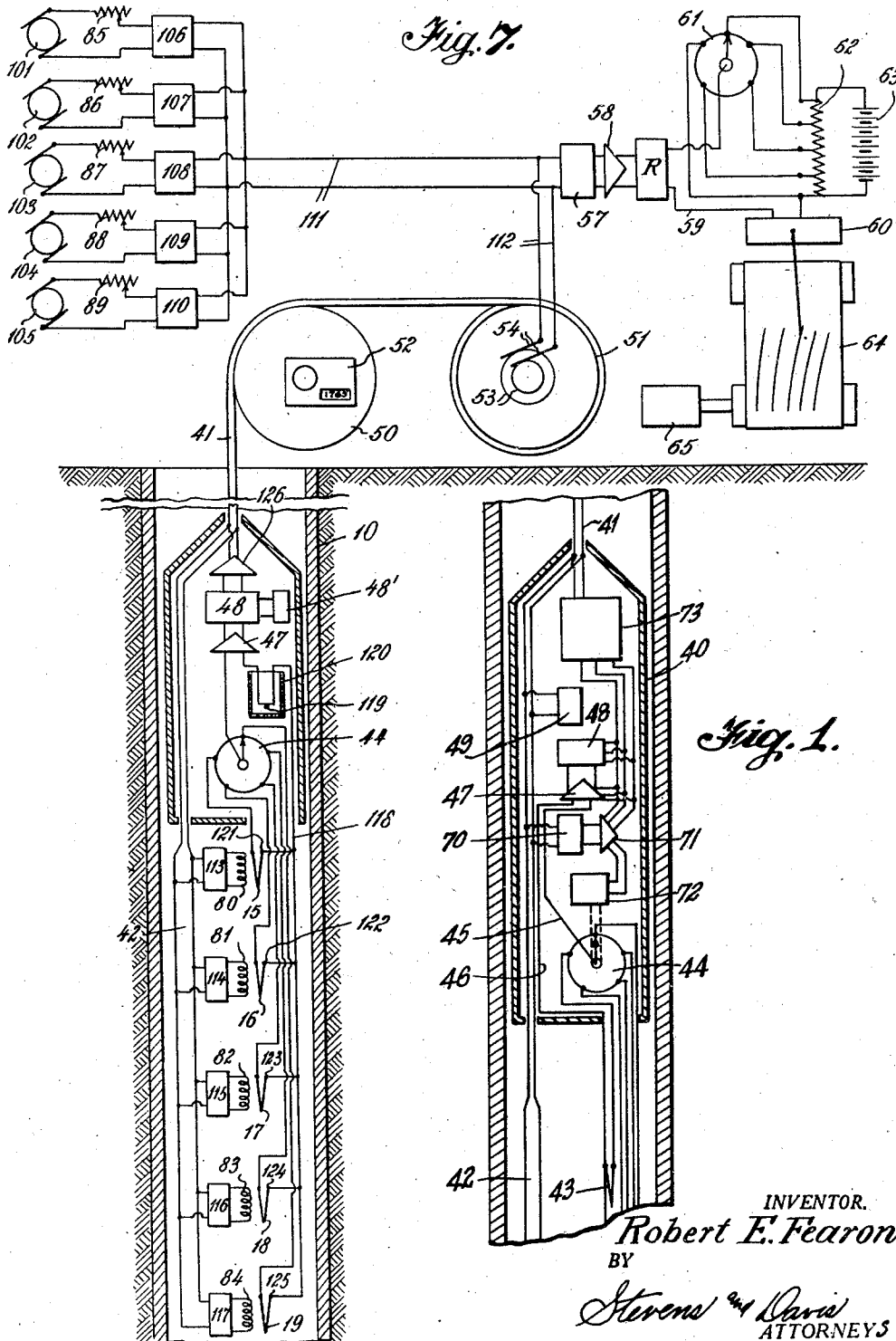
R. E. FEARON

2,414,862

WELL SURVEYING APPARATUS

Filed Aug. 15, 1940

4 Sheets-Sheet 1



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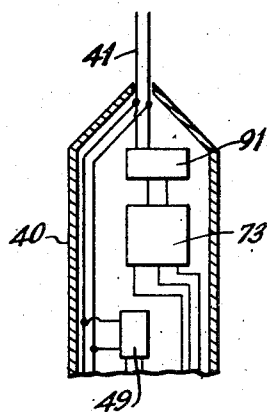
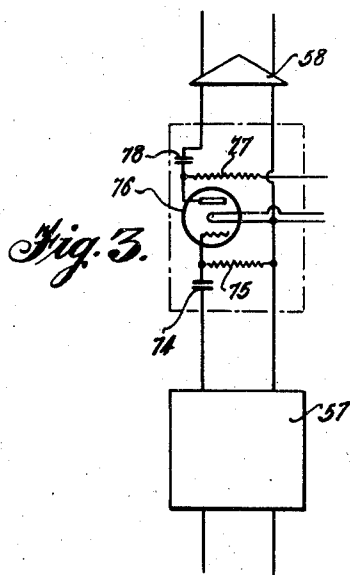
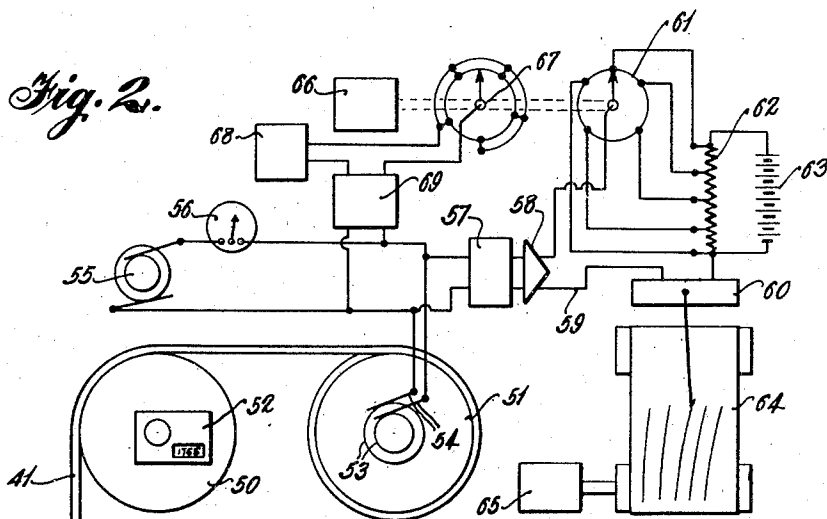
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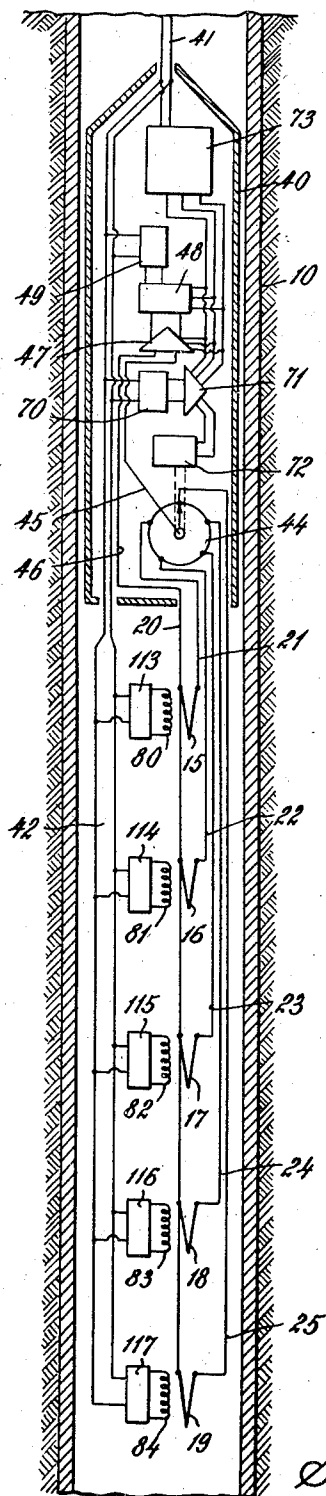
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Fig. 6.



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WELL SURVEYING APPARATUS

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3 Claims. (Cl. 73-154)

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This invention relates to an apparatus for geophysical prospecting, particularly for obtaining indications of the nature of subsurface strata lying adjacent an opening in the earth such as a drill hole. More specifically the present invention relates to an apparatus for differentiating between subsurface strata on the basis of the ability of the strata to absorb heat.

Many devices have been proposed for use in determining the nature of strata that lie adjacent drill holes and the like without the necessity of actually sampling the strata and bringing the samples to the surface. Such devices have differentiated between the various strata on the basis of their electrical conductivity, their magnetic permeability, their radioactivity, their reactions to radioactivity and their reactions to heat. Since the apparatuses vary with the characteristic of the strata upon which they make their distinction it is obvious that the distinction made by one device will not always correspond exactly to the distinctions made by another device but this is desirable rather than otherwise since it tends to prevent the same errors from entering into measurements made by different devices and permits comparison of the results of two or more devices with a resultant gain in information that makes the conclusions reached as to the nature of the strata at various levels more definite and more accurate. It is therefore not the purpose of the present invention to provide a device which will entirely supplant all previous well surveying devices, although the present devices can be used alone with good results and considerable accuracy, but, on the other hand, it is the purpose of this invention to provide a device that will give on the basis of the heat absorption characteristics of the various strata, an accurate indication of the nature of subsurface formations.

Prior to this invention it has been proposed to measure the heat absorption of the various strata penetrated by a drill hole in several different ways. One way was to pump hot or cold liquid into a well bore and then after an interval, to measure the temperatures at various levels thus obtaining an indication of the relative rapidity of heat radiation or absorption to or from the fluid in the well bore from or to the surrounding strata. In such a process the heat begins to be absorbed at first at the point at which the liquid enters the well bore and by the time an appreciable portion of the well bore has been filled with liquid the temperature of the strata surrounding the point of entrance of the fluid has been considerably raised or lowered depend-

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ing upon whether the fluid is at a higher or lower temperature than the surrounding strata. Thereafter the fluid at that point will not change temperature as rapidly as the fluid at some point removed from the point of entry and the temperature of the fluid applied at some point removed from the point of entry will not be the same as that of the fluid applied at the point of entry because the temperature of this fluid will have changed due to its contact with the walls of the drill hole, prior to its reaching its final location. Thus in the practice of a process such as has been just described numerous difficulties are encountered in attempting to obtain accurate results and is not very satisfactory in practice.

Other apparatuses for determining the temperature characteristics of surrounding strata utilize means for applying heat at a point in a well bore and means for measuring the temperature rise at one or more points above or below the point of application of the heat. This gives an indication of the rate at which heat travels through the strata but is affected considerably by any longitudinally extending conductor of heat, such for example as a well casing or the fluid in the well. It is also affected strongly by any movement of fluid in the well that tends to carry heat from the source to the measuring instrument.

There has also been proposed apparatus which comprises means for continuously lowering or raising in a well bore a source of heat and thereafter at a definite time interval lowering past the heated areas a temperature measuring instrument that will measure the relative temperature drop between the time of application of the heat and the time of the measurement. Such a device gives interesting results but the results are affected considerably by differences in temperature at various levels within the well bore prior to the measuring process, and gives only one temperature reading for each location which temperature reading is indicative only of the total absorption of heat over a fixed period rather than a more complete picture of the rate of absorption of the heat over a longer period.

Accordingly, the present invention is directed to an apparatus for measuring the rate of heat absorption at a plurality of points within a well bore in such a manner that a more complete picture of the rate of heat absorption is obtained for each location. This is done in a manner that permits the ready comparison of the measurements made at various levels to give the ultimate infor-

mation about the characteristics of the various strata.

The present invention comprises means for simultaneously applying heat at a plurality of depths within the well or other openings in the earth and means for measuring at the same time the temperature changes at each of these points during the application of the heat. As a result there is obtained for each point at which a measurement is made a temperature, temperature change or heat absorption curve for the surrounding strata which curve is characteristically different for different types of formations. Obviously, a surrounding casing will change the form of the curve but the curves for various formations will still differ and the formations can be differentiated on the basis of these curves even though a casing is present.

It is expedient to supply the heat in the well bore by means of an electrical heating element or plurality of heating elements suspended in the well bore. By properly proportioning the resistances of these heating elements and the voltage applied to them they can be made to emit the same amount of heat at each of the various localities and this has been found desirable since it makes the problem of obtaining comparable heat absorption curves relatively simple. It is possible, however, to pass more current through one or more of the heating elements and perform the heating in their particular locality at a higher rate if desirable, for example, when it is known that some particular formation has a very high rate of heat absorption, or a very low rate of heat absorption and it is desired to get curves of the right magnitude to be useful and yet not get curves of too great or too little a magnitude at other points.

Alongside of each heating unit in the well bore is placed an element that can be used to measure temperature and each of these is arranged to be connected to a recorder on the surface so that a continuous or substantially continuous record of its findings may be made.

Many specific arrangements of detailed systems of apparatus may be made to carry out the principles of this invention as herein set forth. These possibilities and many advantages that have not heretofore been mentioned will be apparent from a consideration of the appended drawings and the following detailed description.

Figures 1 and 2 taken together constitute a diagrammatic illustration of a device which is substantially complete in detail and which is suitable for field work;

Figure 3 is a diagrammatic illustration of a part of the device of Figure 2 illustrating a possible modification thereof.

Figure 4 is a further modification of the present invention which illustrates the use of a stop filter between the power pack and the cable.

Figures 5 and 6 taken together constitute a diagrammatic illustration of a device showing the manner in which varied currents can be supplied to the heaters through the circuits of Figures 1 and 2 and Figure 7 is a diagrammatic showing of the manner in which the cold junctions can be connected into the circuits of Figures 1 and 2.

In the following detailed description of the invention reference will be made to the various figures of the drawings in which the same reference characters are used in the different figures to denote the same elements. As illustrated in Figure 1 the measuring instrument proper consists of a casing 40 adapted to be lowered into a well at

the end of a cable 41 and to have suspended from it a heater element 42 which extends along the whole formation being investigated and a series of thermocouples 43. Thermocouples 43 shown in Figures 1 and 2 and those shown in Figure 6 are similarly spaced. The cable 41 that supports the casing in the well also serves to convey the heater current through the casing 40 and on downward to the heating element 42. In addition to this, the cable 41 serves to carry to the surface currents indicative of the measurements made to the thermocouple and to bring from the surface to the casing a current that causes a switching mechanism to operate whereby one after another of the thermocouples is selected so that its reading will be transmitted to the surface while the other thermocouples are disconnected so that readings from them will not be transmitted simultaneously.

To accomplish this the individual lead wires from the various thermocouples are connected to the fixed contacts of a selector switch 44 and a lead wire 45 from the movable contactor of the selector switch 44, together with the common lead wire 46 from the thermocouples carries the indicating current of one after another of the thermocouples to an amplifier 47. From the amplifier 47 the indicating current passes into an oscillator 48 where it modulates a fixed frequency continuous wave generated by the oscillator. This wave preferably has a frequency of around 250 cycles but may have any desired frequency instead. From the oscillator 48 the modulated continuous wave passes through a filter 49 and into the cable 41 which extends to the surface. The filter 49 is of the band pass type passing only frequencies in the immediate neighborhood of that of the carrier current, i. e. 250 cycles.

At the surface as shown in Figure 2 the cable 41 extends over a measuring wheel 50 and is wound up on a cable reel 51 driven by a source of power not shown so as to raise and lower the measuring instrument in the well. The measuring wheel 50 carries a counter 52 attached to one end of its shaft and this counter serves to register the depth to which the measuring instrument is lowered. At the cable reel 51 the conductors in the cable 41 are connected to slip rings 53 which in turn make contact with brushes 54.

A generator 55 is connected through an ammeter 56 to these brushes 54 so that current is supplied to the cable for the operation of the heater 42. Also connected to the brushes 54 through a filter 57 is an amplifier 58. The filter 57 passes the same band of frequency as does the filter 49 in the oscillator circuit at the measuring instrument. Therefore the carrier waves generated in the well pass through the filter 57 and the amplifier 58. One lead 59 from the amplifier 58 passes directly to a recorder mechanism 60, and the other lead passes through a selector switch 61 to one of five points along a resistance 62, depending upon the setting of the selector switch. From whichever point on the resistor receives it the current passes through the resistor to the other lead of the recording mechanism 60. Across the resistor is a battery 63 which furnishes a constant potential drop across the resistor. A part of this potential is thus in series with the output of the amplifier 58, the amount depending upon the setting of the selector switch 61. Thus as the selector switch 61 is rotated the potential drop will change in steps, each step causing the needle of the recording mechanism to make a step of movement across the recording tape 64 of the recorder. The record-

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ing tape is driven by a clock motor 65 so as to correlate the recordings it makes with time. The recorder is also such a type that the needle will lift from the paper when the circuit is open. Thus as the selector switch 61 moves from one contact to another the needle lifts and then as the circuit is again closed the needle moves to its new position and again contacts the paper to make a record.

The device is so arranged that the selector switch 61 on the surface and the selector switch 44 in the instrument in the well move together so that the record of the measurement made by each thermocouple is placed on the recorder sheet together with the same amount of added potential each time a record is made. This causes a separate record, spaced from the others, to be made for each thermocouple. This is done by means of a clock motor 66 which drives the selector switch 61 in a step by step relation moving it from one contact to the next, allowing it to rest for a definite length of time and then advancing it to the next contact. At the same time the clock mechanism 66 drives the second selector switch 67, also at the surface, and having its fixed contacts offset as compared with selector switch 61 so that when the selector switch 61 is closed on one of the fixed contacts the selector switch 67 is open. Then as the selector switch 61 rotates to the next fixed contact, the selector switch 67 is momentarily closed. All of the fixed contacts of the selector switch 67 are electrically connected together so that when the movable contact member contacts any one of them it merely closes the circuit to the selector switch 67.

The closing of this switch places an oscillator 68 in a circuit through a filter 69 across the brushes 54 which lead to the supporting cable 41. The filter 69 is constructed so that it will pass a narrow band of frequencies different both from the carrier frequency on which the information to be recorded is sent to the surface and from the frequency, if any, of the heater power. A frequency of around 70 cycles has been found satisfactory for this purpose. When the switch 67 is closed the 70 cycle wave is sent down through the supporting cable 41 into the measuring instrument where it is taken from the cable through a filter 70 which is arranged to pass that frequency, to an amplifier 71 and from there to an actuating motor 72 that is arranged to advance the selector switch 44 one position. Thus, every time the clock motor 66 advances the selector switch 61 on the surface, the circuit completed through the switch 67 also advances the selector switch 44 in the well one position. The recording pen is thus moved over to the next position on the recording paper and at the same time the next thermocouple is connected to it through the carrier wave system already described.

The only additional equipment that is necessary to make the device operative is a source of power for the amplifiers and oscillator at the measuring instrument itself. This power is supplied by a power pack 73 of the ordinary type used in radio which power pack gets its original power from the cable 41, using a part of the power supplied by the generator 55 for the heater element. As a possible alternative the power for this power pack may be supplied at a frequency different from that supplied from the generator 55 and placed in the cable 41 through appropriate filters such as is illustrated at 91 in Figure 4. In such a case a filter to prevent the passing of 75

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unwanted current must then be placed in the line between the cable 41 and the power pack 73. No source of power has been shown on the surface of the earth for the generator 63 or the amplifier 58 but this would appear unnecessary since it is a simple matter to obtain power from any suitable source on the surface where power is so easily accessible.

Although it is the intention of this inventor to use any or all parameters that may be obtained by comparing temperature with time by the general methods set forth it has been found that the rate of increase of temperature with time, in other words, the derivative of temperature with respect to time is likely to give quite important indications of the nature of the adjacent strata. Therefore there has been illustrated in Figure 3 a derivating circuit that may be placed between the filter 57 and the amplifier 58 on the surface of the earth to convert what would otherwise be a measurement of temperature to a measurement of a time derivative of temperature. This derivating circuit consists of a condenser 74 having a very small capacity connected in series with a resistor 75 having a relatively small resistance, a vacuum tube amplifier 76 with its input connected across the resistor 75 and the usual output resistor 77 and output condenser 78. The sources of filament and plate potential have not been shown since they can be supplied from any suitable source, for example the same source that supplies power to the amplifier.

Figures 5 and 6 taken together show a modification of a complete surveying system. Figure 5 shows diagrammatically the surface equipment while Figure 6 shows diagrammatically the sub-surface equipment. Generators 101 to 105 supply power at different frequencies through the variable resistors 85 to 89, filters 106 to 110, conductors 111 and 112, and the cable 41 to the heater elements 80 to 84, respectively, through the filters 113 to 117. The heating elements 80 to 84 inclusive are respectively placed adjacent the pyrometers 15 to 19. By this arrangement it is possible to separately control the heat emitted by the heating elements. One terminal of each of the pyrometers 15 to 19 is connected to a common conductor 20 which joins conductor 46, that in turn is connected to the input of amplifier 47. The other terminals of the pyrometers 15 to 19 are respectively connected to conductors 21 to 25. These conductors lead to the selector switch 44. The contactor of the selector switch is connected through conductor 45 to the other terminal at the input of the amplifier 47. The amplified signals from amplifier 47 are transmitted to the surface over the cable 41 in the same manner as described above in connection with Figures 1 and 2.

In Figure 7 there is shown the manner in which the cold junctions can be connected in the circuits of Figures 1 and 2. In this circuit diagram conductor 118 may be of Constantan or like material. The junction 119 between the Constantan conductor and the copper conductors of the rest of the system is made in a Dewar flask 120. The temperature inside the Dewar flask may be maintained colder than the junctions at 121 to 125, or it may be maintained hotter, as desired. In this figure, 48' is an oscillator and 48 is the modulator. The amplifier at 47 is obviously a D. C. amplifier, while that at 126 is an A. C. tuned amplifier.

The surface equipment shown in Figure 7

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differs further in that a rectifier R is connected in the circuit after the amplifier 53.

I claim:

1. Apparatus for geophysical prospecting that comprises a casing adapted to be lowered into a drill hole, a cable adapted to support said casing in the drill hole and connect the mechanism in said casing electrically with the surface of the earth, means to lower said cable into the earth and withdraw it therefrom, means to measure the amount of cable lowered into the earth, an elongated heater element suspended below said casing in the drill hole, means on the surface of the earth for generating electrical current for said heater element, a circuit connecting said generating means with said supporting cable at the surface of the earth, a circuit connecting said heater element with said cable at the casing, means at the surface of the earth for periodically imposing an alternating current of a frequency different from that supplied to the heater element to the supporting cable at its upper end, means in the casing for receiving said alternating current from said supporting cable, a selector switch in said casing adapted to be advanced by said receiving means in response to said alternating current, a series of temperature responsive elements suspended below said casing at various depths alongside of said heating ele-

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ment and connected through said selector switch in sequence, an implifier in said casing to which said temperature responsive elements are sequentially connected, a generator of a fixed frequency carrier wave different from the frequencies of the alternating current and heater currents already mentioned and modulated by the output of said amplifier, means for imposing the output of said carrier wave generator on said supporting cable, means on the surface of the earth for receiving and amplifying said carrier frequency to the exclusion of the alternating current and heater current already mentioned, and means, also on the surface of the earth, for recording the temperature indications superimposed on said carrier frequencies in correlation with time.

2. A device as described in claim 1 in which means are further provided for derivating the temperature indications with respect to time prior to recording.

3. A device as described in claim 1 in which means are further provided to variously bias the recording means as it records the temperature indications of the various temperature responsive elements in order to cause the recordings to be made on different portions of the record sheet of the recording means.

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