

April 14, 1936.

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2,037,306

METHOD AND APPARATUS FOR LOGGING A WELL

Filed June 8, 1934

3 Sheets-Sheet 1

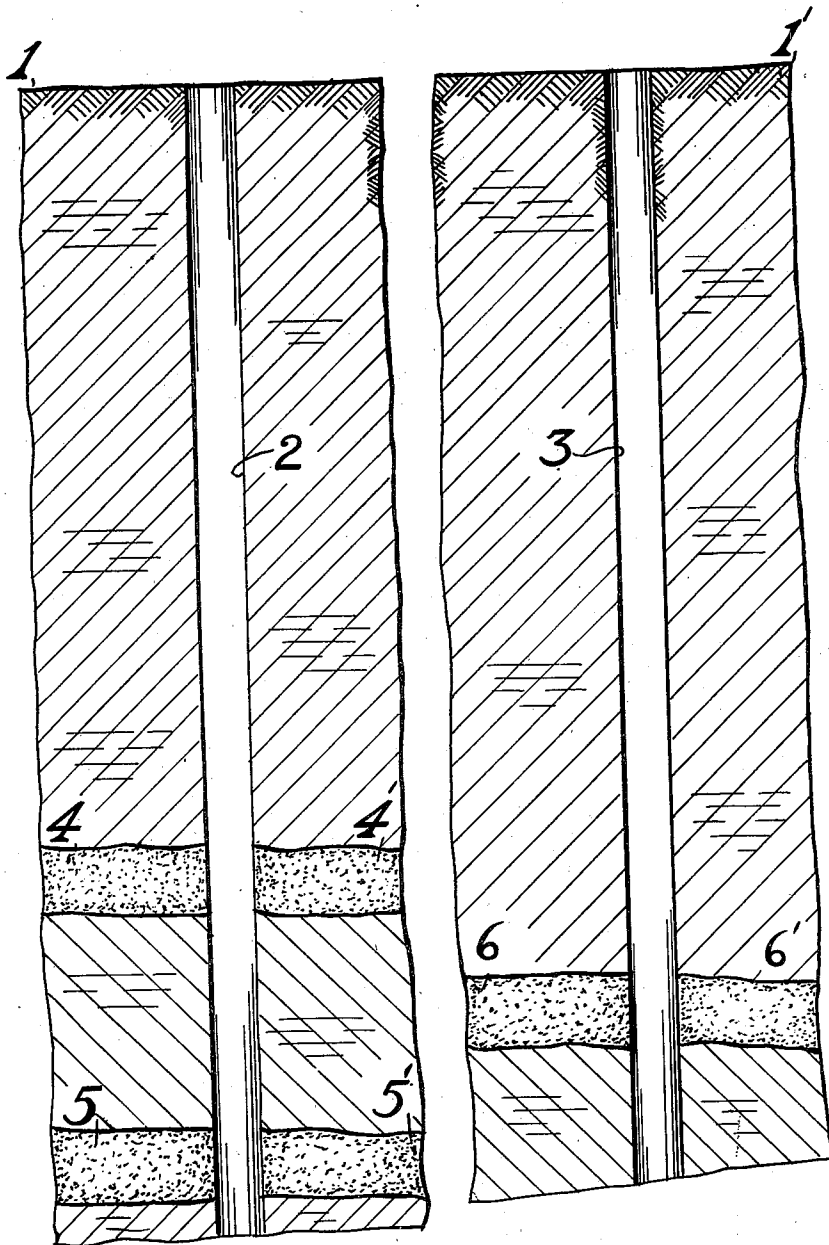


Fig. -1

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3 Sheets-Sheet 2

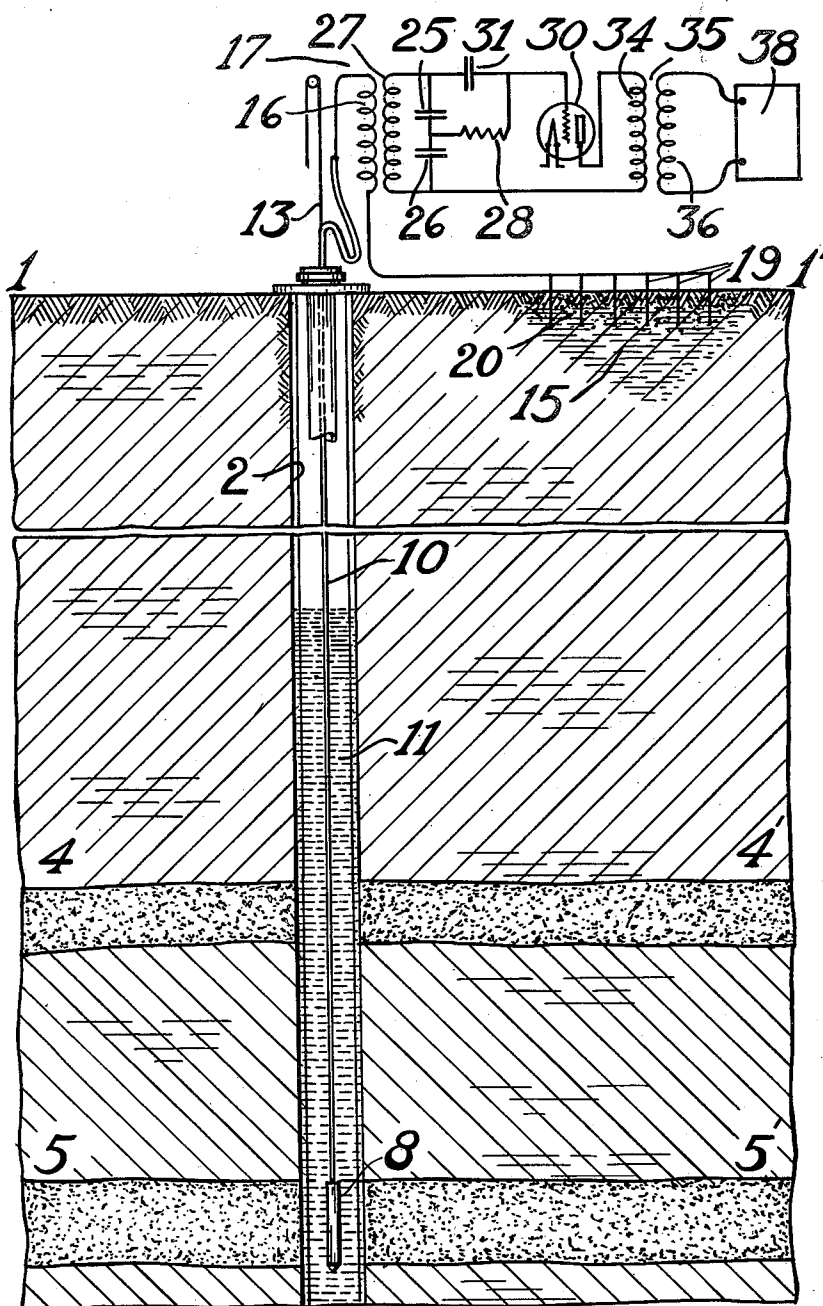


Fig. -2

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3 Sheets-Sheet 3

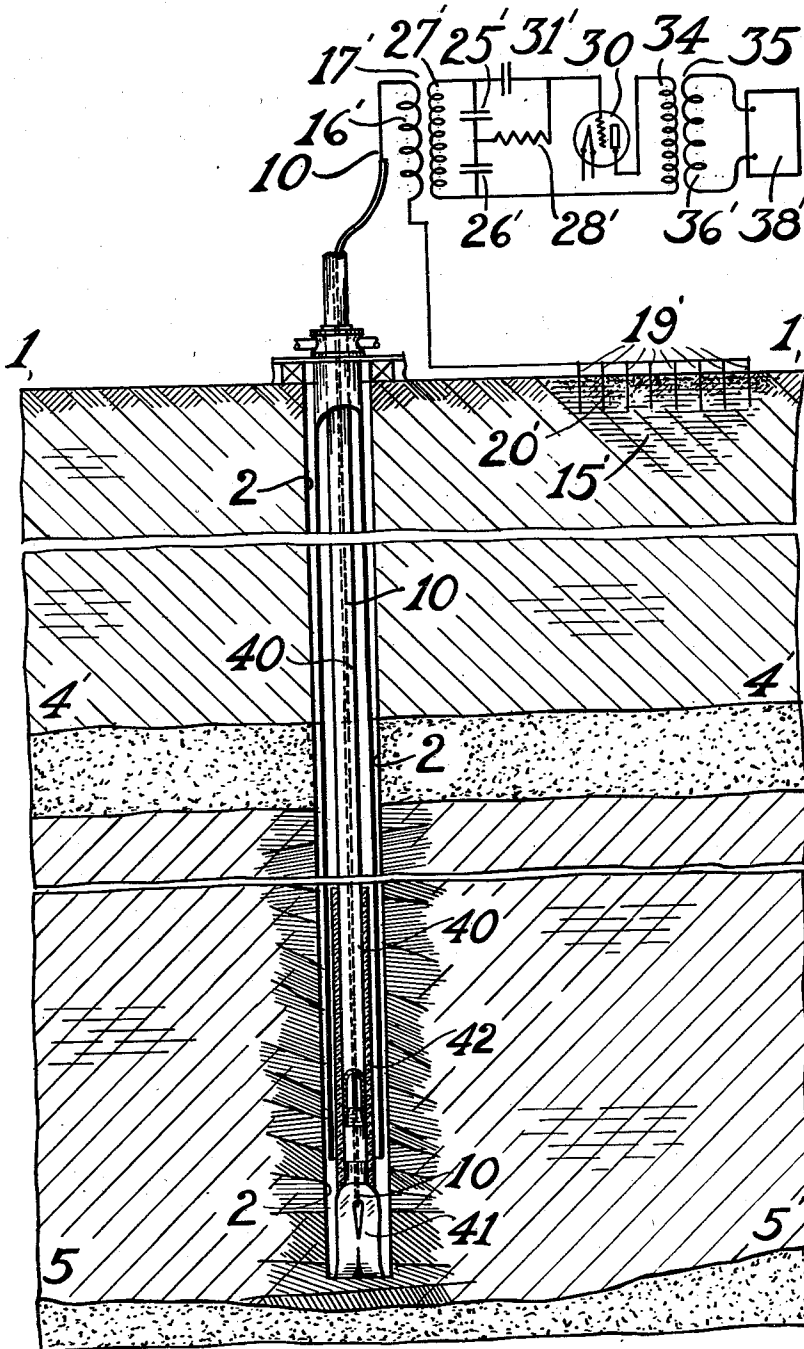


Fig.-3

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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR LOGGING
A WELLLudwig W. Blau and Ralph W. Gemmer, Houston,
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Company, a corporation of Delaware

Application June 8, 1934, Serial No. 729,630

14 Claims. (Cl. 175—182)

This invention relates to improvements in method and apparatus for determining the nature of the earth strata adjoining a well.

In the drilling of wells, especially in drilling for oil, it is very desirable to obtain information about the sequence of the geological strata penetrated by the drill. The customary practice when rotary drills are used is to obtain cuttings while drilling and to core often because the cuttings do not always permit of definite paleontological identification. Coring is very slow and therefore expensive. When several wells are drilled in the same general area and reliable data have been obtained about the depths of the different strata in each well, the information can be obtained by the correlation of strata over the area. The probable depths of any certain strata at points intermediate between the wells are then known with fair accuracy so that little coring is done.

It is an object of this invention to electrically obtain data in bore holes which can be used to correlate strata having the same electrical characteristics over an area. Another object of this invention is to observe the presence of earth strata of different electrical impedance from each other by measuring changes in frequency of current passing through the strata. Other objects will be apparent from the specification and from the accompanying drawings in which latter—

Fig. 1 is a vertical sectional view through two bore holes showing earth strata which have been penetrated by the bore holes;

Fig. 2 is a vertical sectional view through a bore hole showing a preferred form of well logging apparatus in operative position; and

Fig. 3 is a vertical sectional view of a bore hole showing the drill bit used as an electrode.

Referring particularly to Fig. 1 of the drawings, reference numerals 1, 1' designate the surface of the earth, and bore holes 2 and 3 are disposed in the earth spaced from each other any desired distance such as several miles. The bore hole 2 has penetrated through earth strata designated 4, 4' and 5, 5' respectively, while bore hole 3 has penetrated through an earth stratum 6, 6'. It is now very desirable to know whether or not in the case of these bore holes the stratum 6, 6' associated with bore hole 3 is the same as stratum 4, 4' or 5, 5' associated with bore hole 2. If the strata 4, 4' and 6, 6' are found to be the same and are therefore correlated, it would mean that in the case illustrated the bore hole 3 is farther down dip or off structure than the bore hole 2 and that it would, for example, be

very unlikely that any production of oil would be found farther away from the bore hole 2 than the bore hole 3. If, on the other hand, the stratum 5, 5' is found to be the same as the stratum 6, 6' and they are therefore to be correlated, it would indicate that the bore hole or well 3 is higher structurally than the bore hole or well 2, and that more drilling should be done around the bore hole 3.

Referring to Fig. 2, a detailed view of the bore hole 2 lined with casing 7 is shown with suitable apparatus applied to the bore hole for locating earth strata of different electrical impedance from each other. This apparatus comprises an electrode 8 which is suspended by an insulated cable 10 of electrically conductive material within the well 2. The well 2 normally contains water 11 which assures good contact electrically of the electrode 8 with the surrounding earth formations. Suitable means are provided designated 13 for raising and lowering the cable 10 and electrode 8 in the well. The cable 10 is connected to a grounded electrode 15 through the secondary 16 of a transformer 17. The ground 15 comprises a plurality of electrically conductive stakes 19 which are driven into the earth. The earth around the stakes 19 is saturated with a solution of a suitable salt such as copper sulfate, sodium chloride or any other suitable electrolyte designated 20. The solution is disposed in the earth around the stakes 19 over an area of approximately 10 or 20 square feet. The above circuit constitutes an exploring circuit.

An oscillator is operatively connected to cable 10. In the embodiment illustrated the oscillator is of the type commonly known as a Colpitts oscillator. The oscillator comprises condensers 25 and 26 which are connected in series across the primary 27 of the input transformer 17. A grid leak 28 is inserted between the condensers 25 and 26 in the grid circuit of a vacuum tube 30. The grid circuit includes a condenser 31. The plate circuit of the vacuum tube 30 is connected into the primary winding 34 of an output transformer 35, as shown.

The oscillations are delivered from the oscillator through the secondary 36 of the output transformer 35 to a frequency meter 38 which in the embodiment illustrated is a recording frequency meter. It will be understood that the frequency meter 38 may be of the type which will indicate oscillations of current without recording them and some of the advantages of the invention will be retained. It will be understood also that other oscillators than the Colpitts oscil-

lator can be used and some of the advantages of the invention will be retained.

The earth materials lying between the electrode 8 and the ground 15 together with the water 11 and the casing 7 complete the electrical circuit through the cable 10 and the secondary 16 of the input transformer 17. The impedance of this circuit through the earth from electrode 8 to the ground 15 furnishes an electrical load across the secondary 16 of the transformer 17, which electrical load in turn affects the inductance of the primary 27 of the transformer 17. The lower the impedance of the electrical circuit through the earth from the electrode 8 to the ground 15, the lower will be the apparent inductance of the primary winding 27 and the higher therefore will be the frequency of the circuit consisting of the inductance of the primary winding 27 and the condensers 25 and 26 in series. If, on the other hand, the electrical impedance of the current path from the electrode 8 through the earth to the ground 15 is raised, then the inductance of the primary winding 27 of the transformer 17 is also raised. This effects lowering of the frequency at which the inductance of the primary winding 27 tunes with the condensers 25 and 26. It is evident therefore that by the method here outlined, the data regarding the geological formations penetrated by the drill holes will be obtained in terms of the frequency of the primary circuit of the transformer 17 as determined by the electrical impedance of the current path through the earth material intervening between the electrode 8 and the ground 15. Each earth stratum such as 4, 4' or 5, 5' or the like has its own characteristic impedance and it becomes possible therefore to correlate strata in different wells by means of these characteristic frequencies.

The electrical impedance of the current path through the earth from the electrode 8 to the ground 15 is determined largely by the earth lying in very close proximity to the electrode 8 because a large fraction of the voltage drop between the ground 15, which has a very low resistance, and the electrode 8 is confined to a small field of area, perhaps less than one or two feet, surrounding the electrode 8. It is also apparent that the electrode 8 may be very small, for example it may have a diameter of one or two inches.

Referring particularly to Fig. 3, a modified form or means is shown for supporting the cable 10 within the bore hole 2 in which 40 designates a drill pipe which carries at its lower end a drill bit 41. The drill pipe 40 is insulated at 42 for a distance of some few feet above the bit 41 by means of suitable insulating material such as bakelite or the like. The insulated cable 10 is lowered into the well 2 within the drill pipe 40 and is connected through a suitable low resistance contact to the drill bit 41 which functions as the electrode. The cable 10 may or may not be fastened to the center or to the side of the drill pipe 40. By this arrangement of parts, it is possible to obtain the data about the formations penetrated by the drill while the well is being drilled. The method is operative when the drilling fluid is in the bore hole since the drilling fluid assures good contact of the electrode with the surrounding earth formations.

Practical work with this apparatus has shown that a vertical displacement of the electrodes 8 or 41 of as small a distance as one inch will cause a measurable change in the frequency recorded by the frequency meter 38. Further-

more the frequency due to the varying impedance of the earth strata throughout the extent of a well varies over a wide range such as, for example, approximately 25 cycles to 100,000. The frequency meter indicates differences in frequency of less than one-quarter cycle. It is obvious that any one commercial frequency meter will operate with this accuracy over the range indicated above; however the range can be covered with several frequency meters, each operating over a definite range. Consequently, it is apparent that the apparatus is exceedingly sensitive and accurate. It will be understood that the frequency meter 38 can be dispensed with and the impedance of the earth read directly by other means well known to those familiar with the art. Where it is stated in the claims that the oscillatory circuit is separate from the exploring circuit, it is meant that there is no direct connection between the two circuits.

By the procedure described the frequencies recorded by the frequency meter due to changes in the electrical impedance of the current path through the earth are independent of the natural earth currents so that the measurements recorded at any given depth within the well can always be easily and accurately duplicated. The apparatus described records changes in frequency thereby differentiating between earth strata.

Various changes may be made within the scope of the appended claims in which it is desired to claim all novelty inherent in the invention as broadly as the prior art permits.

We claim:

1. Apparatus for logging a well in earth strata of different electrical impedance from each other, comprising a ground at the surface of the earth spaced from the well, an electrode adapted to be disposed at varying elevations in the well, an electrical conductor connecting the electrode with the ground whereby an electrical circuit is formed which is completed through the earth between the electrode and the ground, and a vacuum tube oscillator inductively connected to the conductor to cause changes in the electrical impedance of the current path through the earth between the electrode and the ground due to variations in the earth strata constituting the current path to effect corresponding changes in the frequency of the current in the oscillator.

2. Apparatus for logging a well in earth strata of different electrical impedance from each other, comprising a ground at the surface of the earth spaced from the well, an electrode in the well, the secondary winding of a transformer, an electrical conductor connecting the electrode with the ground through the secondary winding whereby an electric circuit is formed which is completed through the earth between the electrode and the ground, a vacuum tube oscillator connected through the primary winding of the transformer operative to cause changes in the electrical impedance of the current path through the earth between the electrode and the ground to effect corresponding changes in frequency of the oscillator, and a frequency meter operatively connected to the oscillator.

3. Apparatus for exploring sub-surface earth strata for locating deposits of oil or the like, comprising an electrode in electrical connection with a known sub-surface stratum, an electrode in electrical connection with said stratum through a different stratum at a point distant from the point of contact with said known stratum, a vacuum tube oscillator for producing alternat-

ing current, and, means inductively connecting said electrodes with the oscillator to vary the frequency of the alternating currents produced thereby in response to changes due to the varying impedance of the earth strata.

4. Apparatus for logging a well in earth strata of different electrical impedance from each other, comprising an electrode at the surface of the earth spaced from the well, an electrode in the well, one winding of a transformer connected across the electrode in the well and the other electrode, a vacuum tube oscillator for producing alternating currents, the other winding of the transformer being associated with the oscillator in such a way as to vary the frequency of the alternating currents produced thereby in response to changes in electrical impedance of the earth between the electrodes, and a frequency meter supplied by the oscillator for measuring the frequency.

5. Apparatus for logging a well in earth strata of different electrical impedance from each other, comprising an electrode at the surface of the earth spaced from the well, an electrode in the well, one winding of a transformer connected across the electrode in the well and the other electrode, a vacuum tube oscillator for producing oscillating currents, the other winding of the transformer constituting part of the oscillator circuit so that changes in the impedance of the ground between the electrode in the well and the electrode at the surface of the ground will cause changes in frequency of the oscillator circuit, an output transformer the primary of which constitutes part of the oscillator circuit, and a frequency meter connected across the secondary of the output transformer.

6. Apparatus for logging a well in earth strata of different electrical impedance from each other, comprising an electrode at the surface of the earth spaced from the well, an electrode in the well, means for varying the elevation of the electrode in the well, one winding of a transformer connected across the electrode in the well and the other electrode, a vacuum tube oscillator for producing oscillating currents, the other winding of the transformer constituting part of the oscillator circuit so that changes in the impedance of the ground between the electrode in the well and the electrode at the surface of the ground due to variation in the elevation of the electrode in the well will cause changes in frequency of the oscillator circuit, an output transformer the primary of which constitutes part of the oscillator circuit, and a frequency meter connected across the secondary of the output transformer.

7. Apparatus for determining the impedance of earth strata of varying impedance, which comprises a source of electric oscillations of predetermined frequency, and means inductively connected with the source, for passing the oscillations through earth strata of varying impedance whereby variations in the oscillations per second are effected.

8. Apparatus for measuring impedance of the ground, comprising an electric circuit including spaced electrodes disposed in the ground, an oscillator, and means for inductively connecting the circuit through the ground between the electrodes to the oscillator whereby the electrical impedance of the current through the ground af-

fects the frequency of the oscillations generated by the oscillator.

9. Apparatus for measuring impedance of the ground, comprising spaced electrodes disposed in the ground, one winding of a transformer connected across the electrodes, an oscillator for producing alternating currents, the other winding of the transformer being connected to the oscillator to affect the frequency of the alternating currents produced thereby in response to the electrical impedance of the ground between the electrodes.

10. Apparatus for logging a well in earth strata of different electrical impedance from each other, comprising a circuit including an electrode at the surface of the earth spaced from the well electrically connected to an electrode in the well, an oscillator, and means for inductively connecting the circuit to the oscillator whereby changes in the electrical impedance of the current path through the earth between the electrodes effects corresponding changes in frequency of the oscillator.

11. The method of measuring the impedance of the ground between the terminals of an exploring circuit, which comprises creating electric oscillations of given frequency in an oscillatory circuit separate from the exploring circuit, and passing the oscillations by inductance through the exploring circuit whereby the impedance effects of the current path through the ground appear as mutual inductance effects in the oscillatory circuit.

12. The method of exploring subsurface earth strata between the terminals of an exploring circuit, which comprises creating electric oscillations of given frequency in an oscillatory circuit separate from the exploring circuit, passing the oscillations by inductance through the exploring circuit, and placing the terminals in successive portions of the ground whereby the frequency of the alternating current is varied in response to changes due to the varying impedance of the ground.

13. The method of exploring subsurface earth strata between the terminals of an exploring circuit, which comprises creating electric oscillations of given frequency in an oscillatory circuit separate from the exploring circuit, passing the oscillations by inductance through the exploring circuit, and placing the terminals in successive vertical portions of the ground, whereby the frequency of the alternating current is varied in response to changes due to the varying impedance of the ground.

14. The method of measuring impedance of the ground adjacent an earth hole having a metallic casing, the casing and ground lying between the terminals of an exploring circuit, which comprises creating electrical oscillations of given high frequency in an oscillatory circuit separate from the exploring circuit, and passing the oscillations by inductance through the exploring circuit, the frequency being sufficiently high so that the impedance of the metallic casing is high compared with the impedance of the ground whereby the impedance effects of the current path through the ground appear as mutual inductance effects in the oscillatory circuit.

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