MACHINE FOR RECORDING THE VIBRATION OF SHIPS.

BY DANIEL M. LUEHRS.

A machine, scientifically known as a pallograph, is the invention of a German engineer, Herr E. Otto Schlick, and was built by the writer. The records or cards are instantaneous records of the displacement due to vibration of that part of the ship at which the instrument is placed. When the instrument is set up and working, one pen records the vertical, one the transverse, and another the longitudinal vibrations. At the same time a break-circuit clock records half-second time signals, by means of an electric spark from an induction coil piercing the paper. The revolutions of the engine, or engines if a twin-screw steamer, are also recorded at the same time and in the same manner; the breaking of the circuit being done by a contact block, fixed to the engine shaft and revolving with it, passing under a brush and breaking contact at the instant one of the pistons of the engine is at the top or bottom of its stroke. This is important, in order that one may know the exact position and direction of motion of the various pistons, and the propeller at which the maximum vibrations occur.

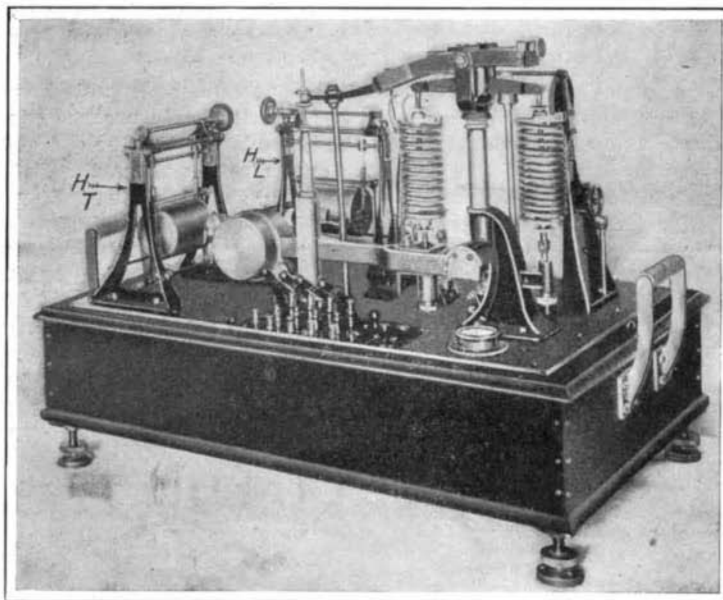


Fig. 1.—THE SCHLICK PALLOGRAPH.

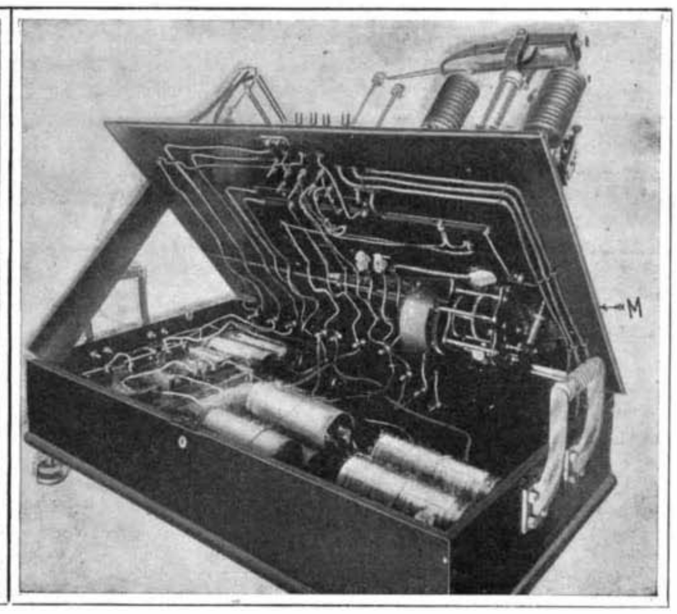


Fig. 2.—THE TOP RAISED.

Vibration in a vertical direction is recorded by the apparatus shown in Fig. 3. This consists of an arm R having at one end, B, a knife edge bearing on agate, and at the other a weight A. This arm is suspended in a horizontal position by the springs S and S. The point of suspension C is below a line joining the center of the weight A and the knife edge B. This is so adjusted that when the weight moves down, and thus increases the tension of the springs, the moment arm $C B$ is decreased; thus the force exerted by the spring supporting the weight remains practically constant, and the weight remains wherever it is placed, or in other words is in indifferent equilibrium. One end of each of the two springs S and S is attached to the beam, having a knife edge bearing at its center, bearing in a block E, capable of movement along the link L, which can be rotated about its center by adjusting screws. The weight A and point of suspension C, can also be moved along the arm R; thus one is able to vary the time of vibration of the system at pleasure, it being very important that this should not coincide with the time of vibration of the ship.

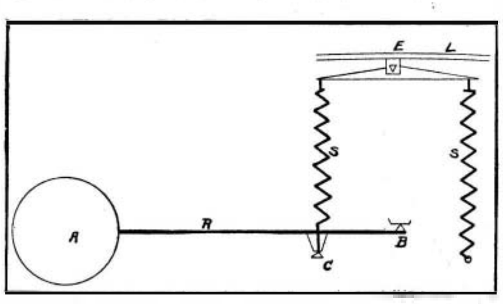


Fig. 3.

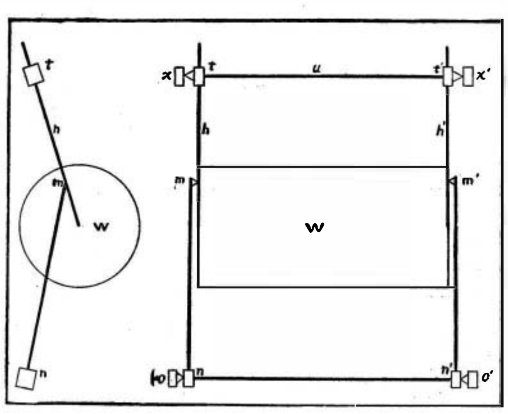


Fig. 4.

The apparatus for recording horizontal vibrations consists of a weight W, Fig. 4, so suspended by linkwork that its motion shall be as nearly horizontal as possible; and for the limited travel of the weight, is for all practical purposes a truly straight line motion. The weight W has attached to it two rods h' free to slide through the sleeves t, which form part of the top rod u. This rod u is pivoted in the blocks $X X'$ sliding in the main frame.

The frame $m n n' m'$ is pivoted to $h h'$ at $m m'$, and is free to rotate about the fixed pivots $O O'$. Thus when the weight moves from its center position, the pivots m m' move in the arc of a circle having its center at O. If h h' were fixed at t t' and not pivoted at $m m'$, W would also move in the arc of a circle having X as its center; however, as $h h'$ is pivoted and free to slide through $t t'$, they will slide enough so that the combination of $h h'$ sliding through $t t'$, and rotating about an axis through $X X'$, raises the center of the weight W an amount it tends to fall due to the rotation of $m m'$ about $O O'$. Thus the center of weight W moves in a horizontal line.

The blocks X X' and the top rod u are capable of being raised or lowered by the miter gears on top. This vertical motion raises or lowers the upper point of suspension of the linkwork, hence the length and therefore the period of the equivalent simple pendulum can be varied at will.

The motion of the center of the weight W of the transverse system is transmitted directly to the recording penholder by means of a rod, provided at each end with universal joints to eliminate friction and side strains. The motion of the longitudinal system is transmitted by means of a bell crank and rods, also provided with universal joints. All transmission rods are provided with turnbuckles and locknuts, so that the pens can be adjusted to the zero position on the paper when the weights are in their mid-position.

The paper is fed in a continuous strip 9 inches wide at the rate of 30 inches per minute, from the supply roll N, Fig. 5, over the brass drum D, thence down around the roll f, thence up and between the rubber-covered feed rolls $f f'$, thence under the shear bar V and out. Power is supplied by a large spring motor.

The penholders are of sheet aluminium, having a long foot, provided with pivot bearings, Fig. 5, and an adjusting screw for varying the pressure of the pen upon the paper. Hunt's round-pointed "Drawing" pens No. 99 were used, carried in aluminium quills capable of adjustment in a vertical plane, in order that all pens and the spark points be brought into the same straight line at right angles to the direction of motion of the paper.

The machine is mounted upon four leveling screws, it being necessary that it stand perfectly level while recording. It has been found impossible to take records while the ship is in rough water; the horizontal systems are so sensitive that the turning of the ship's head even a small amount while under 8 or 10 knots brings the pens into collision and spoils the record. The machine weighs, complete with batteries, 167 pounds.

The question has often been asked, Of what use is such a machine? What if the ship does vibrate, what's the harm? How are you going to stop it? The harm is, that if the vibration is of sufficient magnitude it racks the ship, and even though comparatively slight it makes a ship very uncomfortable to live upon. For example, on the weather deck of the "Kershaw," directly over the propeller, a vertical vibration of 0.06 of an inch was recorded. This vibration occurred 432 times per minute. Now, a person weighing 160 pounds standing beside the machine would have experienced a variation of pressure upon the soles of his feet, above and below his weight, an amount equal to $F = 0.142m \times 10^{-5} \times n^2 S$ (George W. Melville in Marine Engineering, p. 63, vol. viii.) where m is the weight of the person in pounds, n the number of vibrations per minute, and S the amplitude, or 0.06 inch in this case. This gives F the value of 2.54 pounds. So that at one instant his apparent weight is $160 + 2.54$ or 162.54 pounds, at the next $160 - 2.54$ or 157.46 pounds, a total variation of a little over 5 pounds. At the same time he experiences a horizontal vibration having an amplitude of 0.12 of an inch occurring 300 times per minute, producing a horizontal pressure of 2.45 pounds. It will be readily seen that even this slight vibration tends to make a ship uncomfortable. The "Kershaw" is by no means a heavy offender in this respect.

A ship's hull like all bodies possesses elasticity. If an external force acts upon this at regular intervals, it will set up a series of vibrations. This action is best illustrated by taking a slender rod, $A C B$, Fig. 6, of uniform section and material. If a force be applied at A the rod will bend, assuming the position $A_2 C_2 B_2$. If this force be removed the rod will spring back, but will not stop at its original position, but will pass to some position $A_1 C_1 B_1$, finally coming to rest at its original position. If the force, instead of being removed, were periodically reversed in direction, the rod would vibrate between C_2 and C_1, and would come to rest only after the force had ceased acting.

We have a similar condition upon a steamship, our rod being the hull and our force representing the forces produced by the unbalanced forces of the engine and propeller. Like all elastic bodies, every ship has its natural period of vibration, different in every ship and dependent upon the structural arrangement, age, condition, draft of water, speed, depth of water under the ship, position of the fixed weights, boilers, engines, etc., and upon the amount and stowage of the cargo, coal ballast, etc. By taking careful records with the machine, at regular intervals along the deck, a curve can be readily constructed, by taking distances along the deck as abscissas and amplitude of vibration as ordinates. This gives what is known as the node curve, and shows the positions of maximum and minimum vibration throughout the length of the ship. By placing the machine over and as near the propeller as

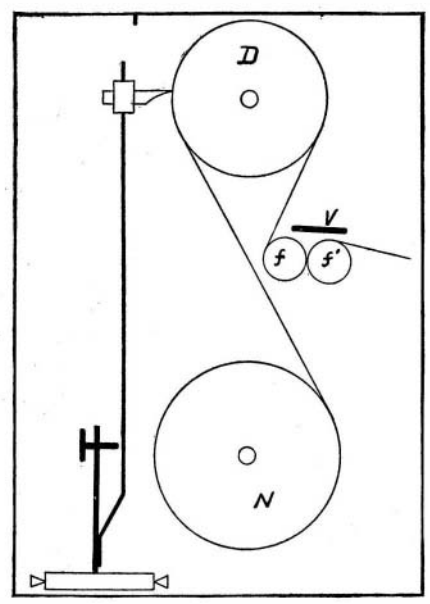


Fig. 5.

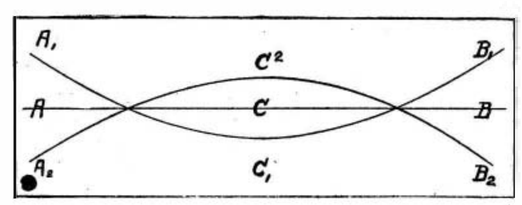


Fig. 6.

possible, one can determine which blade or blades of the propeller, if any, is producing more vibration than the others. As the velocity of the wake, and hence the slip of the wheel, is greatest near the surface, and as the thrust of the propeller increases with the slip, consequently each blade of the propeller experiences a greater resistance near the top, and a less resistance near the bottom of its revolution; hence, as each blade passes through the top position, it produces a vibration upon the ship which is recorded by the machine. Being mainly a transverse vibration, it is most noticeable on the transverse curve, which shows as many vibrations per revolution of the engine as the propeller has blades. If, now, one blade be a trifle larger or of slightly greater pitch than the others, it produces a greater vibration, and, knowing the position of the engine (as explained above) at the instant this blade passes through its position of maximum resistance, it is a simple matter to identify that blade.

The critical number of revolutions of the engine can also be determined with this machine. Vessels having quick-running engines, such as torpedo boats, experience an excessive vibration as the number of revolutions of the engine approaches a certain amount, decreasing as this point is passed but reappearing at each multiple of the original. This number of revolutions is known as the critical number, and is the point at which the number of revolutions of the engine coincides with the natural period of the ship's hull.

With this machine the forces of the engine producing vibration can be studied; and knowing the instantaneous position and direction of motion of each part of the engine, those parts producing vibration can be identified, and means adopted for their suppression. The effect of the various systems of balancing can also be studied and compared.

An ingenious beacon is located at Arnish Rock, Stornoway Bay, in the Hebrides, Scotland. It is a cone of cast-iron plates, surmounted by an arrangement of prisms and a mirror which reflect the light from the lighthouse on Lewis Island, 500 feet distant across the channel.

MORNING AND EVENING STARS FOR 1907.

BY FREDERIC R. HONEY, TRINITY COLLEGE.

The purpose of this article is the same as that of my contribution on this subject for 1906, viz., to assist the non-professional student in identifying the planets which rise before and which set after the sun, for any day of the year.

The orbits of Mercury, Venus, the earth, and Mars are plotted; those of Jupiter, Saturn, Uranus, and Neptune extending beyond the limits of the page.

Mercury's revolution round the sun is performed in very nearly 88 days; and since Venus revolves in her orbit in 224 days and a fraction, a common divisor of 88 and 224, i.e., 8 days, has been selected as a convenient interval of time.

Mercury is represented in eleven positions 8 days apart during each revolution, and Venus is shown in twenty-eight positions at the corresponding dates.

After an interval of exactly 88 days, Mercury gains on his first position only a very small fraction of a degree (= 5⅓ minutes) and in four times 88, or 352 days, during which Mercury makes four revolutions, he advances on his first position about 1-3 deg. (= 22 minutes). By assuming a mean position, this very small error is diminished and is not noticeable in a plot of these dimensions. The positions of the planet are therefore made identical, and four dates are attached to each. Intermediate positions at intervals of four days are also shown.

Mercury's position on January 6 is again reached on April 4, July 1, and September 27. Similarly, his position on January 14 corresponds with that of April 12, July 9, and October 5. By this arrangement the planet's positions are indicated for 44 different dates.

Since the period of Venus's revolution is 224.7 days, after the exact interval of 224 days she falls a little behind her first position of January 6, and during the remainder of the year is represented by an open circle with the new date attached. She reaches on August 18 very nearly the same position as that occupied on January 6; and the same statement applies to each of the subsequent dates.

The positions of the earth and Mars are shown at intervals of eight days from January 6 to December 24. Jupiter's distance from the sun is more than five times that of the earth; it is therefore impracticable to plot his orbit on the same scale, and since his period is less than twelve years, he revolves at an average of about 30 degrees a year. His positions in the heavens are indicated by the arrows for January 6, April 4, July 1, September 27, and December 24. His apparent motion is so slow that the reader will have little difficulty in approximately determining the intermediate position for any assigned date.

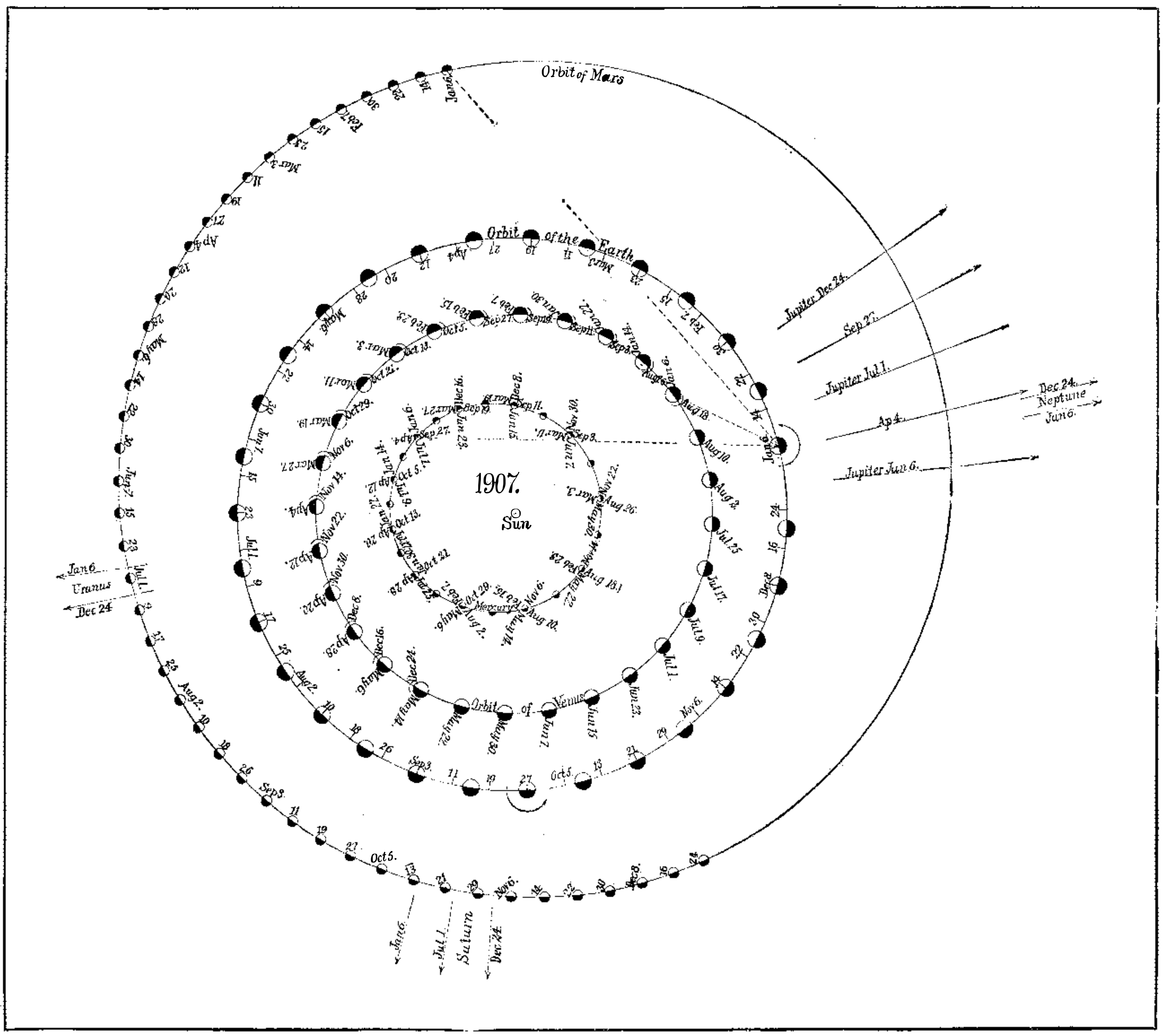
The statements also apply to Saturn, whose distance from the sun is about nine and a half times that of the earth. His positions are indicated by the arrows for January 6, July 1, and December 24. His period is nearly 29½ years.

The apparent motions of Uranus and Neptune are so slow that it is only necessary to indicate the dates at the beginning and at the end of the year. The former is over nineteen times the distance from the sun to the earth, and his period is 84 years; while Neptune is thirty times the distance between the earth and the sun, and his period of revolution is nearly 165 years.

If the reader will note that the earth rotates on its axis in the direction of the arrow (see September 27) he will see that at sunrise the observer is emerging from the shadow area, and that at sunset he is entering it. Before sunrise any planet which in the plot is on the right of the sun will evidently rise before him, and is morning star; and after sunset any planet which is on the left of the sun will set after him, and is therefore an evening star.

In order to ascertain which planets are morning and evening stars, this page should be turned until the earth at the assigned date is between the reader and the sun, so that the date attached to the earth may be read without turning the head. For example, if this page is turned about one-quarter of the way around, until the earth in the plot on January 6 is between the observer and the sun, it will be seen that Mercury, Venus, and Mars are on the right hand of the sun, i.e., they are morning stars at this date.

While it is true that Mercury is approaching aphelion



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