

Aug. 10, 1937.

A. B. RYPINSKI

2,089,860

SLOW TRANSFORMER

Filed March 1, 1935

FIG. 1.

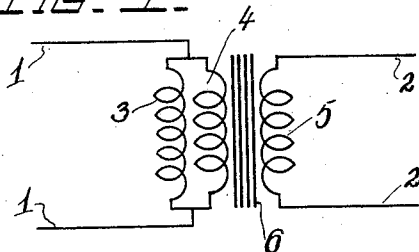


FIG. 2.

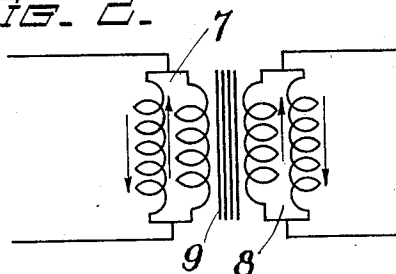


FIG. 3.

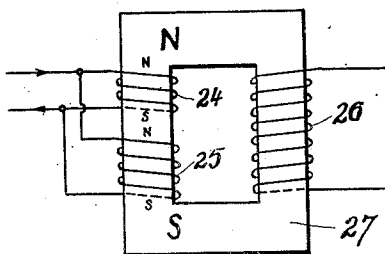


FIG. 4.

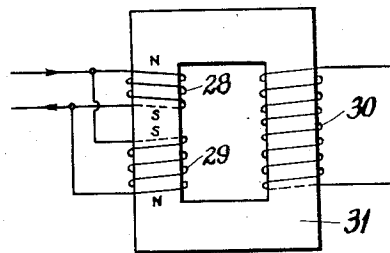


FIG. 6.

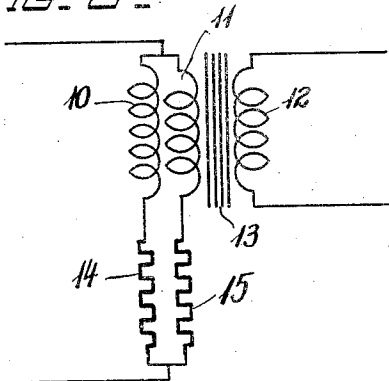


FIG. 7.

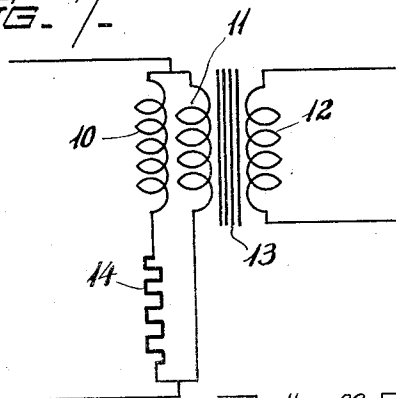


FIG. 5.

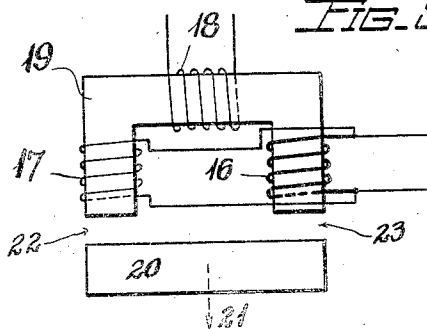
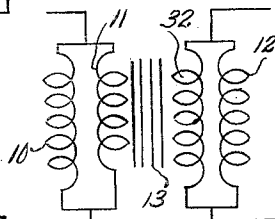


FIG. 8.



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2,089,860

SLOW TRANSFORMER

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Application March 1, 1935, Serial No. 8,913

13 Claims. (Cl. 171-119)

This application is a continuation-in-part of my copending application Serial No. 671,767, for Slow electromagnets having the same or similar temperature coefficients of resistance materials in differential windings, filed May 18, 1933, and its divisional application, Serial No. 705,466, for Slow electromagnetic devices having different temperature coefficient of resistance materials in assistant windings, filed January 5, 1934.

My related applications and patent which will be referred to are listed below:

- S. N. 416,877—filed Dec. 27, 1929—for Slow magnetic regulating devices, S. N. 699,616—filed Nov. 24, 1933—for Motor starting systems, S. N. 699,617—filed Nov. 24, 1933—for Signaling systems, S. N. 699,618—filed Nov. 24, 1933—for Motor control system, S. N. 699,619—filed Nov. 24, 1933—for Distribution system, S. N. 699,620—filed Nov. 24, 1933—for Arc welding apparatus, S. N. 703,313—filed Dec. 20, 1933—for High temperature slow electromagnetic device and Patent No. 1,972,319, dated September 4, 1934, S. N. 671,768—filed May 18, 1933—for Coils for slow electromagnets and reactors.

Throughout these various applications, there are many showings, descriptions and claims for slow transformers, a term I apply to a transformer in which the magnetism and its resultant effects are caused to vary over a time cycle by means of my invention.

In every instance, I employ two inductively coupled windings connected in parallel one with respect to the other, the resultant magnetism being changed over a time cycle either by changes in the resistances of the paralleled circuits or windings, or by changes in the circuit current. Any such winding, when supplied with alternating or varying current necessarily exhibits a transformer action in that the flux set up by one winding threads through and induces a voltage in the other. It is not the purpose of my present invention to claim transformer action as it applies to the effects of mutual induction between the paralleled windings, where these windings are the only ones involved. This has been disclosed and claimed in a number of the above cases.

It is the purpose of my present invention to disclose and claim various modifications of slow transformers in which there is a primary coil and a secondary coil, one or both of which are constituted by two inductively coupled windings connected in parallel. Slow transformers of this type are shown in my application, Serial No. 416,877, but are limited therein to those in which the paralleled windings are connected in opposition

and made up of materials having different temperature coefficients of resistance. This also applies to applications, Serial Nos. 699,616; 699,618; and 699,620. Any of the other continuation-in-part applications based on application Serial No. 416,877 are similarly limited.

In application, Serial No. 671,767, in describing the effects of arrangement and heating, the following statement is made: "If applied to a transformer — the magnetism will alter in the same way, as above described." All of the claims specific to transformers have been transferred from application, Serial No. 671,767 to this application. They include slow transformers having the same or similar temperature coefficient of resistance material in paralleled opposed windings.

In application, Serial No. 705,466, it is stated: "My invention relates broadly to — transformers and particularly to structures thereof employing various temperature coefficient of resistance materials in assisting windings of the devices." All of the claims in application Serial No. 705,466 specific to transformers have been incorporated herein.

One of the objects of my present invention is to produce a slow transformer as described in applications Serial Nos. 671,767 and 705,466 wherein the paralleled windings have the same temperature coefficients of resistance either opposed to or assisting one another, or having different temperature coefficients of resistance and assisting one another.

A further object of my present invention is to produce a slow transformer utilizing any of the means disclosed in the various applications referred to to alter the voltage, current, resistance, impedance, power factor or magnetism in a transformer for any of the uses in the applications cited. I may employ different numbers of turns in the paralleled windings, which, as explained elsewhere herein causes these windings to heat unequally. I may employ constructions resulting in substantially complete flux interlinkage between the paralleled windings, as shown in my patent No. 1,972,319 where one conductor is spiraled over the other or laid on in cable formation. I may, on the other hand, allow considerable magnetic leakage to occur between the paralleled windings as in Fig. 5 where a non-coupling leakage flux will circulate locally around windings 16 and 17 without traversing the entire core 19 and 20, particularly when the air gaps 22 and 23 are open; differential heating or cooling of the paralleled windings by any well-

known method employing radiation, convection, conduction or diffusion of heat; movable or stationary cores in the magnetic circuit as illustrated in the drawing; switching means in one of the parallel windings; transformers in which the magnetism and induced secondary voltage increases, decreases or goes through zero with time, as explained later herein; a slow transformer with a resistor in series with one or both paralleled windings within the paralleled connection as shown in the drawing, the resistors, where there are two being differentially heated by the currents therein or cooled differentially by any well-known method of radiation, convection, conduction or diffusion of heat; resistors or paralleled windings having the same temperature coefficients of resistance, either positive or negative; slow transformers which are substantially silent in operation when there is substantially no magnetism present but which produce a sound of varying intensity corresponding to the change in net magnetism produced by the parallel windings; and any other means for producing a slow transformer within the scope of the appended claims.

A still further object of my present invention is to apply the structure described, and producing the slow transformer effect, to any commercially known type transformer. There are many well known types, such as three-phase transformers, auto-transformers, current and voltage transformers, induction regulating transformers, constant current transformers and others. For simplicity, only a single phase transformer will be illustrated and described, but it is to be understood that the structure may be applied in any of the types known in which it may be useful.

Other and further objects of my invention are set forth more fully in the specification hereinafter following by reference to the accompanying drawing, in which:

Figure 1 diagrammatically shows one form of slow transformer embodying my invention; Fig. 2 illustrates a modified form of slow transformer embodying my invention; Fig. 3 shows an arrangement of slow transformer in which paralleled windings are employed in an assisting relation; Fig. 4 diagrammatically illustrates a slow transformer in which paralleled windings are employed in opposing relation; Fig. 5 discloses a slow transformer embodying my invention and having a movable core member associated therewith; Fig. 6 diagrammatically illustrates a circuit for a slow transformer employing series resistors in circuit with the windings; Fig. 7 shows a modified circuit arrangement for a slow transformer embodying my invention.

In the slow transformer of my invention, two inductively coupled windings are connected in parallel. They may be the primary coil or the secondary coil of the transformer. This is shown in Fig. 1 where windings 3 and 4 are in parallel, and act by electromagnetic induction through core 6 on winding 5. The supply may be brought in at 1-1 and the load connected to 2-2, or vice-versa. In Fig. 2, both primary and secondary coils consist of two parallel and inductively coupled windings. These are shown at 7 and 8 and act through core 9. The operation of slow electromagnetic devices employing two paralleled inductively coupled windings has been explained in the patent applications given above. A brief explanation is given below:—

Consider first the paralleled windings con-

nected to oppose one another magnetically. If the magnetomotive force produced by each is the same and there is complete flux interlinkage, no magnetism will be produced. There will be no self-induction of one turn on the next, no mutual induction between one winding and the other and no electromagnetic induction from a primary winding into a secondary. With no magnetism, there is no vibration or sound, no eddy current or hysteresis losses. The power factor of the device as a whole is 100%.

If now, with current maintained in the circuit, the resistances of the parallel paths are caused to change disproportionately, for instance, if one increases while the other remains constant or decreases, the currents in the parallel paths will change disproportionately, upset the magnetomotive force balance and set up magnetism, the intensity of the magnetization depending on the amount of unbalance. All of the effects of magnetism, stated above as absent, will now appear. The time element will be the time it takes for the resistances in the parallel paths to change, which in the devices disclosed herein is a function of the temperature attained by them, whether the resistances be those of the windings themselves or resistors in series therewith within the parallel connection.

The electrical action is complex, with magnetism present, but the net result is that the currents tend to divide in the inverse ratio of the turns in the paralleled windings biased by the resistance of the paralleled circuits. If the resistance of one parallel path is increased, the magnetomotive force produced by the winding in that path decreases, and the other winding is, in effect, strengthened. This continues until, with infinite resistance (open circuit) in one path, the other develops the maximum possible magnetomotive force and carries the full line current.

The windings need not have equal magnetomotive forces initially. Assume winding 3, Fig. 1, stronger than winding 4 when they are first energized. Assume the heating conditions such that winding 3 gets hot while winding 4 stays cool. Winding 3 will increase in resistance,—assuming it has a positive temperature coefficient of resistance,—will lose in current and magnetomotive force, and if the action continues, will reach a condition at which winding 3 and winding 4 will equalize magnetically and all magnetism in core 6 will have disappeared.

If the action is continued further, winding 3 will continue to weaken, and now winding 4 will predominate and set up the flux in core 6. The instantaneous polarity of this flux will be the reverse of that produced when winding 3 was producing it and the secondary voltage produced in winding 5 will go through the cycle of falling from a maximum to zero in one instantaneous direction and then rising to a maximum in the opposite instantaneous direction.

It will be understood from the statement above, that a slow transformer may produce a secondary voltage by electromagnetic induction which (1) starts at zero and rises to a maximum or (2) starts at a maximum and falls to zero or (3) starts high with one instantaneous polarity, falls to zero, and rises again with the opposite instantaneous polarity.

By altering the heating cycle, other cyclic changes in secondary voltage may be produced automatically over a time period. If, for instance, when current is first supplied, one wind-

ing rises to a much higher temperature than the other and later on, after the heat has had time to soak through from one winding to the other until the temperatures are equal, the original change in magnetism caused by the disproportionate change in resistance will be nullified and the magnetism will have returned to its original value, whether a high value or zero. By compounding the effects of heat diffusion with the type of coil which goes from one value through zero to another value, it is possible to introduce further automatic cyclic variations in the secondary voltage of a slow transformer.

Circulating current in the local circuit produced when two inductively coupled windings are connected in parallel is a factor in the time element of a slow transformer. This circulating current, a product of mutual induction, is present whenever the voltage set up by induction in one winding of the pair differs in intensity from the voltage set up in the other winding. The effect is that the sum of the currents in the parallel paths is greater than the line current, and since heating is determined by current value, and the ampere turns control the magnetomotive force, it will be seen that circulating current is an important factor in the design of slow transformers and affects the secondary voltage in value and in time of production. Where in the claims I refer to "the effects of electromagnetic induction" it is to be understood that I refer to any or all of the effects of self-induction, mutual induction, including circulating current, and the induction from one winding into another with no electrical connection therebetween.

In my copending application Serial No. 671,767, of which this application is a continuation-in-part, I disclose the use of the same temperature coefficient of resistance materials in the paralleled windings, and obtain the disproportionate change in resistance in these windings by disproportionate temperature changes in the windings. Figs. 1, 2, 3, 4, 6 and 7 may be taken as illustrating this arrangement.

Various means for producing differential heating of the paralleled windings are explained therein and will be repeated here. One means for producing a higher temperature in one coil than in the other consists in putting more turns in one paralleled winding than in the other. If the leakage flux between the paralleled windings is zero there will be no net magnetism, assuming the windings forming the windings have the same cross section, same material and same resistance per turn, since the lesser turns of one will be made up for by the larger current therein. But the larger current in the few turn winding will heat that winding to a higher temperature and increase its resistance more than the many turn winding, upsetting the current split between the paralleled windings, and changing the magnetism and induced secondary voltage. As magnetism in the core increases it accentuates this heating by tending to hold the currents in the paralleled windings in the inverse turn ratio biased by the resistance. A relatively large change in resistance is required to pull the currents out of inverse turn ratio, with the net result that the heating of the fewer turn winding progresses at an accelerated rate as its resistance rises.

Using a different number of turns in the two paralleled windings is, therefore, an effective means for producing differential heating therein, even though the windings be of the same material, the conductors of the same cross section and

initial resistance per turn and with substantially complete flux interlinkage between paralleled windings.

A second means of insuring that one coil rises to a higher temperature than the other consists in making the initial resistances of the windings unequal with equal turns. A greater percentage of the total current will pass through the lower resistance winding and their heating will be unequal. This can be accomplished in at least three ways:

1. By varying the relative cross-section of the conductor in the windings, with the same material in each;

2. By using different materials having substantially equal temperature coefficients of resistance, but one of the materials having a higher specific resistance than the other;

3. By making the length of mean turn of one winding different from that of the other, using the same size and kind of conductor in each.

In Figs. 6 and 7 are shown alternate methods for producing slow magnetism in a transformer. In Fig. 6, windings 10 and 11 are the paralleled primary windings, while 12 is the secondary, all inductively coupled through core 13. Two resistors 14 and 15 are connected in series with windings 10 and 11 respectively. The turns of winding 11 are less than the turns of winding 10. With magnetism in core 13, the currents in these windings will tend to change to the inverse turn ratio, a larger current traversing circuit 11-15 and a lesser current circuit 10-14. If resistors 14-15 have the same temperature coefficient of resistance and are, when cold, equal in resistance, the greater current in 15 will heat it faster than 14 and bias the currents away from the inverse turn ratio toward the inverse resistance ratio. The unequal heating of resistors 14 and 15, therefore, results in a change in the magnetism threading core 13 and secondary winding 12 and affects the voltage across winding 12. A slow transformer has, therefore, been shown in which the element producing the change with time is embodied in resistors where the resistors have the same temperature coefficient. This coefficient may be positive or negative and may be zero if the line current is altered cyclically by other means.

In Fig. 7, resistor 15 is omitted and resistor 14 has the same temperature coefficient of resistance as windings 10 and 11. Here, the change is all due to the variation in temperature in resistor 14, but the effect is produced without the use of dissimilar temperature coefficient of resistance materials.

In Fig. 5, a slow transformer is illustrated in which part of the core is movable to introduce air gaps of varying amounts in the magnetic circuit. Here, windings 16 and 17 are the paralleled primaries, while 18 is the secondary. Core 19 has a movable portion 20 biased in the direction of arrow 21 by gravity, a spring, or other means. Windings 16 and 17 have the same turns and are connected to oppose one another magnetically, but winding 16 is of lower initial resistance than 17 and, therefore, 17 will heat more in proportion, and its resistance will rise more rapidly than 16. I have indicated winding 16 in heavier line than winding 17 to designate the lower resistance in winding 16.

When core 20 is down, air gaps 22-23 keep the magnetism at a low value, and the flux threading 16-17 may be assumed insufficient to appreciably affect the current values therein.

But, as heating continues, the flux rises until it is sufficient to cause core 20 to move and close the air gaps. The large increase in flux when this occurs tends strongly to pull the currents in 16—17 into a 1 to 1 ratio, since the turns are equal. Thus, a larger percentage of the total current flows through 17 than before the core moved, accelerating the heating of this winding. The effect is cumulative, the disproportionate increase in resistance raising the flux density and the increase in magnetism accelerating the resistance rise. The changes in magnetism in core 19—20 result in a relatively slow rise in voltage in winding 18 until core piece 20 moves, at which time there is a rapid increase in voltage in winding 18, and after that the relatively slow rise, due to the windings heating, is resumed.

If windings 16—17, Fig. 5, are of the type which start with maximum magnetism and decrease with time, the core piece 20 will be instantly attracted when the transformer is energized, and then the magnetism will begin to decrease, relatively slowly, dropping the secondary voltage slowly until the holding force of the magnetism is less than the bias 21, when the core piece 20 will move, opening air gaps 22—23 and rapidly dropping the magnetism and secondary voltage to a low or zero value.

As has been explained above, the more magnetism there is linking with the paralleled windings the greater is the effect, common in transformers, of tending to hold the currents in the paralleled paths in their inverse turn ratio. Since the current split in these windings directly influences their heating, the action of the movable core in increasing or decreasing the reluctance of the magnetic circuit changes the magnetism therein and thus influences the current split, heating and resistances of the paralleled windings.

The paralleled windings of Fig. 5 may be connected to assist one another magnetically as in Fig. 3 or to oppose as in Fig. 4.

In application Serial No. 705,466, of which this application is a continuation-in-part, various electro-magnetic devices are disclosed using a pair of paralleled inductively coupled windings connected to assist one another magnetically. This is useful in a slow transformer where it is not necessary for the magnetism set up by the windings to fall to zero with current in the windings. In Fig. 3, windings 24—25 and 26 are all inductively coupled through core 27 and 24—25 are connected to assist, as indicated by the N—S markings, meaning north and south pole, respectively.

In Fig. 4, windings 28—29 and 30 are inductively coupled through core 31 and are connected in opposition as indicated by the N—S markings.

The assist connection of Fig. 3 is more effective in producing a large change in magnetism for a given change in resistance, since there is no subtractive magnetic action, whereas the opposed connection of Fig. 4 is essential where it is necessary for the net magnetism to fall to zero, at any point of operation with current in the windings. In Fig. 2, the arrangement of the parallel connected windings 7 and 8 is such that the windings magnetically assist each other. In certain cases, I may employ the parallel connected windings in magnetic opposition. Fig. 8 shows the arrangement of windings in magnetic opposition. The parallel connected primary windings are shown at 10 and 11 connected in opposition. The

secondary windings are shown at 12 and 32 connected in parallel and in magnetic opposition.

I have described my invention in certain of its preferred embodiments, but I fully understand that modifications in construction and circuit arrangements may be made and I, accordingly, intend no limitations upon my invention other than may be imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, and means to produce disproportionate resistance changes with temperature changes therein, to alter the effects of electro-magnetic induction in said transformer.

2. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, said parallel paths including only the necessary connections and said windings, and means to produce disproportionate resistance changes with temperature changes in said windings, to alter the effects of electromagnetic induction in said transformer.

3. A slow transformer including a primary coil and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, at least one of said windings having a resistor in series with it within the parallel connection, means to produce disproportionate resistance changes in said parallel paths with temperature changes in said resistor, to alter the effects of electromagnetic induction in said transformer.

4. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, said parallel paths including only materials having substantially the same temperature coefficient of resistance other than zero, means to produce disproportionate resistance changes with temperature changes in said parallel paths, to alter the effects of electromagnetic induction in said transformer.

5. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, said parallel paths including only said windings and the necessary connections, said windings formed of materials having substantially the same temperature coefficient of resistance other than zero, and means to produce disproportionate resistance changes with temperature in said windings to alter the effects of electromagnetic induction in said transformer.

6. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, a resistor in series with each winding within the parallel connection, said resistors and said windings formed of materials having substantially the same temperature coefficient of resistance other than zero, and means to disproportionately change the resistance of said parallel paths by disproportionate changes in

temperature in said series resistors, to alter the effects of electromagnetic induction in said transformer.

7. A slow transformer having primary and secondary coils, at least one of said coils comprising a pair of inductively coupled differential windings connected in parallel one with respect to the other, said windings formed of materials having substantially equal temperature coefficients of resistance other than zero, and means for causing said windings to operate at different temperatures in coaction with one another, to alter the effects of electromagnetic induction in said transformer.

8. A slow transformer having primary and secondary coils, at least one of said coils comprising a pair of inductively coupled windings arranged to oppose one another and connected in parallel one with respect to the other, said windings formed of materials having substantially equal temperature coefficients of resistance other than zero, and means for causing said windings to operate at different temperatures in coaction with one another, to alter the effects of electromagnetic induction in said transformer.

9. A slow transformer having primary and secondary coils, at least one of said coils comprising a pair of inductively coupled windings arranged to assist one another and connected in parallel one with respect to the other, said windings formed of materials having substantially equal temperature coefficients of resistance other than zero, and means for causing said windings to operate at different temperatures in coaction with one another, to alter the effects of electromagnetic induction in said transformer.

10. A transformer having a primary coil and a secondary coil, one of said coils comprising a

pair of inductively coupled windings disposed in parallel one with respect to the other, means to produce disproportionate changes in the resistance of the windings with temperature changes, said windings coacting to produce substantially 100% flux interlinkage.

11. A transformer having a primary coil and a secondary coil, one of said coils comprising a pair of inductively coupled windings connected to assist one another magnetically disposed in parallel one with respect to the other, said windings being formed of materials having substantially different temperature coefficients of resistance.

12. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, said windings mounted on a core having a movable portion, means to produce disproportionate resistance changes with temperature in said parallel paths, said resistance changes and the changes in magnetism resulting from movement of said movable core portion cooperating to alter the effects of electromagnetic induction in said transformer.

13. A slow transformer including a primary and a secondary coil, at least one of said coils constituted by a pair of inductively coupled windings connected in parallel one with respect to the other, a resistor in series with each winding within the parallel connection, said resistors formed of materials having substantially the same temperature coefficient of resistance other than zero, and means to disproportionately change the resistance of said resistors by disproportionate temperature changes therein, to alter the effects of electromagnetic induction in said transformer.

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