B. McCOLLUM.

INDUCTION MOTOR.

APPLICATION FILED MAR. 3, 1911.

1,038,775.

Patented Sept. 17, 1912.

2 SHEETS—SHEET 1.

Fig 1

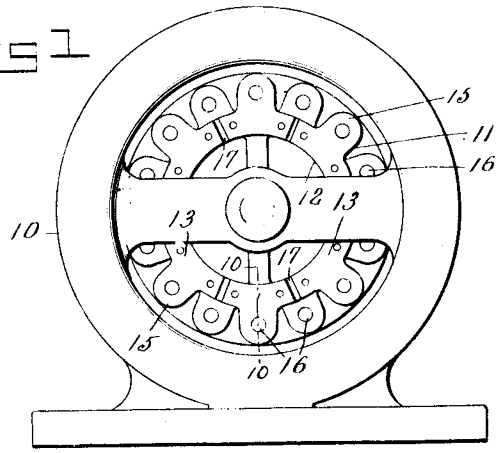
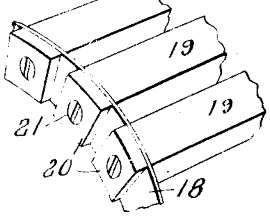


Fig 5



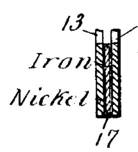


Fig 4

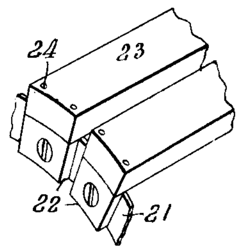


Fig 6

Fig 2

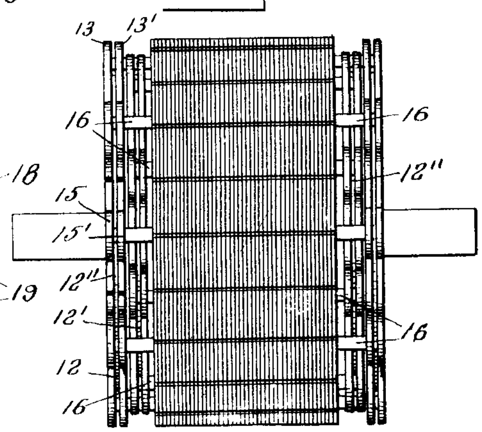
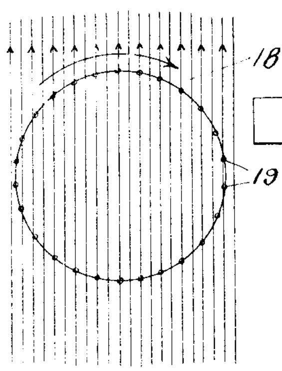


Fig 3



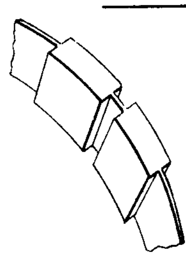


Fig 7

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2 SHEETS—SHEET 2.

Fig 3

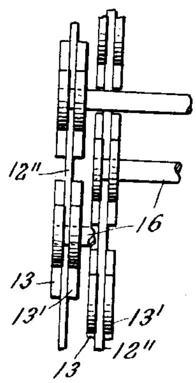
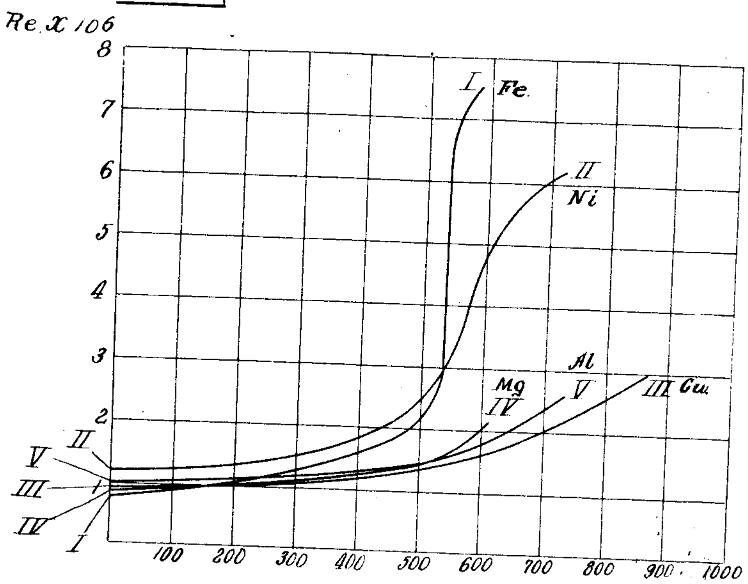


Fig 8



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UNITED STATES PATENT OFFICE.

BURTON McCOLLUM, OF WASHINGTON, DISTRICT OF COLUMBIA.

INDUCTION-MOTOR.

1,038,775. Specification of Letters Patent. Patented Sept. 17, 1912.

Application filed March 3, 1911. Serial No. 612,118.

To all whom it may concern:

Be it known that I, BURTON McCOLLUM, a citizen of the United States, residing at Washington, in the District of Columbia, have invented new and useful Improvements in Induction-Motors, of which the following is a specification.

My invention relates to alternating current induction motors, and particularly to starting devices for the same.

My invention consists of a conductor of relatively fixed dimensions placed permanently in the circuit of one of the rotor or stator windings of an induction motor, and adapted to be heated to a sufficient degree by the starting currents of the motor to give a temporary resistance sufficient to give the motor a good starting torque.

I am aware that it has heretofore been proposed to start induction motors with a conductor of copper in circuit with one of the windings and adapted to be temporarily heated by the starting currents of the motor. This conductor has a positive temperature coefficient of resistance and at starting is heated, its resistance being thereby increased and the motor given a certain increased starting torque, and upon the motor's speeding up the conductor is cooled due both to the decreased current and to the cooling action of the air as it rotates.

The principle of my invention consists in having one or more of the short circuiting rings of squirrel cage composed wholly or in part of a metal having a temperature resistance curve characterized by an abrupt rise of the resistance upon the reaching of a certain defined critical temperature value and making it of such proportions that the normal full load current of the motor is too small to carry the temperature to the critical value while the motor is running, but at the same time make certain portions of it of such dimensions that the starting current in those portions is sufficient to heat them to the critical temperature in a very short period of time, whereupon the resistance jumps quickly to a manifold value, giving the motor a very high starting torque. When the motor reaches full speed the reduced current combined with the rotation through the air, reduces the temperature and the resistance falls rapidly to a low value. I find that such a device gives satisfactory operation on motors of all sizes, giving a high starting torque and a high running efficiency. I have found that such results cannot be obtained by the use of other resistance elements at present known in the art.

I have experimented with many substances, and of them have found only two, up to the present time, which give satisfactory results, all other substances which I have experimented with lacking the characteristic temperature resistance relation which I have outlined above. The two substances which I find usable are iron and nickel, preferably used in their pure state. It is characteristic of these metals that they have a temperature resistance relation, such as described, and further that they have a very high positive temperature coefficient and a very high melting point.

It is when iron and nickel are so proportioned as to be heated to and above the critical temperature value by the starting current that the superior results of my invention are obtained, and my invention consists in part of giving such proportions to the resistance element having the defined temperature resistance relation as will insure its being heated to the critical temperature value by the starting current of the motor and not so heated by the normal full load current. In applying such a device in practice, however, difficulties at once arise because of the high specific resistance of all metals exhibiting the desired properties. If the metal to be used is applied in the ordinary way, viz: in the form of rings short circuiting the bars of the rotor, it is obvious that the currents will have to flow through a considerable length of the conductor, and because of the high specific resistance the conductor would have to be made of large cross section in order that the resistance under running conditions would be small enough to give to the rotor a high running efficiency. On the other hand, if the ring is given a sufficiently large cross section to keep its resistance down to the desired value, the quantity of metal, and therefore its capacity for absorbing heat, will be so great that its temperature will rise very slowly when the current is turned on. This result is a very sluggish starting of the motor under load, which is not only objectionable in itself, but also may give rise to dangerous heating of the windings of the motor by the heavy starting currents. In order, therefore, that iron and nickel may be used for the purpose above set forth it is necessary that they be so proportioned that those portions that are to be heated shall contain a very small amount of metal so that they will heat quickly, and at the same time, they must be of such short length that the total resistance will not be great enough to reduce seriously the efficiency of the motor.

I have given my invention several practical embodiments, some of which I show in the accompanying drawings. In these illustrative embodiments I make use of the resistance element of the material specified, portions of which are of very small cross section, somewhat ribbon like or filament like in shape, and the adjoining portions which may be of the same or of different material are relatively massive and adapted for connection to the conductors of the circuit in which the element is to be used. By making these intermediate portions of relatively large size, and the elements of reduced cross section sufficiently short the total running resistance of the rotor circuit may be kept low, while the portions of the relatively small cross section are particularly adapted to be rapidly heated, having small capacity for absorbing heat, and for the same reason as rapidly cooled.

Of the drawings;—Figure 1 is an end elevation of the motor, the rotating element of which is equipped with the device of my invention. Fig. 2 is a side elevation of the rotor of this motor. Fig. 3 is a view in elevation on a somewhat larger scale than Fig. 2, to show the relation of the parts of the starting device. Fig. 4 is a sectional view on the line 10—10 of Fig. 1, showing one construction of resistance element which I have found desirable. Fig. 5 is a view in perspective of a portion of a rotor showing a simplified form of my invention. Fig. 6 is a view similar to Fig. 4, of a slightly different mechanical arrangement. Fig. 7 is a view of a portion of a resistance element of slightly different form. Fig. 8 is a showing of some curves which I have obtained from actual tests upon metals which I use according to my invention, and of other metals which I found not suitable for use. Fig. 9 is a diagram explaining the effect of the resistance elements under running conditions.

Referring particularly to Fig. 1, 10 designates the stator and 11 the rotor. The rotor winding, as shown, is of the squirrel cage type, the resistance elements of my invention being inserted in one or more of the short circuiting end rings. In the case illustrated in Figs. 1 and 2 there are two of these rings 12 and 12′, on each end of the rotor although it will be seen that one or a greater number than two may be used if desired. A description of one of them will suffice, since all of them are alike.

The ring is made up of a central edgewise band of the material having the characteristics above described, such as iron or nickel, and spaced embracing members 13, 13′ of larger cross section than the ribbon like band 12 and relatively massive in form. The members 13, 13′ are identically alike in form, and are spaced in pairs one on each side of the band and riveted or otherwise attached thereto. From their outer sides project ears 15, 15′ through which connection is made to the conductors 16 of the rotor by any suitable method.

The portions 17 of the band 12 between the members 13, 13′ are of such dimension as to section and length as to be heated by the starting currents of the motor to and above the critical temperature value. Upon starting therefore, a very high resistance is interposed in the path of the current, and the motor starts with high torque. Upon rotation, however, the current is cut down by the counter electro-motive force due to rotation and the temperature, and therefore the resistance falls rapidly to its running value, the normal full load current being below the critical value. By virtue of the enlarged portions 13, 13′ which may be made of a more conductive material than iron or nickel if desired, the running resistance of the device is kept as low as desired.

The double squirrel cage form shown in Figs. 1 and 2 is particularly advantageous, since with this type of construction fewer resistances are in series in any given circuit than when but a single squirrel cage is used. It is to be observed that there are two resistance rings on each end of the rotor and that every second conductor 16 is connected to the same ring. Generally stated, in this embodiment of my invention I make use of *n* rings on each end of the rotor, and connect every *nth* conductor to the same ring. It is to be understood, however, that it is not necessary to use several rings of the type described on both ends of the rotor, but all the rotor bars at one end of the rotor may be connected to a short circuiting element ring of the usual or any desired type.

In the embodiment of my invention shown in Fig. 5, a slight mechanical variation in structure is disclosed, in which alternated attenuated and massive resistance sections are formed by a band 18 which abuts the ends of the conductor bar 19, being held thereto by the spaced massive sections 20, suitable fastening devices, such as screws 22, serving to hold the parts in position.

In Fig. 6 the same result is secured by coupling the attenuated band 21 with the massive lugs 22, spaced from one another, the conductor bars 23 being secured by suitable fastenings 24 which pass through the ends of the conductor bars and into the lugs 22, as shown.

In Fig. 7 the resistance element is shown as made up of integral and spaced attenuated and massive portions to which resistance ring the conductor bars may be secured in any desirable mechanical way.

I have found that iron under the high temperature sometimes obtained, has a tendency to oxidation and where high temperatures are to be used I propose to coat the iron with a substance which does not readily oxidize at the temperatures to be used. Nickel is very much more resistant to oxidation, and is therefore a satisfactory material to use as a coating. As nickel in common with iron possesses the characteristics I have found desirable, no impairment of the operating efficiency results from this expedient, and the deterioration of the metal due to oxidation is eliminated. Iron alone may be used if the temperature is not carried to the point of oxidation.

I have shown diagrammatically in Fig. 4 a strip or band of iron coated with nickel as above described, it being understood that this structure may be embodied in any of the forms of resistance elements hereinbefore described.

Referring to Fig. 8 it will be seen that I have shown a number of curves. These are resistance current curves. The curves numbered 1 and 2 are resistance current curves of iron and nickel respectively. It will be seen that at a certain critical current value these curves rise abruptly, increasing to a manifold value. On the other hand referring to curves 3, 4 and 5, which are respectively the curves for copper, magnesium and aluminum, it will be seen that there is no such abrupt rise. The points at which these curves terminate represent softening or melting points of the metal beyond which it is impossible to make use of them for the obvious reason that their efficiency is destroyed long before the desired point of critical current value has been reached. It is to be noted that the curves 1 and 2 for iron and nickel do not reach the melting point until long after the abrupt rise in resistance has taken place.

As stated at the outset, these elements, which are adapted to have a high resistance at starting and a relatively low resistance under running conditions, are to be left permanently in circuit. This is important, not alone for mechanical simplicity, but more especially because of the improved power factor which they impart to the motor. The reason for this improved power factor may be readily seen by reference to the diagram in Fig. 9. Here the parallel lines represent the direction of the magnetic field at any instant, and the curved arrow 18, the direction of rotation of this field. It is understood that under normal load conditions the conductors 19 of the rotor are rotating in the same direction as the magnetic field but at slightly lower speed. The conductors will, therefore, have induced in them an electromotive force which is of the frequency of slip, and which is approximately a sine wave, in phase with the resultant magnetism. If now the resistance is constant, as is usually the case, the current will also be a sine wave and the resultant magnetomotive force of the rotor currents will obviously be in space quadrature with the flux. If, however, the resistance elements having low heat inertia are kept permanently in the circuit, the resistance will pulsate under the passage of the alternating current, this pulsation being augmented by the low frequency of the alternating current. It is obvious that the resistance is lower during the first quarter of the current wave than during the second quarter, since the heat is cumulative as long as the square of the current is above its mean value, approximately speaking. It follows, therefore, that the current in those bars that are approaching the middle point or axis of the field will carry larger currents than those bars which have passed this mean position. The resultant magnetomotive force of the rotor currents will therefore have a component in phase with the main magnetism, and the effect is similar to that of a leading current in the rotor. The rotor currents can therefore be made to supply a part or all of the magnetism of the motor, thus relieving the primary winding of the corresponding portion of the exciting current and hence raising the power factor of the motor. Further, this transference of the exciting current from the stator to the relatively low resistance rotor increases the efficiency of the motor.

An appreciable time is taken for the resistance to rise, as shown, on the curves 1 and 2, and this time is very advantageous since it is very desirable that a high torque be not applied suddenly but gradually.

While I have shown and described the best forms of my invention now known to me, I desire to have it understood that many other modifications may be made by those skilled in the art without departing in anywise from the generic spirit of my invention as disclosed herein. Further I desire to cover in the annexed claims all such modifications that come within the generic spirit of my invention.

Having thus described the invention what is claimed as new is:—

1. In an induction motor of the squirrel cage type, conductor bars, and a short circuiting device permanently connected in circuit with said conductor bars of the squirrel

cage winding comprising a resistance element characterized by an abrupt rise of resistance at a critical current value.

2. In an induction motor of the squirrel cage type, conductor bars, and a short circuiting device permanently connected in circuit with the conductor bars of the squirrel cage winding, said device comprising a resistance element having portions of reduced cross section of a material having a positive temperature coefficient of resistance and a resistance curve characterized by an abrupt rise of resistance at a critical current value, and so proportioned that the starting currents of the motor are above the critical current value and the normal load currents of the motor are below the critical current value.

3. In an induction motor of the squirrel cage type, conductor bars, and a short circuiting device permanently connected in circuit with the conductor bars of the squirrel cage winding, said device comprising a resistance conductor of a material having a resistance curve characterized by an abrupt rise of resistance at a critical value of rising current and so proportioned as that the starting currents of the motor are above the critical current value and the normal load currents of the motor are below the critical current value.

4. In an induction motor of the squirrel cage type, a short circuiting device permanently connected in circuit with the conductor bars of the squirrel cage winding, said device comprising a resistance conductor having portions which are alternately attenuated and massive in cross section and of a material having a resistance curve characterized by an abrupt rise of resistance at a critical current value and so proportioned that the starting currents of the motor are above the critical current value and the normal load currents of the motor are below the critical current value.

5. In an induction motor of the squirrel cage type, conductor bars, and a short circuiting device permanently connected in circuit with the conductor bars of the squirrel cage winding, said device comprising a resistance conductor having portions which are alternately attenuated and massive in cross section, said attenuated portions being of a material having a resistance curve characterized by an abrupt rise of resistance at a critical current value and so proportioned as that the starting currents of the motor are above the critical current value and the normal load currents of the motor are below the critical current value.

6. In an induction motor of the squirrel cage type, conductor bars, and a plurality of short circuiting devices permanently connected in circuit with the conductor bars of the squirrel cage winding, each of which has portions of relatively low resistance connected by portions of relatively high resistance, said portions of high resistance being characterized by an abrupt rise of resistance at a critical value of current and so proportioned that the said critical value of current will lie between the starting current and the normal load current of the motor.

7. An induction motor, of the squirrel cage type having conductor bars, two or more short circuiting end rings on its motor, portions of which rings are alternately attenuated and massive in cross section, and permanent connections between one series of conductors of said rotor and one of said rings, and like permanent connections between the other series of said conductors and the other rings.

8. An induction motor, of the squirrel cage type having conductor bars; two or more short circuiting end rings on said rotor having portions which are alternately attenuated and massive in cross section; permanent connections between one series of conductors of said rotor and one of said rings; and like permanent connections between the other series of said conductors and the other rings; said ring portions of reduced cross section being of a material having a relatively high positive temperature coefficient of resistance, and a temperature current curve characterized by an abrupt rise of resistance at a certain critical current value which lies between the starting current and the normal load current of the motor.

9. An induction motor, of the squirrel cage type having conductor bars; two or more short circuiting end rings on said rotor, said rings having alternated attenuated and massive portions of which the attenuated portions are of a material having a high positive temperature coefficient of resistance, and a temperature current curve characterized by an abrupt rise of resistance at a certain critical current value which lies between the starting current and the normal load current of the motor; a series of rotor conductors spaced approximately one pole pitch or less being permanently connected to one of said rings; and other series of rotor conductors similarly spaced and similarly connected to others of the said rings.

10. A short circuiting end ring for induction motors comprising an edgewise thin band of material having a temperature resistance curve characterized by an abrupt rise of resistance at a defined critical value of current, and spaced connecting portions of relatively greater cross-section adapted to be connected to the conductors of the rotor winding.

11. A short-circuiting end ring for induction motors comprising an edgewise thin band of material having a temperature re-

sistance curve having an abrupt rise of resistance at a defined critical value of temperature, and spaced connecting portions of relatively greater cross section adapted to be connected to the conductors of the rotor winding.

12. A short-circuiting end ring for induction motors comprising a band of material having a temperature resistance curve characterized by an abrupt rise of resistance at a defined critical value of current, said band having alternated attenuated and massive portions.

13. In an induction motor, a resistor comprising a material having a resistance current curve characterized by an abrupt rise of resistance at a critical current value, and a coating on said conductor of a material substantially non-oxidizable at the temperature reached by the body of said resistor under the normal starting currents of the motor.

14. In an induction motor, a resistor comprising a material having a resistance current curve characterized by an abrupt rise of resistance at a critical current value, and a coating on said conductor of a material having a similar characteristic resistance current curve and substantially non-oxidizable at the temperatures reached by said resistor under the normal starting currents of the motor.

15. In an induction motor, the combination with a secondary winding; of resistance elements permanently connected in circuit therewith, and comprising conductors of a magnetic material characterized by an abrupt rise of resistance at a critical current value and so proportioned that the normal starting currents are above this critical current value and the normal full load currents below said critical current value.

16. In an induction motor, the combination with a secondary winding; of resistance elements permanently connected in circuit therewith, said resistance elements comprising conductors of iron, said conductors being so proportioned that the normal starting currents are above the critical current value and the normal full load currents below the critical current value.

17. In an induction motor, the combination with a secondary winding; of resistance elements permanently connected in circuit therewith, said resistance elements comprising conductors of iron coated with nickel, said conductors being so proportioned that the normal starting currents are above the critical current value and the normal full load currents below said critical current value.

In testimony whereof I have hereunto set my hand in presence of two subscribing witnesses.

BURTON McCOLLUM.

Witnesses:
ARTHUR L. BRYANT
G. M. STUCKER.