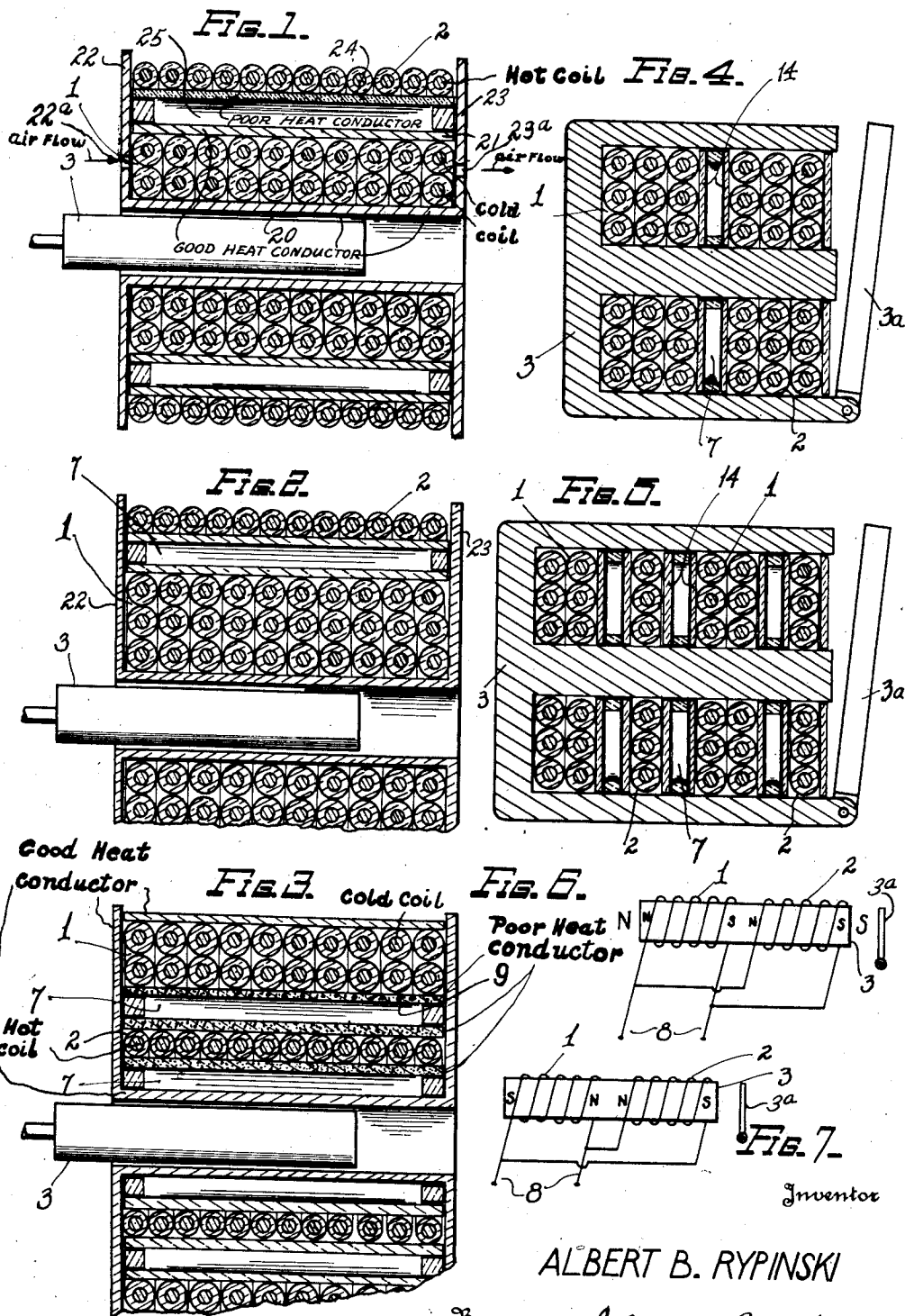


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SLOW ELECTROMAGNETIC DEVICE HAVING THE SAME OR SIMILAR TEMPERATURE COEFFICIENTS OF RESISTANCE MATERIALS IN DIFFERENTIAL WINDINGS
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SLOW ELECTROMAGNETIC DEVICE HAVING
THE SAME OR SIMILAR TEMPERATURE
COEFFICIENTS OF RESISTANCE MATERIALS IN DIFFERENTIAL WINDINGS

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20 Claims. (Cl. 175-336)

My invention relates broadly to slow electromagnets and more particularly to a construction of slow electromagnet constituted by magnetically coupled electromagnetic windings having the same or similar temperature coefficients of resistance.

My invention relates generally to that class of slow electromagnets as set forth in my copending application Serial No. 416,877, filed December 27, 1929, for Slow magnetic regulating device, now Patent 2,082,121, dated June 1, 1937. In the said patent I have set forth and claimed slow electromagnets constituted by magnetically opposed windings having different temperature coefficients of resistance.

My Patent 1,972,112 for Slow reactor or circuit controller is a continuation-in-part of application 416,877 above and embraces a slow reactor constituted by magnetically opposed windings of materials having the same or similar temperature coefficients of resistance.

My present invention is directed to a slow electromagnet having windings constituted by materials having the same or similar temperature coefficients of resistance where the windings are either magnetically opposed, or assist one another magnetically.

One of the objects of my invention is to provide a construction of slow electromagnet utilizing materials in the inductively coupled windings having the same or substantially equal temperature coefficients of resistance.

Another object of my invention is to provide a construction of slow electromagnet formed by windings of materials having the same specific resistance, as well as the same temperature coefficients of resistance.

Still another object of my invention is to provide a construction of slow electromagnet or reactor having magnetically coupled differential windings having the same or similar temperature coefficients of resistance and magnetically coacting one with the other.

A further object of my invention is to provide a construction of slow electromagnet utilizing windings of inexpensive and commercially obtainable materials and which will have the desired characteristics of the slow electromagnet of my invention as set forth more fully in my aforesaid copending application,

A still further object of my invention is to construct a slow electromagnet having inductively coupled windings in which changes in ambient temperature do not affect the time element of the coil.

Another object of my invention is to construct a slow electromagnet or reactor, the power factor of which remains substantially constant with changing magnetism in the coil.

Still another object of my invention is to construct a slow electromagnet or reactor in which the energy consumed in the windings is less than one watt per square inch of surface for one winding and more than one watt per square inch of surface in the other winding.

A further object of my invention is to construct a slow electromagnet or reactor in which the radiating surface of the hot winding fixes the change in its resistance while the mass of material in which the hot winding is embedded fixes the time element of the coil.

A still further object of my invention is to construct a slow electromagnet or reactor with substantially no magnetic leakage between the differential windings.

Another object of my invention is to construct a slow electromagnet or reactor in which substantially all of the magnetism produced by one winding threads through the other but wherein only a small amount of the heat generated in the one is dissipated through the other.

Still another object of my invention is to construct a slow electromagnet or reactor having the same or similar temperature coefficient of resistance materials in the windings in which the magnetism of the coil passes through various cycles determined, first, by the relative rate of rise in temperature of the windings, and second, by the subsequent exchange of heat between the windings.

A further object of my invention is to provide a construction of slow electromagnet or reactor where the windings are in parallel and arranged to assist one another magnetically, the windings having the same or similar temperature coefficients of resistance.

Other and further objects of my invention will be understood from the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view taken through one of the slow electromagnets embodying the principles of my invention; Fig. 2 is a cross sectional view showing a modified form of the slow electromagnets of my invention; Fig. 3 is a cross sectional view illustrating a further modified form of slow electromagnet of my invention; Fig. 4 illustrates an arrangement of windings for a slow electromagnet involving the principles of my invention where the opposed windings are arranged side by side on the core structure of the slow electromagnet; Fig. 5 shows a further form of slow electromagnet construction in accordance with my invention in which the opposed windings are arranged in alternate pancakes on the core structure; Fig. 6 illustrates a pair of windings connected to assist each other magnetically; Fig. 7 illustrates a pair of windings connected to oppose each other magnetically.

In all cases two windings are connected in parallel so that any magnetism and magnetic attraction produced is the resultant of two M. M. F.'s either opposed or assisting. The value of the M. M. F. of each winding is determined in any given coil by its ampere turns, hence by the amperes in the two windings. The current in each winding varies for direct current coils, inversely as the resistance of that winding, and for alternating current coils with substantially zero magnetic flux inversely as the resistance of each winding. For alternating current coils with magnetism in the core the currents do not vary inversely as the resistance of the windings but tend to split in the inverse ratio of the turns biased by the resistance of the windings. The effect of a pair of inductively coupled windings reacting on each other by electromagnetic induction and thereby tending to maintain the currents therein in the inverse ratio of their turns is well understood and is present in every transformer. An effect present in the slow electromagnetic devices of my invention, but not ordinarily present in a transformer, is the circulating current set up due to the parallel connection of the inductively coupled windings of my device. They are short circuited on each other and the circulating current is due to a higher voltage being generated in one than the other by the magnetism threading their windings.

If the windings are of equal turns but are threaded by different amounts of magnetic flux the circulating current will be present. If the flux threading both is the same, but the turns of the windings are unequal the circulating current will be present.

This circulating current is the result of mutual induction between the two windings and its intensity and relative direction may reverse as the windings go through their cycle of resistance changes and relative values of magnetomotive force. The circulating current will alter the current balance in the windings by its heating and electromagnetic effects, and may be utilized by a designer to affect the slow production of magnetism in devices shown herein.

A second effect of mutual induction in my devices is the unique phenomena of a winding having a lower impedance voltage across it than the amperes in that winding multiplied by its resistance. This occurs whenever one of two paralleled, inductively coupled windings is stronger magnetically than the other and the magnetism set up by the stronger winding, cutting through the weaker winding induces there-

in a voltage in a direction to assist the current flowing in the weaker winding. The net impedance voltage of that winding is the vector sum of its IR drop less the induced voltage, the result being less than the IR drop.

A third effect of mutual induction in my devices is that the rate of change in magnetism of the device as a whole is a mean between the rates of change in the two parallel paths. Since any change in current flowing in one path must be accompanied by a corresponding change in the other path by reason of the mutual induction therebetween, it follows that a slow change resistance element in one path will slow down the change produced by a fast change element in the other, and vice versa.

In the claims the parallel connection and inductive coupling included as part of the structure, in combination with the term "mutual induction between said windings" is to be understood as embracing all of the usual characteristics of inductively coupled windings plus the unique characteristics of circulating current and two other effects described.

From the foregoing it will be seen that changing the resistance of one or both of the windings will alter the current split and the net magnetism, whether on direct current, alternating current with no magnetism present or alternating current with magnetism present and with or without circulating current. One way of producing this result is to make the windings of materials having different temperature co-efficients of resistance. In this case heating affects the resistance of one conductor more than the other. (This is fully disclosed in my copending application Serial No. 416,877, filed December 27, 1929.)

It is not essential that the materials be of different temperature coefficients of resistance. If identical materials with a high coefficient are used, and one is heated more than the other, the resistance of the hotter conductor will rise more than that of the cooler one, alter the current split between them and consequently change the magnetism of the coil. Using the same coefficient materials give rise to advantages not present where radically different coefficient materials must be employed. For instance, for temperatures not exceeding its oxidation point, or where the heated wire is not exposed to oxidation, copper may be employed in both windings. It is inexpensive, commercially available in many sizes, and easy to handle. Due to its low specific resistance many more turns of copper can be employed for a given resistance than with other conductors, which is an important advantage in electromagnet design. The specific resistance of copper is 10.55 ohms per circ. mil. ft. A copper to copper coil may be more readily constructed than a coil where low coefficient materials such as one well known alloy with specific resistance of 675 ohms per circ. mil. ft. are used.

Where the temperatures are below the melting point of aluminum, aluminum and copper may be used, the aluminum for the hotter coil. Aluminum oxidizes but the oxide once formed is a non-conductor, very tough and elastic so that it does not scale off. For higher temperatures, copper and nickel may be used, the nickel in the hot coil. Nickel does not oxidize as does copper but is more expensive than aluminum or copper. Other metals may be used, depending on physical and commercial considerations. All ele-

mentary metals except mercury have a temperature coefficient of approximately .004 as shown in the following table, as given on pages 323, 324 and 325 of the Smithsonian Physical Tables for 1929:

Material	Temp.	Temp. coeff. of res.	Material	Temp.	Temp. coeff. of res.
Iala.....	25° C.	.000002	Aluminum.....	25° C.	.0034
Advance.....			Antimony.....	20° C.	.0036
Constantan.....			Bismuth.....	20° C.	.004
Calido.....			Cadmium.....	20° C.	.0038
Ideal.....			Calcium.....	20° C.	.0036
Climax.....	20° C.	.0007	Copper.....	20° C.	.00393
Excello.....	20° C.	.00016	Gold.....	20° C.	.0034
German silver.....	20° C.	.0004	Iron.....	25° C.	.0032
Manganin.....	25° C.	Zero	Lead.....	20° C.	.0039
Monel metal.....	20° C.	.0020	Magnesium.....	20° C.	.0040
Therlo.....	20° C.	.00001	Mercury.....	20° C.	.00089
			Molybdenum.....	25° C.	.0033
			Nickel.....	25° C.	.0043
			Palladium.....	20° C.	.0033
			Platinum.....	20° C.	.003
			Silver.....	20° C.	.0038
			Tantalum.....	20° C.	.0031
			Tin.....	20° C.	.0042
			Tungsten.....	18° C.	.0045
			Zinc.....	20° C.	.0037

It will be noted that the alloys are generally of lower coefficient than solid elementary metals. In the claims where I specify materials of equal or substantially equal temperature coefficients it is to be understood that all elementary metals except mercury are substantially equal to each other, but the solid elementary metals are not substantially equal to the alloys.

Coupled with the use of equal or substantially equal materials is the inherent necessity for producing a higher temperature in one conductor than in the other in order to produce a change in magnetism with time. There are many means of accomplishing this and while I have confined the illustrations to only a few of the forms which the slow electromagnet of my invention may assume, I desire that it be understood that in illustrating my invention in the several forms shown that I do not intend such illustrations to be intended in the limiting sense.

Figure 1 shows one arrangement, consisting in having the cooler winding 1 of copper adjacent the core 3 and wound and insulated as is common for electromagnets of the usual type. The carrying capacity of the conductor is made sufficient to insure its operation at the accepted temperature rise for electromagnets. The opposing winding 2 designed for higher temperature operation is wound over the other with suitable air spaces or heat insulation or both, or any other means to prevent the heat soaking through into the cool coil and to insure proper heat dissipation from both coils. Assume both coils of the same coefficient material and of the same specific resistance (copper to copper for instance) and also assume the conductors of the same cross section and total resistance. On direct current and on alternating current when balanced magnetically the currents in each of the windings will be equal. The energy expended in each winding will be equal. The heat is measured by the watt loss and the windings would rise to equal temperatures if all other factors were equal. In the coil described above, (Fig. 1) the outer winding may be made to rise to a higher temperature than the inner one by having materials of higher heat conductivity in contact with the inner than with the outer winding. The tubes 20 and 21 and headers 22 and 23 in contact with winding 1 may be of good heat conducting material such as brass or copper, while

the tube 24, in contact with winding 2 may be a poor heat conductor such as asbestos. This effect is assisted by the fact that the thermal conductivity of air is lower than that of practically all solid materials. Surrounding one winding with solid material of relatively good conductivity and large radiating surface while the other is mainly in contact with air is a practical means for producing a higher temperature in the winding surrounded by air, providing the cooling effect of air circulation is controlled in the design. Where design conditions require it, the air space 25 may be vented to the outside air, or in extreme cases, a forced draft of air may be introduced to keep winding 1 at a low temperature while winding 2 rises to a higher temperature. I have indicated openings or vents 22a and 23a in headers 22 and 23, respectively, through which a cooling current of air may pass between the rows of turns of the winding 1. The arrows and the legends indicate the passage of the air from the outside of the coil to winding 1 and out again.

A more pronounced difference results if the resistance of the two windings is changed by altering the turns, putting more on the inner coil and less on the outer coil, as illustrated in Fig. 2, leaving the materials and the wire sizes equal as before.

Another means of producing a higher temperature in one coil than in the other is by altering the ratio of the turns, that is, putting more turns on the inner coil and less on the outer coil, as shown in Fig. 2.

The current in the inner coil is decreased and the current in the outer coil increased due to the fact that the resistance of the many turn winding is greater than that of the few turn winding. If the total resistance and line current remain the same as before, the inner coil will have less and the outer more current than before. However their ampere turns will remain the same, since the change in turns is balanced by the opposite change in amperes in each winding. The increased current in the outer winding will speed its heating and cause it to rise to a higher temperature than before. As its resistance rises, the current split between the windings will be altered and the net magnetism will change. The temperature rise of the outer coil can be further increased by using a smaller conductor in it than in the inner winding, using the same material as before (copper to copper for instance). Extra turns will need to be added to the inner coil or turns removed from the outer coil to insure that the light wire gets enough current to insure its heating.

I may vary the arrangement from that described above in various ways. In Fig. 3 the hot winding 2 is located adjacent the core and may be with or without an air space 7 and heat insulation 9 between the inner and outer windings and the core. The two windings may be alongside each other on the core, Fig. 4, or be arranged as alternate pancakes on the core as shown in Fig. 5. A coil may contain more than two windings, one or more of which tend to produce a magnetomotive force in one direction while one or more opposing windings are tending to produce an opposite magnetomotive force.

When different coefficient materials are used and the ambient temperature changes, the resistance of one winding is affected more than the resistance of the other. If, however, the temperature coefficients are substantially equal a change in ambient temperature eventually af-

fects both windings substantially alike. A slow electromagnet or reactor employing the same coefficient materials in both windings will be substantially unaffected by ambient temperature changes, provided the ambient temperature changes are slow enough, and the thermal conductivity from both windings to the ambient medium is good enough, to avoid a material temperature difference between windings during the change. This is an important advantage in coils whose time element must be independent of ambient temperature changes.

It is well known that an increase in the inductive reactance of an alternating current coil lowers its power factor, while an increase in resistance raises its power factor. By constructing a coil of properly proportioned materials, the increase in inductive reactance and the corresponding increase in resistance may be made to result in a substantially constant power factor. This is of advantage in coils operating in circuits where it is undesirable to lower the power factor when the magnetism of the coil is increased.

In general the watts dissipated per unit area of surface is a measure of the temperature which that surface will attain. Coils which operate at one half watt per square inch of radiating surface will generally not rise higher than 50° C., whereas coils with 7 watts per square inch of radiating surface will rise to approximately 300° C. One definition of a slow electromagnet or reactor using the same or similar temperature coefficient materials in the differential windings is one dissipating a watt per square inch of surface or less in one winding and more than a watt per square inch of surface in the other.

The time of operation of a slow electromagnet or reactor employing materials in the differential windings of the same or similar temperature coefficient of resistance will in general be fixed by the time required for its hot winding to reach a definite temperature. The maximum temperature is fixed by the ratio of the energy dissipated to the area of the dissipating surface, but the time is a function of the mass to be heated. For instance the wire of a winding alone will have a definite area and thus rise to a definite temperature, the wire being practically all in contact with the surrounding air only. If this same wire is buried in a solid mass of material having the same surface area as the wire, it will rise to the same temperature, but the time required will be increased due to the time required to heat the mass as against the time to heat the wire alone. By largely increasing the mass in which the wire is buried but not increasing its radiating surface in proportion, the time of operation may be largely increased.

The term "leakage reactance" is used to measure the leakage magnetism in a two coil transformer or other magnetic device, that is, the magnetism originating in one coil but not linking with the other. In slow electromagnets or reactors it is important to keep this leakage at a low value. To accomplish this I may entirely surround one winding with the other.

It is standard practice in transformer and other constructions to wind one coil over another, but not to surround one with the other on all sides. With a slow electromagnetic device, constructed as disclosed herein, it is not ordinarily essential that all flux originating in one winding thread the other, but in cases where the result is hard to attain due to a relatively small temperature difference, a low amount of energy available for

operation, or any other cause, it is desirable to employ all available magnetism in producing the difference between the cold and hot condition. In such a case, any of the means shown herein or in my copending application Serial No. 12,292, for Slow electromagnetic devices with substantially complete flux interlinkage between parallel connected windings, may be employed to reduce the leakage reactance of the device.

If the windings take the form of alternate pancakes on a core as in Fig. 5, in the form of my invention wherein an armature 3a is moved by the magnetic condition of core 3, the barriers 14 between the windings may be heat insulating barriers.

The action of heat diffusion may be taken advantage of in slow electromagnets or reactors to produce a secondary action subsequent to the primary action of the coil. To illustrate, assume the electromagnet of Fig. 1 designed to attract its core 3 against a load, not shown, when the temperature difference between windings 1 and 2 reaches 250° C. When current first passes, the windings are cold and begin to heat at a very slow rate and then at a rapid rate. The difference soon reaches 250° C. and the core is pulled in. If the current is maintained, the heat from winding 2 will diffuse itself partly through winding 1 and will tend to equalize the temperature of the two windings. If they are of the same or similar coefficient materials, the magnetic effect will drop and, if the core is under a load such as a spring or gravity tending to pull it out, the coil strength will reach a point at which the core will be pulled out.

If applied to a reactor, transformer, or other electromagnetic device the magnetism will alter in the same way as above described and affect the inductive drop or secondary voltage correspondingly. Coils of this type will have two time elements, (1) the initial heating time to produce a definite difference in temperature between windings and (2) the secondary time of diffusion reversing the previous effect and tending to restore the magnetism to its initial value. With differently proportioned windings, the coil shown in Fig. 1 may have its maximum magnetism when cold and lose it as it heats. In this case the core 3 would be sucked in at once when current was turned on, released on initial heating and drawn in again as the heat diffuses through the windings. A corresponding effect may be produced in a slow reactor, transformer, or other device giving an electromagnetic effect.

The slow electromagnet of Fig. 1 may be wound so that the magnetism is zero when it is partly heated. Assume that when cold, winding 2 is stronger, that is, has more ampere-turns than winding 1, the core 3 will be pulled in initially. When partly heated, to say 125° C. difference, windings 1 and 2 equalize magnetically, the core will be released. The heating continues, winding 2 becoming weaker, and a point is reached say at 250° C. difference, where the core 3 is sucked in again due to winding 1 overpowering winding 2 sufficiently to do so. If to this effect heat diffusion is added, the cycle of operations just described will be reversed. The core 3 will first be released as the temperature difference drops from 250° C. to 125° C. and will be attracted again as the difference falls sufficiently under 125° C. The same cycle of magnetism may be produced in slow reactors or transformers.

It will thus be seen that slow electromagnets or reactors utilizing the same or similar tempera-

ture coefficient of resistance materials in the differential windings may be produced with many different time characteristics of which the following are illustrations:

1. Increase in magnetism, time fixed by heating.
2. Decrease in magnetism, time fixed by heating.
3. Decrease in magnetism to zero, then increase in the opposite direction, time fixed by heating.
4. Increase in magnetism, time fixed by heating, subsequent decrease in magnetism, time fixed by diffusion.
5. Decrease in magnetism, time fixed by heating, subsequent increase in magnetism, time fixed by diffusion.
6. Decrease in magnetism to zero, then increase in the opposite direction, time fixed by heating, subsequent decrease in magnetism to zero, and increase in the initial direction, time fixed by diffusion.

With an electromagnet or reactor designed to operate, as in case 6, the magnetism will pass through four distinct cycles with the coil constantly connected and current flowing in it.

Fig. 6 shows the connection of two windings 1 and 2 arranged to draw current from a pair of lines 8 and both wound over the same core 3. They are shown side by side for convenience but may be arranged in any suitable manner. Connected as shown, their magnetic effect on the core will be additive as indicated by the N and S markings, signifying north and south magnetic poles. I have indicated a movable armature member 3a adjacent the end of the core structure 3.

If the same windings are connected as shown in Fig. 7, the magnetic effect on the core will be subtractive, that is, they will be in magnetic opposition. For uses where it is not essential that the magnetism reduce to zero when current is flowing in the windings the coils may be connected to assist each other magnetically as in Fig. 6. The movable armature 3a has been indicated adjacent the end of the core structure 3. To illustrate the change in net magnetism (measured by the ampere turns) with a pair of windings as shown in Figs. 6 and 7, first assisting each other and then opposed, a tabulation is given below:

	Assisting				Opposed			
	Windings cold		One winding heated		Windings cold		One winding heated	
	#1	#2	#1	#2	#1	#2	#1	#2
Turns.....	1	2	1	2	1	2	1	2
Ohms.....	1	2	2	2	1	2	2	2
Amperes*.....	2	1	1.5	1.5	2	1	1.5	1.5
Ampere-turns.....	2	2	1.5	3	2	2	1.5	3
Combined ampere-turns.....	2+2=4		1.5+3=4.5		2-2=0		-3+1.5=-1.5	

*Current held constant at total of three amperes.

It will be seen in the above table that when the resistance of one winding increases and the total current through the device is kept constant, the net ampere-turns of the coil increase whether the windings are assisting or opposing each other, but in the former case there is a relatively heavy magnetization cold (4 ampere-turns) and a relatively small increase when heated (.5 ampere-turns), whereas in the latter case there is zero magnetization cold and rela-

tively heavy magnetization (1.5 ampere-turns) when heated to the same degree.

Slow electromagnets or reactors may be constructed with paralleled windings which assist each other magnetically, whether the materials of which the windings are composed have different temperature coefficients or the same or similar temperature coefficients of resistance. In the former case, the windings may be heated to the same temperature and function, but in the latter case, the windings will need unequal heating in order to function. Equal or unequal turns and initial resistances will function to alter the magnetism with time either up or down as described above for windings made of the same or similar coefficient materials.

In the claims I have referred to diffusion of the heat from one winding into the other. In providing for such diffusion the heat insulation or air space which I have represented for example at 7 and 9 in Fig. 3 is omitted. In this arrangement winding 1 is wound directly over winding 2 and heat from winding 2 will necessarily have to soak out through winding 1, thereby introducing diffusion means and heating means by which to cause the magnetism of the coil to pass through four cycles of change with time, first a decrease from an initial value to zero, second, a subsequent increase in the reverse direction, both being the result of unequal heating of the winding, third, a subsequent decrease to zero, and fourth, an increase in the initial direction as the result of heat diffusion between windings.

Coils may be utilized for all purposes as disclosed in my copending application Serial No. 416,877, for electromagnets which move a plunger or keeper or for extinguishing arcs as in a magnetic blowout.

I have described my invention in certain preferred embodiments, but I desire that it be understood that modifications may be made and no limitations upon my invention are intended other than are 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 electromagnet comprising a pair of magnetically coupled and opposed windings disposed in parallel with each other, said windings being formed of metals having substantially equal positive or negative temperature coefficients of resistance, means to raise the temperature of one winding more than the other, thermal conducting means other than air disposed between the two windings, the changes in relative resistance of said windings with temperature changes constituting means to cause the opposed magnetomotive forces of the windings to equalize at more than the minimum but less than the maximum temperature of the hotter winding.

2. A slow electromagnet comprising a pair of magnetically coupled and opposed windings disposed in parallel with each other, said windings being formed of metals having substantially equal positive or negative temperature coefficients of resistance, means to raise the temperature of one winding more than the other, thermal conducting means other than air disposed between the two windings, the resistances of said windings proportioned so that the winding for high temperature operation is weaker magnetically when the temperatures of both are the same, stronger magnetically when the temperature difference is greatest, and equal magnetically at a point between these extremes.

3. A slow electromagnet comprising a pair of

inductively coupled windings connected in parallel one with respect to the other, said parallel paths including only materials having substantially equal temperature coefficients of resistance other than zero, said windings being mounted on a core of magnetic material having a movable portion, and means for causing substantial disproportionate changes in resistance of said parallel paths by substantial disproportionate temperature changes therein, while energized, the movement of said core, changes in impedance of said device, and changes in the mutual induction between said inductively coupled windings, mutually cooperating to alter the magnetism of said device.

4. An electromagnetic device comprising a pair of inductively coupled windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, one winding having a lower resistance than the other winding at ambient temperature, constituting means, when energized, to cause a larger initial current flow into the lower resistance winding sufficient to heat said windings to substantially different temperatures, to alter their resistances disproportionately to a substantial extent, and alter the magnetism of said device.

5. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, one winding having fewer turns than the other, said windings when energized producing substantially zero magnetism with both windings at ambient temperature, the relative resistance of said windings proportioned to cause disproportionate heating and disproportionate changes in resistance, to alter the current split in said windings, to produce magnetism, to further alter said current split by transformer action between said windings, to further alter the magnetism of said device.

6. An electromagnetic device comprising a pair of windings on a core of magnetic material, said core having a movable portion, said windings being connected in parallel, arranged and connected for inductive coupling, said windings both being formed of materials having the same temperature coefficients of resistance other than zero, and means for causing substantial disproportionate changes in resistance of said windings by substantial disproportionate temperature changes therein when energized, to alter the magnetism of said device and to move said movable portion.

7. An electromagnetic device as in claim 3 in which the means for causing substantial disproportionate temperature changes in said windings comprise unequal heat dissipation means so that with equal amounts of energy liberated in the two windings, said windings will rise disproportionately in temperature.

8. An electromagnetic device as in claim 3 in which the means for producing disproportionate temperature changes in said windings includes in one winding heat radiating surface to permit no more than .5 watt to be consumed in said winding per square inch under maximum load conditions, and includes in the other winding heat radiating surface to permit 7 watts per square inch, or more, to be consumed in said winding under maximum load conditions.

9. An electromagnetic device as in claim 3 including artificial cooling means for one winding only.

10. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, one winding having fewer turns than the other, said windings proportioned, when energized with alternating current, to produce magnetism with both windings at ambient temperature, the inductive coupling of said windings biasing the current values in said windings, by the effects of mutual induction therebetween, away from the inverse ratio of their resistances toward the inverse ratio of their turns, to thereby produce a different cycle of heating and magnetism than if the currents divided in the inverse ratio of the resistances.

11. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, the relative resistances of said windings proportioned to produce disproportionate heating and disproportionate resistance changes therein when energized, heat insulation between windings to permit partial heat diffusion from the hotter winding to the cooler winding, said heat insulation proportioned to permit substantial temperature equalization between windings until the total current in said windings exceeds a predetermined critical maximum above which the heat flow through said insulation is insufficient to balance the temperatures, currents greater than said critical maximum serving to produce disproportionate changes in resistance in said windings to alter the magnetism of said device.

12. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, the relative resistances of said windings proportioned to produce disproportionate heating and disproportionate resistance changes therein when energized, heat insulation between windings to permit partial heat diffusion from the hotter to the cooler winding, said heat insulation proportioned to prevent temperature equalization between windings until a predetermined temperature difference has been maintained for a predetermined time, temperature equalization at the end of said time serving to substantially nullify said disproportionate temperature and resistance change and restore initial magnetic conditions.

13. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, said windings having means to radiate part of the heat generated in each winding into the atmosphere without passing through the other winding and with insulation means to regulate the quantity of heat diffusion between windings, the relative resistances of and currents in said windings, when energized, producing substantial disproportionate temperature changes, substantial disproportionate resistance changes, and changes in magnetism of said device, the ratio of said radiated heat to said diffused heat serving to subsequently alter

the relative temperatures and resistances of said windings and the magnetism of said device.

14. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, one winding having fewer turns than the other, the fewer turn winding having a greater resistance than the other at ambient temperature, said windings proportioned, when energized with alternating current, to produce magnetism with both windings at ambient temperature, the inductive coupling of said windings biasing the current values in said windings, by the effects of mutual induction therebetween, away from the inverse ratio of their resistances toward the inverse ratio of their turns, to thereby produce a different cycle of heating and magnetism than if the currents divided in the inverse ratio of the resistances.

15. An electromagnetic device comprising a pair of inductively coupled and opposed windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, one winding having fewer turns than the other, the fewer turn winding having a lesser resistance than the other at ambient temperature, the relative resistances of said windings proportioned when energized with alternating current, to cause disproportionate heating and disproportionate changes in resistance to alter the current split and the magnetism of said device, the inductive coupling of said windings biasing the current values in said windings, by the effects of mutual induction therebetween, away from the inverse ratio of their resistances toward the inverse ratio of their turns, to thereby produce a different cycle of heating and magnetism than if the currents divided in the inverse ratio of the resistances.

16. A slow electromagnet comprising a pair of inductively coupled windings connected in parallel one with respect to the other, said windings and said parallel paths including only materials having substantially equal temperature coefficients of resistance other than zero, said windings being mounted on a core of magnetic material having a movable portion, and means for causing substantial disproportionate changes in the resistance of said parallel paths by substantial disproportionate temperature changes therein, while energized, the movement of said core, changes in impedance of said device, and changes in the mutual induction between said inductively coupled windings mutually cooperating to alter the magnetism of said electromagnet.

17. An electromagnetic device comprising a pair of inductively coupled windings connected in parallel one with respect to the other, said windings being formed of materials having the same temperature coefficients of resistance other than zero, one winding having a lower resistance than the other winding at ambient temperature, constituting means, when energized, to cause a larger initial current flow into the lower resistance winding than into the other, to heat said windings disproportionately, to alter their resistance disproportionately, to effectively alter the magnetism of said device, and the resultant voltage induced in any winding threaded by said magnetism.

18. An electromagnetic device comprising a pair of windings on a core of magnetic material, said core having a movable portion, said windings being connected in parallel, arranged and connected for inductive coupling, said windings both being formed of materials having the same temperature coefficients of resistance other than zero, and means for causing substantial disproportionate changes in resistance of said windings by disproportionate temperature changes therein when energized, to alter the magnetism of said device, the resultant voltage induced in any winding threaded by said magnetism, and to move said movable portion.

19. An electromagnet having a movable core, two windings comprising a first winding adjacent the core and a second winding outside the first winding, said windings being composed of solid elementary metals and magnetically coupled and connected in parallel, and thermal means adjacent the windings, said thermal means and windings being proportioned as to current loading and heat dissipation to produce a flux distribution operative to move the core by maintaining the first winding with temperature rise of less than 50° C. and producing in the second winding a temperature rise exceeding 50° C. consequent to the energization of the electromagnet.

20. An electromagnet having a movable core, two windings comprising a first winding adjacent the core and a second winding outside the first winding, said windings being composed of solid elementary metals and magnetically coupled and connected in parallel for magnetically assisting each other, and thermal means adjacent the windings, said thermal means and windings being proportioned as to current loading and heat dissipation to produce a flux distribution operative to move the core by maintaining the first winding with temperature rise of less than 50° C. and producing in the second winding a temperature rise exceeding 50° C. consequent to the energization of the electromagnet.

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