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3,421,949
COMPOSITION AND PROCESS FOR PRODUCING AN ELECTRICALLY RESISTANT COATING ON FERROUS SURFACES

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No Drawing, Filed Aug. 12, 1964, Ser. No. 389,178
 U.S. Cl. 148-6.2
 Int. Cl. C23c 1/10

9 Claims

ABSTRACT OF THE DISCLOSURE

A composition and process for forming an electrical resistant chemical coating of the non-conversion type on ferrous metal. The coating composition used contains a source of hexavalent chromium, such as CrO₃; a source of silicons such as SiO₂; and an organic reducing material, such as polyacrylic acid. Additionally, the composition may also contain aluminum, such as Al₂O₃ and iron, such as ferrous or ferric acetate. The composition, as an aqueous solution or dispersion is applied to the metal surface, the surface heated to cure the coating and, thereafter, the treated surface is annealed.

This invention relates to an improved composition and process for producing coatings on metal surfaces and more particularly relates to improved compositions and processes for producing heat-resistant electrical insulation coatings on ferrous surfaces.

In the processing of metals, such a strip steel for electrical and magnetic uses, such as for forming magnetic cores for stators, rotors, transformers and the like, it is desirable that the laminations of which the core is formed be provided with electrical insulation between one another in order to minimize eddy current and to achieve low losses. Desirably, this insulation should be in the form of an extremely thin film, generally not more than about 1 percent by volume of the total core, so as to conserve space in the manufactured unit. Additionally, the insulating film applied to the laminations should be capable of withstanding the elevated temperatures which are encountered in annealing the laminated cores after assembly in order to relieve strains or stresses in the core and improve their efficiency. Typically, the temperatures encountered in such annealing operations are in the range of about 1000 to 1200 degrees centigrade and are rarely less than about 600 degrees centigrade.

In forming core structures, the desired shapes are generally punched or stamped from a sheet or strip of steel which has been coated on both sides with the insulating material. These shapes, which are laminates of plates of steel, are then assembled into the desired core shape, often being stacked, bent, and/or wound, during the course of the assembly operation, to produce the predetermined core structure. Moreover, the assembled cores may be subjected to machining or grinding operations and in some cases, even etching with acid in order to remove burrs and other surface defects. Accordingly, it is further desirable that the insulating film on the steel sheets or strips from which the shapes or laminates are formed be capable of withstanding the various bending, scraping and other mechanical abuse or chemical treatment which may be encountered in forming the core structure. Additionally, it is desirable that the coating material be as nonabrasive as possible in order to prolong the life of the dies used in the punching or stamping operations.

Generally, the aforementioned strain or stress annealing of the core structures is carried out on the stacked laminate plates so that it is desirable that little or no sticking of the plates occurs during the annealing operation.

Any sticking which takes place interferes with the efficiency of the core unit inasmuch as at the stick points, the conductivity of any currents results in electrical energy loss and an overheating of the unit. Where such sticking does occur, hand labor is generally required to break or crack the fused or stuck points, often by hitting them with a hammer. It is, therefore, desirable that the insulating coating used, in addition to fulfilling the above-mentioned criteria and providing satisfactory electrical resistance, also prevent or at least are substantially resistant to sticking during the annealing operation.

In the past, many and diverse coating compositions have been proposed for use in forming electrical resistant coatings on metal surfaces, such as steel. Many of these coatings have been of the phosphate type and particularly reactive phosphate coatings wherein the coating material reacts chemically with the surface of the metal being treated to form with the metal an integral coating. Up to the present time, however, none of the coating compositions which have been proposed by the prior art have satisfactorily met all of the criteria as indicated hereinabove and have still been easily and economically applied to the steel surface, using different coating techniques, including roll coating, spraying and the like.

It is, therefore, an object of the present invention to provide an improved composition for producing electrical resistance coatings on metal surfaces and particularly ferrous metal surfaces.

A further object of the present invention is to provide an improved method for applying electrical resistant coating compositions to ferrous metal surfaces.

Another object of the present invention is to provide an improved electrical resistance coating for ferrous metal surfaces, which coating is characterized by its ability to prevent sticking of core laminates or plates during annealing or other high temperature treatment.

These and other objects will become apparent to those skilled in the art from the description of the invention which follows:

Pursuant to the above objects, the present invention includes a composition having electrical resistance properties when applied to a metal surface, which composition comprises a source of hexavalent chromium, a source of silicon and an organic reducing compound containing at least one reactive group which is oxidizable by hexavalent chromium. When this composition, desirably as an aqueous solution formed by dissolving the composition in water, is applied to a metallic surface, so as to form a thin film of the composition on the surface, and the surface is thereafter subjected to a heat cure the thus-treated surface is found to have excellent electrical resistance properties and a number of coated sheets or plates stacked one on top of the other are found to be substantially free of sticking after a high temperature heat treatment.

More specifically, the composition of the present invention comprises a source of hexavalent chromium in an amount within the range of about 0.2 percent to about 22 percent and preferably within the range of about 0.6 percent to about 6.0 percent, a source of silicon, calculated as SiO₂, within the range of about 0.15 percent to about 15 percent and preferably within the range of about 0.5 percent to about 2.0 percent and an organic reducing compound, containing at least one reactive group which is oxidizable by the hexavalent chromium, in an amount within the range of about 0.08 to about 8 percent and preferably in an amount within the range of about 0.3 percent to about 2.0 percent. This composition may be prepared as a concentrate containing water in an amount within the range of about 45 to about 98 percent and may then be diluted with water to obtain the desired operating composition to apply to the surfaces to be treated.

Dilution ratios of water to concentrate of about 4:1 to about 1:3 are typical. The method of application and the physical properties of the components of each particular composition will determine the various amounts of the components in both the concentrate and the operating solution. Moreover, for a particular method of applying the coating, the concentration of the operating solution will determine the coating weight obtained on the metal surface.

The source of hexavalent chromium in the present composition may be any of various suitable hexavalent chromium compounds, such as chromic trioxide, or chromic acid, as well as many of the water-dispersible and/or water-soluble derivatives of chromic acid, including chromate and dichromate salts. Particularly satisfactory results have been obtained when using chromic trioxide or chromic acid or ammonium, chromium, cadmium, manganese, strontium, or aluminum dichromates. Other sources of hexavalent chromium which may be employed, however, include the chromates and dichromates of magnesium, the water-soluble alkali metal chromates and dichromates, ammonium chromates and dichromates and the alkaline earth metal chromates and dichromates. It is to be appreciated, that as is used hereinafter in the specification and claims, the term "alkali metal" is intended to refer to lithium, sodium, potassium, cesium, and rubidium. Additionally, the term "alkaline earth metal" is intended to refer to calcium, barium, as well as strontium, and manganese which have been indicated hereinabove. In many cases, the preferred source of hexavalent chromium has been found to be chromic acid, or as it is sometimes referred to, chromic trioxide and for this reason, hereinafter specific reference will be made to this material. This is not, however, to be taken as a limitation on the present invention but merely as being exemplary of the hexavalent chromium sources which may be used.

With regard to the organic reducing compound which contains at least one reactive group which is oxidizable by the hexavalent chromium, reactive groups which may be contained in these compounds include carboxyl groups, hydroxyl groups, amino groups, amido groups, oxy groups, nitrile groups, aldehyde groups, unsaturated groups containing carbon to carbon double bonds, and the like. It is to be appreciated, that the above named groups are merely exemplary of those which these organic reducing compounds may have and are not to be taken as a limitation on such groups. Typical examples of organic reducing compounds which may be used include phenolic resins, including the aldehyde-phenolics, vinyl resins containing oxy and hydroxy groups, polymethacrylates, ammonium polyacrylates, polyacrylic acids, polyacrylic acid derivatives such as those containing amino, amido, nitrile, aldehyde groups and the like, as well as polyalcohols, and the like. Specific vinyl resins of the type which are satisfactory are the polyvinyl alkyl ethers having from about 1 to about 4 carbon atoms in the alkyl groups and copolymers of methyl vinyl ether and maleic anhydride. The polyvinyl alkyl ethers specifically include polyvinyl methyl ether, polyvinyl ethyl ether, polyvinyl isobutyl ether, and the like. Typically, the copolymers of methyl vinyl ether and maleic anhydride are formed of alternating methyl vinyl ether and maleic anhydride units and are polymerized to a specific viscosity in the range of about 0.2 to about 3.5. Exemplary of the polyacrylic acid derivatives which may be used include polyacrylamide, polymethacrylamide, polyacrylic aldehyde, polyacrylic nitrile and the like. Additionally, as has been indicated hereinabove, polymethacrylate, ammoniated polyacrylates and polyacrylic acid itself may also be used. Exemplary of the organic polyalcohols which may be used as the organic reducing compounds, are sucrose, invert sugar, dextrose, glycols, polyglycols, such as diethylene glycol, glycerine, manitol, sorbitol, and the like. It will be appreciated, that in many

instances satisfactory results have been obtained using polyacrylic acid as the organic reducing compound and for this reason, primary reference will be made hereinafter to polyacrylic acid. This is not, however, to be taken as a limitation on the organic reducing compounds which may be used but merely as being exemplary of these compounds.

With regard to the source of silicon, various water soluble or water dispersible silicon compounds may be used. Exemplary of such compounds are silica, and particularly colloidal silica, silicic acid, natural silicon products, such as the kaolins, micas, feldspars, and the like. In many instances, particularly satisfactory results have been obtained when using colloidal silica as the source of silicon in the present composition so that hereinafter, specific reference will be made to colloidal silica as the preferred silicon source. This is not, however, to be taken as a limitation on the silicon materials which may be used but merely as being exemplary thereof.

In addition to the source of hexavalent chromium, the silicon source and the organic reducing compound, it has been found that in some instances desirable properties are imparted to the electrical resistance compositions of the present invention by also including therein other components or adjuvants. Exemplary of such additional components are the metals of Groups II-A, II-B, VI-B, VII-B and VIII of the Periodic Table and the metals of Groups III-A, IV-B and V-B of the Periodic Table. Typical of the metals in the first of these groupings which may be used are iron, trivalent chromium, manganese, nickel, cobalt, cadmium, zinc, and the alkaline earth metals, i.e., calcium, barium, magnesium and strontium and the like. Of these, the preferred is iron and primary reference thereto will be made hereinafter. Typical of the metals in the second of these groupings which may be used are aluminum, titanium, zirconium, vanadium, niobium, and the like. Of these, the preferred is aluminum and hereinafter, primary reference will be made thereto.

Desirably, as with the other components of the composition, such adjuvants are added to the composition in a form which is water soluble or readily water dispersible, so as to minimize any settling out or stratification of the various ingredients of the composition. Accordingly, the additive metals in both groupings may be added in any such water soluble or dispersible form wherein the anion added with the metal does not have a detrimental effect on the composition itself, the metal treated or the electrical resistance coating produced.

With regard to aluminum and the metals grouped therewith, these are preferably added as the hydroxides or oxides, such as aluminum oxide (Al_2O_3) or the like, although other compounds may also be used. For example, where the silicon source used is a natural product, such as the feldspars, micas or kaolins, the aluminum will be added in this form. When using these natural products, however, it may be desirable to effect at least a partial removal of alkali metal ions therefrom, as by ion exchange techniques, before incorporating them in the composition, as in some instances the natural water solubility of these ions have been found to be undesirable in the coatings formed. Typically, the aluminum or similar metal grouped therewith, when used, is present in an amount within the range of about 0.1 to about 3 percent by weight of the composition and preferably within the range of about 0.2 to about 1 percent.

With regard to the iron and the metals grouped therewith, these are preferably added as the salts of weak acids, such as the acetates, formates, oxalates, citrates, carbonates and the like although other compounds such as the oxides, hydroxides and the like may also be used. Where iron is the metal from this grouping used, it is preferably added as a ferrous iron compound rather than ferric. In some instances, the metal itself may also be used, although

in these cases, a weak acid is normally also added so as to form the preferred weak acid salt in situ. Typically, the iron or similar metal grouped therewith, when used, is present in an amount within the range of about 0.02 to about 0.5 percent by weight of the composition and preferably within the range of about 0.05 to about 0.3 percent.

In many instances, the presence of acetate ions in the composition have also been found to impart desirable electrical resistance and anti-sticking properties to the coating formed on the metal surface. For this reason it is preferred that an acetate and preferably iron acetate (ferrous acetate) be used in forming the present composition. Desirably, the acetate ions are present in an amount within the range of about 0.1 to about 5 percent by weight of the composition and preferably within the range of about 0.2 to about 0.6 percent.

A particularly preferred composition, in terms of its ability to provide the desired electrical resistance on a metal surface when it is applied thereto and to resist sticking when metal surfaces coated therewith are stacked one on top of the other during a heat treatment, is one formulated from the following components in amounts within the ranges indicated:

	Percent
Polyacrylic acid -----	0.3 to 3.0
Chromic acid -----	0.4 to 2.2
SiO ₂ -----	0.3 to 1.6
Alumina (Al ₂ O ₃) -----	0.15 to 1.0
Ferrous acetate -----	0.10 to 0.80
Water -----	Balance

Desirably, as will be pointed out in more detail herein-after, such compositions are applied so as to obtain a coating weight on the treated metal within the range of about 20 to about 300 milligrams per square foot and preferably within the range of about 50 to about 150 milligrams/square foot. A specifically preferred composition, which has been found to be suited for application by roll coating, using a knurled roll, to obtain a coating weight within the preferred range is as follows:

	Percent
Polyacrylic acid -----	1.5
Fe -----	0.08
Acetic acid -----	0.2
CrO ₃ -----	1.1
Al ₂ O ₃ .H ₂ O (30.5% Al) -----	0.72
SiO ₂ (as a 30% aqueous solution) -----	2.5
Water -----	Balance

In formulating the compositions of the present invention, and in particular those compositions such as the preferred materials as indicated hereinabove which contain components which have a limited water solubility, it is desirable to combine the various components of the composition in such a way that the less water-soluble materials will be maintained in suspension in the composition so as to minimize stratification or settling of solids in the composition. One method of effecting this involves forming a solution of alumina dissolved in concentrated chromic acid by adding the alumina to a water solution of the chromic acid with stirring. Thereafter, a second solution is formed by adding the ferrous acetate to an aqueous solution of the polyacrylic acid while rapidly stirring the solution to avoid coagulation and then slowly adding the dilute solution of silica while continuing rapid stirring or homogenization, to avoid coagulation. The two solutions are then combined to form the coating composition of the present invention, which combined solution may be further diluted with water, as has been indicated above, to obtain a coating solution of the concentration desired, depending upon the particular technique for applying the solution to the metal surface which is to be used. The use of rapid stirring or homogenization has been found to be beneficial in obtaining a non-

stratified composition when used for the preparation of both the concentrate and the working solution.

In applying the coating compositions of the present invention, various application techniques may be used. For example, the compositions may be sprayed on the metal to be coated or they may be applied by roller coating techniques. Because of the desirability of obtaining a relatively thin film of coating material on the metal surface, coating techniques such as immersion and flooding, or flow coating, wherein large quantities of the coating material are brought into contact with the surface to be coated will generally not be used. Where, however, means are provided to remove the excess amounts of coated material from the metal surface so as to obtain the desired thin film, for example, by a squeegee, application techniques such as immersion, flow coating and flooding may be used. In general, however, spraying or roll coating application techniques are preferred since by these methods the amount of coating material applied to the surface is more easily controlled to obtain the thin film which is desired in order to conserve space in the ultimate core assembly.

When using the roll coating techniques, it has been found to be preferable to use a knurled or grooved applicator roll, rather than a smooth roll. Desirably since knurled or grooved roll has at least about 15 grooves or knurls per linear inch and, preferably, has 24 or more gooves per linear inch. It has been found that in order to provide the desired electrical resistance to the metal surfaces coated with the subject composition, a coating weight of at least about 20 milligrams per square foot should be provided on the metal surface. Generally, it is desirable that the amount of coating applied to the metal surface does not exceed about 300 milligrams per square foot in order to maintain the desired saving of space in the assembled core. Accordingly, coating weights within the range of about 50 to about 150 milligrams per square foot are preferred.

In typical operation, the coating composition of the present invention is applied to a strip of steel which strip may be in coiled form, or may be treated as it comes from the strip-forming operation in the steel mill. Obviously, where the strip is coiled, it will first be uncoiled before the compositions of the present invention are applied thereto. Typically, the temperature of the strip will be from about room temperature up to about 70 degrees centigrade, depending upon whether the strip is treated as it is formed in the mill operation or whether it has been coiled first and stored for treatment at a later time. The compositions of the present invention are applied to the steel strip using one of the aforementioned preferred application techniques, such as spraying or roller coating, to obtain a film of the desired coating weight on both the top and bottom surfaces of the strip. After the desired coating has been obtained on the strip, it is heated to a temperature within the range of about 90 to about 430 degrees centigrade for a period of time sufficient to effect a curing of the film on the strip. The time needed to effect this curing will, of course, depend upon the curing temperatures used, times of about 15 seconds to about 3 minutes being typical with curing temperatures within the range of about 150 to about 595 degrees centigrade. Thereafter, the strip coated with the cured film of the present composition is subjected to an annealing operation wherein the strip is heated at temperatures within the range of about 760 to about 1150 degrees centigrade for a period of time within the range of about 1 hour to about 3 hours, annealing temperatures of about 1040 degrees centigrade for about 1 hour being typical. If desired, this annealing step may be carried out on the steel strip after it has been recoiled or the strip may be uncoiled and annealed in long horizontal towers. After annealing, the coil or the recoiled strip is then shipped to the customer who uncoils the strip and stamps or punches the

desired core plates from the strip. These plates are then assembled by stacking them and welding them or are merely stacked for future assembly and are then subjected to a second annealing operation to relieve the stresses which are produced by the stamping operation. Typically, both of the above annealing operations are carried out in a so-called neutral gas atmosphere in a gas fired annealing furnace using six parts of natural gas to one part of air. After the second annealing operation, carried out by the ultimate fabricator of the core assemblies, the annealed stacks of core plates or laminates are assembled into the final cores for stators, rotors, transformers or the like.

By carrying out the process of the present invention in the manner as has been described hereinabove, and using the compositions of the present invention as have been described, it is found that there is obtained on the steel articles treated a coating having excellent electrical resistant properties. Additionally, it is found that there is substantially no sticking of the coated metal during either of the annealing operations, whether the coated

30 seconds to about 45 seconds. Thereafter, laminates or plates for electrical motor rotors and stators were punched out of the thus coated steel strip. These laminates were then stacked in the desired form for the finished rotor or stator, annealed at a temperature within the range of about 880 degrees to about 1100 degrees centigrade, in a non-oxidizing atmosphere. The thus-annealed laminate stacks were then tested for electrical resistance using the American Society for Testing Materials (ASTM) Method B of A344-60T. Additionally, the amount of sticking of the laminates was noted. Using the above procedure, the following results were obtained. In these examples, it is to be noted that the balance of the compositions to make up 100 percent by weight is water. Additionally, the electrical resistance values are given in amperes as Franklin Test Values and the resistance, in ohm centimeters squared is determined from the formula:

$$R = \frac{6.45}{I} - 6.45$$

Examples	Hexavalent chromium: source, type and amount, percent by weight	Organic reducing compound, type and amount, percent by wt.	Silicon source, type and amount, percent by weight	Other additives, type and amount, percent by weight	Franklin test value, amperes	Sticking
1.....	CrO ₃ , 2.18.....	Polyacrylic acid (M.W. 50,000), 0.74.....	SiO ₂ , 1.5.....	A, 1.44; F, 0.17; L, 0.40.....	0.30	None
2.....	Same as 1.....	Polyacrylic acid (M.W. 150,000), 0.52.....	Same as 1.....	Same as 1.....	0.32	None
3.....	do.....	Polyacrylic acid (M.W. 300,000), 0.30.....	do.....	do.....	0.38	None
4.....	CrO ₃ , 8.72.....	Polyacrylic acid (M.W. 50,000), 1.20.....	SiO ₂ , 6.20.....	A, 1.30; F, 0.40; L, 3.20.....	0.28	None
5J.....	CrO ₃ , 4.00.....	Polyacrylic acid (M.W. 50,000), 2.00.....	SiO ₂ , 0.70.....	None.....	0.44	None
6.....	ZnCr ₂ O ₇ , 5.00.....	Sucrose, 0.50.....	Wyoming bentonite, 1.00.....	None.....	0.50	None
7.....	(NH ₄) ₂ Cr ₂ O ₇ , 3.00.....	Polyvinyl alcohol (M.W. 30,000), 1.00.....	Mica, 0.20.....	B, 0.70.....	0.43	None
8.....	CrO ₃ , 6.00.....	Polyvinyl ethyl ether (M.W. 40,000), 0.50.....	SiO ₂ , 3.00.....	G, 0.30.....	0.31	None
9.....	Same as 1.....	Same as 1.....	Same as 1.....	C, 1.20; H, 0.70.....	0.20	None
10.....	do.....	do.....	do.....	D, 1.70; I, 0.33.....	0.28	None
11.....	do.....	do.....	do.....	E, 0.70; K, 0.80.....	0.48	None
12.....	do.....	do.....	do.....	B, 1.40; J, 0.35.....	0.37	None

metal is in the form of coiled strip or in the form of stacked core laminates or plates.

In order that those skilled in the art may better understand the present invention and the method in which it may be practiced, the following specific examples are given. It is to be appreciated, however, that these examples are merely exemplary of the preferred embodiment of the present invention and are not to be taken as a limitation thereof. In these examples the compositions used were formulated by admixing the source of hexavalent chromium, the organic reducing compound, and the source of silicon, in a water base. To this composition, in some instances, other materials were added, which materials were as follows:

- A—Al₂O₃ (30.5% Al)
- B—TiO₂
- C—ZrO₂
- D—AlF₃
- E—AlPO₄
- F—Fe
- G—Fe(OH)₃
- H—FeF₃
- I—Ferrous acetate
- J—Fe(H₂PO₄)₂
- K—Fe(NO₃)₃
- L—Acetic acid

The thus-formed aqueous solution was applied to cold rolled steel strip by roll coat application wherein the coating rollers and the speed of strip were adjusted so as to apply a coating weight of about 100 milligrams/square foot. The application temperatures were within the range of 40-70 degrees centigrade, and the solution temperatures were within the range of about 27 to about 55 degrees centigrade. After the aqueous solution was applied to the steel strip, the strip was oven dried at a temperature within the range of about 230 to about 595 degrees centigrade for a period of time within the range of about

The procedures of the preceding examples were repeated using the same compositions but in different dilutions within the range of about 4 parts water to 1 part of the composition to about 1 part of water to 3 parts of the composition. In each instance, comparable results were obtained.

While there have been described various embodiments of the invention, the composition and methods described are not intended to be understood as limiting the scope of the invention as it is realized that changes therewithin are possible and it is intended that each element recited in any of the following claims is to be understood as referring to all equivalent elements for accomplishing substantially the same results in substantially the same or equivalent manner, it being intended to cover the invention broadly in whatever form its principle may be utilized.

What is claimed is:

1. A composition suitable for coating ferrous metal surfaces to produce thereon an electrically resistant chemical coating of the non-conversion type which composition comprises a source of hexavalent chromium in an amount within the range of 0.2 to about 22% by weight, a source of silicon in an amount within the range of about 0.15 to 15% by weight and an organic reducing compound containing at least one reactive group which is oxidizable by hexavalent chromium, in an amount within the range of about 0.08 to 8% by weight.

2. A method of producing an electrical resistance coating on a ferrous metal surface which comprises applying to the metal surface to be treated an aqueous solution formed by admixing water and the composition as claimed in claim 1 in a ratio of about 4:1 to about 1:3, heating the thus-obtained coated metal surface at a temperature within the range of about 150 to about 595 degrees centigrade for a period of time sufficient to effect curing of the coating material thereon, and thereafter, annealing the thus-treated metal surface at a temperature within the range of about 760 to about 1150 degrees centigrade.

3. A ferrous metal surface having an electrical resist-

ance coating thereon as produced by the method of claim 2.

4. The composition as claimed in claim 1 wherein the source of hexavalent chromium is chromic acid, the source of silicon is colloidal silica, and the organic reducing compound is polyacrylic acid.

5. A method of forming an electrical resistance coating on a ferrous metal surface which comprises contacting the metal surface to be treated with aqueous coating composition formulated by admixing water and the composition as claimed in claim 4 in an amount within the ratio of about 4:1 to about 1:3, effecting the formation of the desired coating on the metal surface, heating the thus-coated metal surface at a temperature within the range of about 150 to about 595 degrees centigrade for a period of time sufficient to effect curing of the coating on the surface and thereafter, subjecting the thus-coated surface to annealing at a temperature within the range of about 760 to about 1150 degrees centigrade.

6. The composition as claimed in claim 4 wherein there is also present at least one material selected from the group consisting of:

(A) Metals of Groups II-A, II-B, VI-B, VII-B and VIII of the Periodic Table and

(B) Metals of Groups III-A, IV-B and V-B of the Periodic Table, the material from A, when present, being in an amount within the range of about 0.1 to about 3.0 percent by weight of the composition and the material from B, when present, being in an amount within the range of about 0.02 to about 0.5 percent by weight of the composition.

7. A method of providing an electrical resistance coating on a ferrous metal surface which comprises contacting the metal surface to be treated with an aqueous coating composition formulated by admixing water and the composition as claimed in claim 6 in a ratio of about 4:1 to about 1:3 and effecting the formation of the desired coating on the metal surface, heating the thus-coated metal surface to a temperature within the range of about 150 to about 595 degrees centigrade for a period of time sufficient to effect curing of the coating thereon, and, thereafter, annealing the thus-coated metal surface at a temperature within the range of about 760 to about 1150 degrees centigrade.

8. The composition as claimed in claim 6 wherein there is contained chromic acid in an amount within the range of about 0.2 to about 22% by weight, colloidal silica in an amount within the range of about 0.15 to about 15% by weight, polyacrylic acid in an amount within the range of about 0.08 to about 8% by weight, aluminum in an amount within the range of about 0.1 to 3% by weight, iron in an amount within the range of about 0.02 to about 0.5% by weight, and water in an amount within the range of about 48 to about 99.5% by weight.

9. A method for producing an electrical resistance coating on a ferrous metal surface which comprises contacting the metal surface to be coated with an aqueous solution formed by mixing water and the composition as claimed in claim 8 in a ratio of about 4:1 to about 1:3, effecting formation of the desired coating on the metal surface, heating the thus-coated metal surface at a temperature within the range of about 150 to about 595 degrees centigrade for a period of time sufficient to effect curing of the coating thereon and thereafter, annealing the thus-coated metal surface at a temperature within the range of about 760 to about 1150 degrees centigrade.

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U.S. Cl. X.R.