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ELECTRIC RESISTANCE ELEMENT

Clarence George Bleber, Huntington, W. Va., assignor to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware

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This invention relates to an improved electric resistance element, especially one for use in electric furnaces adapted to operate at high temperatures.

It is a well known fact that various nickel alloys have been proposed as substitutes for the more expensive resistance elements, such as platinum, nichrome and chromel. However, such alloys have not been adopted commercially particularly for electric resistance elements intended to operate at elevated temperatures especially above 1800° F. for a variety of reasons including their susceptibility to embrittlement or oxidation at such high temperatures, particularly in atmospheres which changed in character, such as from oxidizing to reducing. Although many proposals have been made, none as far as I am aware, has been wholly successful and satisfactory commercially, especially when carried into practice on an industrial scale.

An object of the invention is to provide an electric resistance element comprising a heat-treated chromium plated nickel or nickel alloy wire which can be operated in oxidizing or reducing atmospheres at elevated temperatures including 1800-2500° F.

A further object of the invention is to provide an electric resistance element utilizing the electrical resistance properties of nickel or a nickel alloy at elevated temperatures above 1800° F. and below 2600° F. without destruction of the nickel due to oxidation.

It is also within the contemplation of the invention to provide a process for heat treating chromium plated nickel or nickel alloy wire whereby an electric resistance element can be produced in a suitable condition for use in electric resistance furnaces.

Other objects and advantages of the invention will become apparent from the following description of a preferred embodiment of the invention and a procedure for carrying the invention into practice.

According to the present invention an efficient and inexpensive resistance heating element is provided by utilizing the desirable features of nickel and nickel alloys and avoiding the shortcomings thereof. I have discovered that envelopment of nickel or nickel alloy with chromium, especially the electrodeposited type, and the subsequent formation of a bond of a nickel-chromium alloy provides an electric resistance element with a desirable temperature coefficient, an excellent resistance to oxidation and embrittlement, especially at super or elevated temperatures and changing atmospheres including oxidizing and reducing and with a relatively high melting point.

A method of producing the new electric resistance element is to electrolytically deposit

thin layers of chromium about .0002" to about 0.005" thick, upon nickel or a nickel alloy wire or the like. The plated product is subjected to a special heat treatment in a hydrogen atmosphere. It is preferred to effect the treatment by heating the wire rapidly by the passage of an electric current therethrough. The heat treatment is such as to cause chromium to diffuse into the surface skin or layer of the nickel or nickel alloy so as to form an intermetallic alloy of chromium with the base metal or alloy. The treated wire constitutes an improved electric resistance element which can be installed in any type of electric resistance heating furnace and will function satisfactorily at a much higher temperature than prior electric resistance elements composed of chromium-nickel alloy or other base metals or alloys known to the trade.

For the purpose of giving those skilled in the art a better understanding of the invention, a preferred embodiment and a preferred procedure of making the present low priced resistance element will be described.

Nickel wire of any suitable diameter is pickled free from oxide, etc. and carefully cleaned with carbon tetrachloride or sodium tri-phosphate to remove any grease or dirt etc. It is preferred to then clean the wire electrolytically in a solution containing 10 per cent of sodium carbonate and about 1 per cent of sodium hydroxide. The wire acts as a cathode with a current density of about 10 amperes per square foot. Following this treatment, the wire is cleaned further as cathode in a solution of about 50 Bé. sulfuric acid with a current density of about 20 amperes per square foot. The cleaned wire is finally rinsed with water. The wire is coated with about 0.0002" to about 0.005" of chromium by the electrodeposition in a chromic acid bath containing approximately 250 grams of the chromic acid and about 2.5 grams sulfuric acid per liter using a current density of approximately 1 ampere per square inch and a temperature of about 115°-120° F.

After this plating operation, the chromium plated nickel wire is subjected to heat treatment by passing a regulated electric current therethrough so as to maintain the wire temperature at about 1800 to about 2000° F. for about 1 to about 2 hours in a hydrogen atmosphere which I have found to be best suited for the diffusion or alloying of the chromium with the nickel. The product is then an electric resistance heating element capable of being used for any kind of an electrical resistance furnace. Tests have demonstrated that it will operate satisfactorily without oxidation at a higher temperature than any base-metal resistor, is more convenient to use than non-metallic resistors of the carborundum type, and is cheaper to the public.

In carrying the invention into practice, the improved electric resistance element was subjected to severe tests to demonstrate its usefulness and to establish its unique properties.

5 Some of these tests will now be described.

A rectangular furnace with a heating chamber 5" x 8" x 14" was provided with a hair-pin type of the improved electric resistance heating element made in accordance with the procedure
10 outlined hereinabove by electro-depositing about 0.001 inch of chromium upon a nickel wire about $\frac{3}{16}$ " in diameter and heat treating the same at about 1800° to about 2000° F. in hydrogen for about 2 hours to alloy the chromium with the nickel. This furnace has been used, intermit-
15 tently for 40 heats of 8 hours each at temperatures of 2000-2300° F. in an oxidizing atmosphere, and for 8 heats of 8 hours each at temperatures of 2000-2100° F. in a hydrogen atmosphere. The heating unit was found to be in
20 practically as good a condition as at the time of installation.

A cylindrical furnace about 6" in diameter and 10" high was provided with a helical unit
25 constituted of the present electric resistance element of $\frac{1}{4}$ " diameter nickel wire plated with about 0.001 inch of chromium after heat treatment in hydrogen for about two hours at about 1800 to about 2000° F. This furnace has been
30 used for 50 heats of about 4-8 hours each at temperatures of about 2150 to about 2350° F. in a hydrogen atmosphere and for 12 heats of about 8 hours each at temperatures of about 2000° to about 2100° F. in an oxidizing atmos-
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(b) Reheated to 2000° F. for 8 hours and cooled over-night,

(c) Reheated to 2100° F. for 8 hours and cooled over-night,

(d) Reheated to 2200° F. for 8 hours and
5 cooled over-night,

(e) Reheated to 2300° F. for 8 hours and cooled over-night,

(f) Reheated to 2500° F. for 2 hours and cooled over-night, and
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(g) Reheated to 2600° F. for $\frac{1}{2}$ hour, when the wire burned out.

During the two hours at about 2500° F., a small charge of a nickel-copper alloy sold under the trade-mark "Monel Metal" was placed inside
15 the furnace core and melted.

A similar furnace would with a conventional resistance element composed of about 15% chromium and 85% nickel burn out after a few
20 hours at 2100-2200° F.

An examination of the burned-out chromium-plated nickel wire after the 2600° F. exposure showed that the nickel interior had actually
25 been in a molten condition inside the chromium shell, and that the wire had operated for a time as a molten resistor.

It is to be observed that the present application provides an improved electric resistance heating element which possesses new and unique
30 properties and superior characteristics to prior electric resistance heating elements. Some of the new, improved and unique properties and characteristics may be appreciated from the following schedule:

Schedule

	New chrome plated nickel	Prior alloy of 80% Ni, 20% Cr	Prior alloy of 85% Ni, 15% Cr	Prior alloy of 60% Ni, 25% Fe, 11% Cr, 4% Mn
Resistance.....	15 microhms per cm ²	100 microhms per cm ²	85 microhms per cm ²	105 microhms per cm ²
Temperature resistance co-efficient	.002 per °F.	.00006 per °F.	.00008 per °F.	.0001 per °F.
Maximum useful temperatures.....	2600° F.	2000° F.	1900° F.	1400° F.
Resistant to atmospheres.....	Excellent.	Good.	Fair.	Poor.
Resistant to fluctuation.....	do.	do.	Good.	Fair.

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phere. The improved heating unit or electric resistance element is in practically as good a condition as when it was originally installed.

Careful examination of the improved electric
50 resistance elements in both furnaces described hereinabove showed practically no signs of deterioration, their electrical characteristics have not changed and a practically constant electric current has continued to give the same furnace temperatures at all times. The remarkable efficiency of the novel electric resistance element can be judged further by comparison with the fact that a $\frac{1}{4}$ " diameter conventional heating
55 unit made from an alloy containing approximately 20 per cent of chromium and about 80 per cent of nickel was used in the cylindrical furnace and was found to have failed due principally to oxidation after three heats of about 4 hours each at about 2300° F. in a hydrogen atmosphere.
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A further description of my new results will show the remarkable performance at elevated temperatures of my improved resistance element. Some 0.051" nickel wire with a heat treated
65 0.001 inch chromium coating was wound on a refractory cylinder and assembled into a tube furnace. This furnace was subjected to the following heating cycles in air:

(a) Heated to 1900° F. for 8 hours and cooled
75 over-night,

It is also to be observed that the new and improved electrical heating resistance element has a longer life at temperatures of 2000° F. and above. The life of the present improved electrical resistance heating element is distinctly superior to the life obtainable with prior electric resistance heating elements as may be clearly seen from the following table:

Table

Life at—	New, etc.	Prior, etc.	Prior, etc.	Prior, etc.
	Hours	Hours	Hours	Hours
2000° F.	Indefinite	Indefinite	1610	360
2100° F.	Indefinite	1000	57	47
2200° F.	960	22	11	$\frac{1}{2}$
2300° F.	240	1	1	0

NOTE.—Indefinite means "longer than 1680 hours or 10 weeks."

Furthermore the present invention has been applied to a nickel-chromium wire which was coated with a film of nickel having a thickness of about 0.00025" to about 0.0005" and then plated with a film of chromium having a thickness of about 0.0002" to about 0.0005". This doubly plated wire had increased life at temperatures
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in excess of 2200° F. Thus, this wire lasted from about 24 to about 57 hours when operated continuously at 2300° F. It even lasted as long as 1 hour when operated continuously at 2350° F.

5 This doubly plated wire is very useful for operating at high temperatures. A satisfactory composition of the nickel-chromium alloy was found to be 50% to about 90% of nickel, 10% to about 25% of chromium, .1% to about 25% of iron and 10 especially 80% of nickel, 19.8% of chromium and .2% of iron.

Other advantages of my improved resistance wire will become readily apparent to those familiar with the subject. For instance, I could 15 chromium plate a chromium-nickel resistance wire and increase its operating range to higher temperatures, but I prefer to provide a less expensive article of manufacture by utilizing nickel, or some of its commercial alloys, as a base product. 20

Although the present invention has been described in connection with preferred embodiments it will be appreciated that variations and modifications may be resorted to without departing from the spirit and scope of the invention. For instance nickel alloys may be used. Thus nickel alloys having the following composition may be used: 25

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Ni	Cr	Fe	Mn
Percent	Percent	Percent	Percent
80	20	-----	-----
85	15	-----	-----
75	11	12	2
60	11	25	4

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The size of the wire or element may vary de-

pending upon specific conditions. For practical purposes the size may vary from 0.005" to about 1" in diameter or thickness. The heating element may have various shapes including the conventional types, such as rounds, flats, strip, ribbon or T grid. Moreover tungsten or molybdenum may function like chromium but are not as commercial as chromium. All of these variations and modifications are to be understood to be within the purview of the present specification and the scope of the appended claims. 5 10

What I claim is:

1. As a new article of manufacture, a composite electrical resistance heating unit comprising a core constituted of a nickel-chromium alloy, an outer layer of chromium enveloping said core, an intermediate layer of nickel, and diffusion zones between the outer layer and the nickel layer and between the nickel layer and the core intimately bonding the layers with each other and with the core, said chromium layer being substantially more resistant to failure at temperatures in excess of 2200° F. than said core. 15 20

2. As a new article of manufacture, a composite electrical resistance heating unit comprising a core containing a nickel-chromium-iron alloy, an intermediate layer of nickel surrounding said core, an outer layer of at least one metal of the group consisting of chromium, molybdenum and tungsten surrounding said nickel layer, and diffusion zones between the outer layer and the nickel layer and between the nickel layer and the core intimately bonding the layers with each other and with the core, said outer layer being substantially more resistant to failure at temperatures in excess of 2200° F. than said core. 25 30 35

CLARENCE GEORGE BIEBER.