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FLAME SPRAY CLAD POWDER COMPOSED OF A REFRACTORY
MATERIAL AND NICKEL OR COBALT
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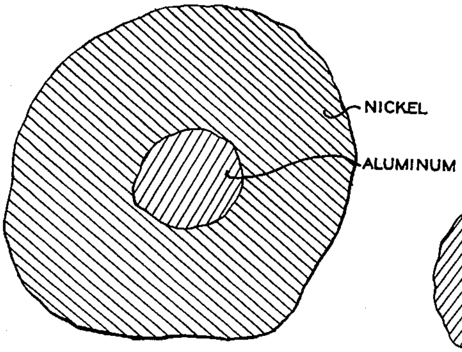

Fig. 1

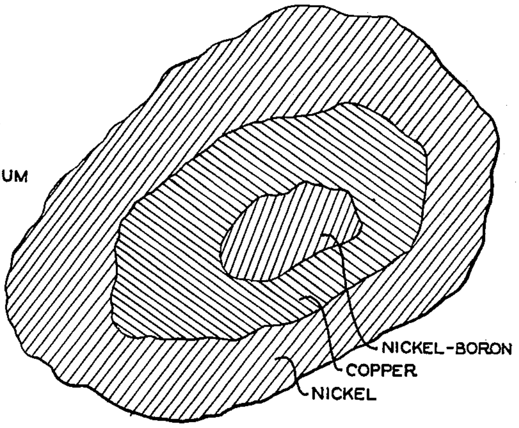

Fig. 2

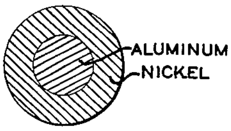

Fig. 3

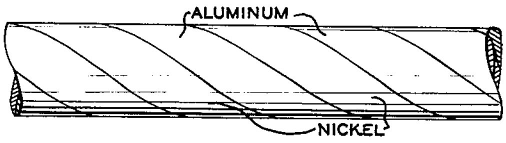

Fig. 4

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FLAME SPRAY CLAD POWDER COMPOSED OF A REFRACTORY MATERIAL AND NICKEL OR COBALT

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14 Claims. (Cl. 29—183.5)

This is a continuation-in-part of application Serial No. 72,543, filed November 22, 1960, now abandoned.

This invention relates to the flame spraying of synergistic composites. The invention more particularly relates to the flame spraying of synergistically-clad flame spray powders, to a novel group of flame spray materials comprising such synergistically-clad flame spray powders, and more broadly to the spraying of other synergistic composites wherein the synergistic action involves the generation of heat.

Flame spraying involves the feeding of a heat-fusible material into a heating zone, wherein the same is melted or at least heat-softened and then propelled from the heating zone in a finely divided form, generally onto a surface to be coated.

The material being sprayed is generally fed into the heating zone in the form of either a powder or a wire (the latter term designating both rods and wires). The spraying is effected in a device known as a heat-fusible material spray gun or a flame spray gun.

In the wire type flame spray gun the rod or wire of the material to be sprayed is fed into the heating zone formed by a flame of some type, where it is melted or at least heat-softened and atomized, usually by blast gas, and thence propelled in finely divided form onto the surface to be coated. The rod or wire may be a conventionally formed rod or wire of a metal, or may be formed by sintering together finely divided material or by bonding together finely divided material by means of a plastic binder or other suitable binder which disintegrates in the heat of the heating zone, thereby releasing the material to be sprayed in finely divided form.

For spraying finely divided, i.e., powdered material, a powder type flame spray gun is used in which the powder, usually entrained in a carrier gas, is fed into the heating zone of the gun formed by a flame of some type. The powder is either melted or at least the surface of the grains heat-softened in this zone, and the thus thermally conditioned particles propelled onto a surface to provide a coating. In the powder type spray gun, as no "atomizing" energy is required, a separate blast gas is often dispensed with, though the same may be supplied in order to aid in accelerating the particles and propelling them toward the surface to be coated.

The blast gas may be provided for both the wire type and powder guns to perform the additional function of cooling the workpiece and the coating being formed thereon.

The heat for the heating zone is most commonly produced from a flame caused by the combustion of a fuel, such as acetylene, propane, natural gas or the like, using oxygen or air as the oxidizing agent. The heat may, however, also be produced by an electrical arc flame or in the newer type of guns, by a plasma flame. The plasma flame may in itself constitute part of an electric arc or, in accordance with a newer development, may be in the form of a "free plasma stream," i.e., a stream of plasma which may be considered independent of the arc as it does not contribute to the electric flow between electrodes.

Heat-fusible material spray guns utilizing electric resistance heating or induction heating as the heat source have also been proposed but have not proven commercially successful except in connection with the spraying of low melting point metals, such as solders, lead and zinc.

Flame spraying in the initial stages of its commercial development was used mostly for the spraying of various metals and was often referred to as metallizing. However, the art of flame spraying extends to the spraying of a much wider group of materials, including higher melting point or refractory metals, ceramic, cermets and the like, and such materials are of increasing commercial interest.

In the case of spraying heat-fusible materials in the initial form of a rod or wire, the rod or wire is generally of a single composition, i.e., in the form of a specific metal, alloy, ceramic or the like. While it is true that rods or wires formed from finely divided material bound together with a binder of plastic or the like, as mentioned above, were known, the binder did not take part in the spraying or contribute to the coating and merely served the purpose of maintaining the rod or wire in shape until fed into the heating zone.

In the case of flame spray powders, while powders formed of several constituents were known, the same were generally in the form of a powder mixture of the individual constituents or, at best, a particle aggregate.

One object of this invention is the spraying of the heat-fusible material in a novel form, which allows the obtaining of superior results.

A further object of this invention is a novel group of flame spraying materials.

These and still further objects will become apparent from the following description read in conjunction with the drawings in which:

FIG. 1 diagrammatically shows a cross-section of a grain of a novel flame spray powder in accordance with the invention;

FIG. 2 is a diagrammatic cross-section of a further embodiment of a grain of a novel flame spray powder in accordance with the invention;

FIG. 3 is a diagrammatic cross-section of an embodiment of a novel flame spray rod or wire in accordance with the invention; and

FIG. 4 shows an elevation of a further embodiment of a novel flame spray rod or wire in accordance with the invention.

In accordance with a broad aspect of the invention the flame spraying is effected with the material being sprayed in the form of a powder, the individual grains of which are in the form of a clad composite consisting of nuclei and at least one coating layer of a different material which will synergistically act with the nuclei in the process.

Each grain of the synergistically clad composite powders may also be in the form of a nucleus with two or more different coating layers which will synergistically act with each other and/or with the nucleus.

The synergistic action of the coating layer with the nucleus and the coating layers with each other, as the case may be, may manifest itself as a chemical or physical action or both, and may appear in the heating zone and/or along the path of travel to the surface to be coated, or at the sprayed coating as sprayed, or after a subsequent treatment such as a heating or fusing operation.

The synergistic action between the nuclei and/or the coating layer or layers may, for example, involve the physical or chemical generation of heat by exothermic reaction in the heating zone, along the path of travel to the target, or on the coated surface itself, so as to increase the thermal efficiency of the process, aid in the bonding of the coating and/or produce results and effects by this in situ generated heat which cannot be achieved by the externally supplied heat. The synergism resulting in the exothermic reaction may be caused by the utilization of two components which will combine at the temperatures involved to form a material with a melting point higher than that of either of the constituents, with a considerable release of heat, by the use of components which will chemically combine in exothermic reaction, as for example where one acts as an oxidizing and the other a reducing agent, or by the use of components which will dissolve together in generation of heat or the like.

Thus, for example, one of the components may be a nickel-containing component and the other an aluminum-containing component which will combine under the spraying conditions to form a nickel-aluminum inter-metallic compound with an exothermic reaction. Similarly, one of the components may contain the aluminum and the other antimony, calcium, cobalt, lanthanum, lithium, manganese, nickel, palladium, praseodymium, dysprosium, or a combination thereof which, upon combining during the spraying, form a higher melting point compound with the generation of heat. Similarly, the clad-composite powder may be a combination of nickel with elemental phosphorus, silver, copper, aluminum or the like, which will combine in exothermic reaction.

The synergistic action may also involve a protective effect of the coating material on the nuclei or a lower coating layer in order to prevent loss or destruction of this under-material and allow the spraying of the combination. Thus, for example, nickel may be coated on nickel-phosphorus, nickel-boron, or the like in order to prevent loss or destruction of the fluxing agent and allow the formation of a self-fluxing coating, as for example in the "spray-weld process."

The synergism may also involve a bonding effect in order to allow a satisfactory bonding on a base of sprayed materials which normally present bonding difficulties, as for example the synergism of a matrix metal, such as nickel or cobalt, with a hard or refractory material, such as tungsten carbide, Al_2O_3, diamonds or other hard gems or the like.

Bonding to the base or substrate being coated may also be aided by the synergistic action of exothermic reaction, as for example in the case of nickel-coated aluminum powder.

The synergistic effect may also involves the combining of the components to form a third component, such as a compound or alloy or inter-metallic compound desired as the coating constituent. This may involve a dissolving together of the components, alloying the components, or a chemical reaction between components which may be endothermic in nature if sufficient heat is available for the process.

The powder particles may be in the form of a nucleus with a single coating layer, or may be in the form of a nucleus with a multiple number of layers of the same or different materials.

The clad powders in accordance with the invention may be formed in any known or desired manner and preferably by the known chemical plating processes in which a coating material is deposited on a seed or nucleus of another material, or in which multiple layers of various materials are built up on the seed material, or in which various materials are co-deposited in a single layer on the seed material.

A preferred mode of forming the clad powders involves the depositing of a metal from a solution by reduction on a seed or nucleus, such as the hydrogen reduction of ammoniacal solutions of nickel and ammonium sulphate on a seed powder catalyzed by the addition of anthraquinone. It is also possible to form the coating by the use of other known coating processes, such as coating by vapor deposition, by the thermal decomposition of metal carbonyls, by hydrogen reduction of metal halide vapors, by thermal decomposition of halides, hydrides, carbonyls, organometals or other volatile compounds, or by displacement gas plating and the like.

The clad powders for this invention should have the general over-all shape and size of conventional, flame-spray powders, and thus for example should have a size between −60 mesh and +3 microns and preferably −140 and +10 microns (U.S. standard screen mesh size). Most preferably the powder should be as uniform as possible in grain size, with the individual grains not varying by more than 250 microns and preferably 75 microns.

Depending on the particular flame spray process and the desired purpose, the clad powders may be sprayed per se or in combination with other different clad powders, or in combination with other conventional flame spray powders or powder components.

FIG. 1 diagrammatically shows an embodiment of a clad powder having a nucleus of aluminum and a coating of nickel.

FIG. 2 shows a multi-layer powder of nickel and copper on nickel-boron.

While the powders are preferably sprayed, as such, in a powder-type of flame spray gun, it is also possible to combine the same in the form of a wire or rod, using a plastic or similar binder which decomposes in the heating zone of the gun, or, in certain cases the powders may be compacted and/or sintered together in the form of a rod or wire.

In the limited case where the synergistic action of the components involves an exothermic reaction as, for example, the combination of nickel and aluminum to form the nickel-aluminum inter-metallic compounds, the spray material may assume a form other than the clad powder and may, for example, be in the form of a suitable aggregate or a composite wire, such as a wire having a coating sheath of one material, such as nickel, with a core of the other material, such as aluminum, as shown in FIG. 3, or wire formed by twisting together and rolling separate wires of components, such as nickel and aluminum, as shown in FIG. 4. Various combinations of other exothermically-reacting components may of course be used in the formation of such wire, which exothermic reaction will substantially contribute to the heat economy of the flame spraying and may even show self-ignition characteristics when fed through the spray gun.

The following examples are given by way of illustration and not limitation:

EXAMPLE 1

An aluminum powder having a particle size between −140 mesh and +325 mesh (U.S. standard screen size) is coated with nickel in the known manner by the hydrogen reduction of an ammoniacal solution of nickel and ammonium sulphate, using anthraquinone as the coating catalyst. The reduction is effected at a temperature between about 300 and 350° F. in a mechanically agitated autoclave using solutions containing 40–50 grams per liter of nickel and 10–400 grams per liter of $(NH_4)_2SO_4$ and 20–30 grams per liter of NH_3. About .2 gram per liter of anthraquinone is used as the catalyst and the autoclave is pressurized with hydrogen at a pressure of about 300 lbs. p.s.i.g. After the nickel solution is depleted and the aluminum coated with an initial coating of nickel, the solution is discharged from the autoclave and replenished with a fresh solution which need not contain further amounts of the anthraquinone coating catalyst, as the initially formed nickel coating in itself acts as a catalyst. The cycle is continuously repeated until a composite powder is formed containing about 16 to 18% by weight aluminum and 84 to 82% by weight of nickel, and a size of −100 to +270 mesh.

The powder thus formed is flame-sprayed on a mild steel plate which has been surface-cleaned with emery cloth. The spraying is effected at about 7 inches from the plate, using a powder-type flame-spray gun as described in U.S. Patent 2,961,335, issuing November 22, 1960 and sold by Metco, Inc. of Westbury, Long Island, N.Y., under the trade name of "Thermospray" powder gun. The spraying is effected at a rate of 6 to 9 lbs. of powder per hour, using acetylene gas as the fuel at a pressure of 10 p.s.i. and a flow rate of 17 to 25 cu. ft./hr. and oxygen as the oxidizing gas at a pressure of 12 p.s.i. and a flow rate of 29 to 35 cu. ft./hr.

The nickel coating and the aluminum base combine in the heat of the flame with a strong exothermic action, forming a nickel aluminum inter-metallic compound which deposits on the base as a dense, high quality coating which exhibits self-bonding characteristics. A coating layer of .002"–.004" thickness is built up in this manner. The coating may be used as a base material for spraying of further layers of different metals or the like and serves as an excellent intermediate bonding layer.

The coating layer may also be built up to a greater thickness as, for example, .004"–.008", for use as an oxygen barrier undercoat, or to even greater thickness as, for example, .020"–.040" or thicker as a wear-resistant, oxidation-resistant surface.

Due to its self-bonding characteristics the sprayed coating will adhere to a base without the conventional surface preparation or roughening, and due to the natural characteristics of a sprayed material, will allow further materials to be sprayed thereon with good bonding. The coating formed from the powder has excellent oxidation-resistant characteristics even at high temperatures and in oxidizing atmospheres, and will for example eliminate the oxidation of base materials, such as molybdenum or the like. The sprayed coatings may be used as a lining in metal-melting crucibles or molten metal-handling equipment, and will not be wetted or penetrated by many molten metals, including self-fluxing alloys. Coatings formed of the sprayed material also show good potential as high temperature, wear-resistant coatings.

When the example is repeated on a molybdenum rod of 3/16" diameter, with a coating between .008"–.010" thick, the coated rod may be repeatedly heated to approximately 2000° F. in air, with a welding torch, and cooled to room temperature with no visible oxidation occurring.

Similar results may also be obtained if the composite powder contains 10–45% by weight of aluminum and 55–90% by weight of nickel.

EXAMPLE 2

Example 1 is repeated with the spraying being effected in turn on the following bases and prepared in the following manner:

Low alloy steels and stainless steels, smooth-ground to remove surface contamination; copper and copper base alloys, rough-ground or light-grit-blasted; aluminum and aluminum base alloys, rough-ground or light-grit-blasted; magnesium, rough ground or light-grit-blasted; and titanium, rough-ground or light-grit-blasted.

In each case when a further material, such as steel, alumina or the like, was sprayed over the coating in the conventional and well known manner, the same was bonded with a tenacious bond, though if this material had been initially sprayed on the surface as prepared in the manner indicated above, a satisfactory bond would not be obtained.

EXAMPLE 3

The nickel-clad powder of Example 1 is mixed with an Al_2O_3 powder having a particle size between 62 microns and 10 microns, in the ratio of about 40% of the nickel-clad powder with 60% by weight of the ceramic. The powder is sprayed, using the gun described in Example 1, on a mild steel plate which has been surface-cleaned by smooth grinding. Spraying is effected at a distance of about 7" from the plate at a rate of about 4 to 8 lbs. of powder per hr., using acetylene at a pressure of 10 lbs. p.s.i. and a flow rate of 17–25 cu. ft./hr., and oxygen at a pressure of 12 p.s.i. and a flow rate of 29–35 cu. ft./hr.

A self-bonding cermet coating is formed which showed excellent thermal shock-resistance, hardness, abrasion- resistance, and which strongly inhibited oxidation of the base.

It is possible to vary the percentages of the ceramic in the mixture between 5 and 85% in order to vary the properties of the coating. With an increased amount of the inter-metallic compound in the cermet coating formed, the bonding and thermal shock-resistant properties increased, whereas with an increased amount of the ceramic the hardness and wear-resistant properties of the coating are increased and the thermal conductivity decreased.

EXAMPLE 4

Example 3 is repeated, using the following materials in place of the aluminum oxide:

Zirconia, calcium zirconate, magnesium zirconate, spinel, ceric oxide, hafnium oxide, rare earth oxides, molybdenum disilicide, tungsten silicide, chromium silicide, titanium silicide, tungsten carbide, titanium carbide and chromium carbide.

In each case an excellent coating was formed.

EXAMPLE 5

A nickel-phosphorus powder having a size between 200 and 325 mesh and containing 8 to 12% phosphorus is coated with nickel to form a composite-clad powder having a size between 140 and 270 mesh and containing 20 to 40% of the nickel phosphorus nucleus and 60 to 80% of the nickel coating.

The powder is sprayed in the identical manner described in Example 1. The coating obtained is mechanically bonded to the base and is slightly porous. This coating may be subsequently fused by a welding torch or furnace heated to form a homogenous porefree coating welded to the base material.

EXAMPLE 6

A nickel-boron powder is coated with nickel to form a composite flame-spray powder having a size between 120 and 325 mesh and containing 70 to 90% nickel, based on the nickel boron. The powder was sprayed in the manner described in Example 1 and a high quality of self-fluxing coating was formed.

The coating is mechanically bonded to the base and may be subsequently fused with a welding torch or in a furnace to form a dense homogenous, non-porous coating. When applied to a reactive base material, such as molybdenum, in a thickness of .006" to .010" or heavier, the coating can be fused to the base material by a torch or furnace without atmosphere control and below the recrystallization temperature of pure molybdenum, and will protect the molybdenum base from an oxidizing atmosphere at elevated temperatures up to the melting point of the nickel-boron coating.

EXAMPLE 7

Metallic cobalt is deposited as a coating on zirconia powder by the reduction of a cobalt ammonium sulphate solution with hydrogen so as to form a cobalt-clad zirconia flame-spray powder having a size between 140 mesh and 15 microns and containing 25 to 95% cobalt, based on the zirconia. The material is sprayed in the manner described in Example 1 on a grit-blasted base and a cermet coating is formed which shows excellent adhesion to the base and which will retard oxidation of the base. The coating furthermore has a high degree of hardness even at elevated temperatures, excellent shock-resistance and abrasion-resistance, and the metal matrix material is evenly distributed throughout the applied coating.

It is possible to vary the percentages of the ceramic in the composition between about 5 and 75% by weight in order to vary the properties of the coating. With an increased amount of ceramic in the cermet coating, the hardness and wear-resistant properties of the coating are correspondingly increased and the thermal conductivity decreased. Conversely, with an increasing amount of the cobalt matrix the bonding and shock-resistant properties are increased.

EXAMPLE 8

Al_2O_3 powder of a mesh size between 80 microns and 10 microns is coated with nickel in the manner described in Example 1 to produce a composite powder containing 25 to 95% of the nickel based on the aluminum oxide and having a particle size between 140 mesh and 15 microns. The powder is sprayed in the manner described in Example 1 on a grit-blasted base, and a cermet coating is formed which shows excellent adhesion to the base, a high degree of hardness even at elevated temperatures, and excellent thermal shock and abrasion-resistant characteristics. The metal matrix is evenly distributed throughout the sprayed coating.

In this case too it is possible to vary the percentage of the ceramic in the composite between 5 and 75% by weight, and with an increasing amount of ceramic, the hardness and wear-resistant properties increase, whereas with an increase of the nickel, the thermal conductivity, bonding and shock-resistant properties are increased.

EXAMPLE 9

Industrial diamond powder having a size between −120 and +140 mesh was coated with nickel in the manner described in Example 1 so that the nickel-clad composite powder formed contained about 25 to 50% by weight of the nickel, based on the diamonds. The powder was sprayed in the manner described in Example 1 on a steel base prepared by grit blasting, thus forming an excellent hone or lap in which the diamonds were firmly bonded in place.

EXAMPLE 10

Cobalt-bonded tungsten carbide particles of sharp, angular shape were coated with nickel in the manner described in Example 1 so as to produce a nickel-clad flame spray powder having a particle size between 100 and 325 mesh and containing 20 to 50% nickel based on the tungsten carbide. The powder was sprayed in the manner described in Example 9, with the formation of an excellent cutting hone or lap. The sharp angular edges of the initial tungsten carbide were retained in the coating.

Similar results were obtained when using crystalline tungsten carbide in place of the cobalt bonded tungsten carbide particles.

EXAMPLE 11

A nucleus of elemental phosphorus powder was coated with nickel to form a nickel-clad flame spray powder having a particle size between 100 and 325 mesh and containing 80 to 98% nickel based on the phosphorus. The composite powder is sprayed with the flame spray gun described in Example 1 on a steel base prepared by lightly grit-blasting, using the spraying conditions as described in Example 1. During the spraying phosphorus combines with the nickel in an exothermic reaction, greatly enhancing the thermal efficiency of the spraying and producing an excellent coating which has self-fluxing properties.

EXAMPLE 12

A nickel boron powder is coated with copper and the copper-coated composite further coated with nickel to form a composite-clad flame spray powder having a particle size between 100 and 325 mesh containing 63 to 67% nickel and 26 to 32% copper and 2 to 10% boron by weight. The powder is sprayed in a powder-type flame spray gun on a lightly grit-blasted steel base with the flame spray gun and method as described in Example 1. An excellent self-fluxing alloy is formed, which when fused in place by heating with an acetylene torch, forms a dense coating which corresponds in characteristics to Monel.

EXAMPLE 13

A nickel boron powder is coated with chromium and the resulting coated powder in turn coated with nickel so as to form a flame spray composite-clad powder having a mesh size between 100 and 325 and containing 70 to 80% nickel and 18 to 20% chrome and 2 to 10% boron by weight. The powder is sprayed in the manner described in Example 12, resulting in a self-fluxing alloy coating which, when fused in place in the manner described in Example 12, produces a high grade coating having characteristics similar to Nichrome V.

EXAMPLE 14

Nickel-bonded titanium carbide particles having a size between 140 and 325 mesh are coated with nickel, as described in Example 1, so as to produce a nickel-clad flame spray powder having a particle size between 100 and 270 mesh and containing 20 to 50% nickel based on the titanium carbide. The material is sprayed in the manner described in Example 1 on a base with surface roughened by grit-blasting, and a high grade, bonded titanium carbide coating is formed in which the nickel acts as a matrix binding material.

When properly finished by grinding, the resultant coating is an excellent hard-facing, extremely resistant-to-wear coating even at elevated temperatures.

Similar results are obtained when using crystalline titanium carbide particles in place of the nickel-bonded titanium carbide particles.

EXAMPLE 15

Copper powder is coated with nickel in the manner described in Example 1 so as to form a nickel-clad composite flame spray powder having a particle size between 100 and 325 mesh and containing 60 to 70% nickel based on the copper. Upon spraying in the manner described in Example 1 on a base roughened by grit-blasting or other means, an excellent, corrosion and oxidation-resistant coating is formed. A similar coating is formed if the copper is replaced with chromium in an amount of 15 to 25% chromium based on the nickel.

EXAMPLE 16

Molybdenum disilicide powder is coated with nickel in the manner described in Example 1 so as to form a composite-clad flame spray powder having a particle size between 140 mesh and 10 microns, and containing 15 to 40% nickel by weight based on the disilicide. The powder is sprayed with the flame spray gun described in Example 1 on a base material roughened by grit-blasting.

The resultant oxidation-resistant coating is very dense, but may be further improved by subsequent heat treatment in a neutral to reducing atmosphere.

EXAMPLE 17

Example 10 is repeated except in place of the nickel, nickel phosphorus is used containing 4 to 12% of phosphorus. A similar coating resulted upon spraying, which however was self-fluxing.

EXAMPLE 18

Chromium boride powder is coated with nickel in the manner described in Example 1 so as to form a flame spray powder having a mesh size between 120 and 325 and containing 15 to 50% of nickel, based on the chromium boride. Upon spraying in the manner described in Example 1, a boride coating of high quality is obtained which is resistant to wetting by molten metals.

EXAMPLE 19

Silver solder powder is coated with nickel in the manner described in Example 1 so as to produce a nickel-clad composite powder having a size between 120 and 325 mesh and containing 25 to 50% nickel based on the silver solder. Upon spraying in the manner described in Example 1 on a base material prepared by grit-blasting, a low-fusing temperature, self-fluxing coating is formed which, when subsequently fused, is a homogenous, pore-free coating securely fused to the base material.

A simple mixture of powders consisting of 20 to 65% of this nickel-coated silver solder and 35 to 85% of a carbide (Example 10) is sprayed in the manner described in Example 1. The resultant coating, when fused, consists of angular carbide particles securely bonded to each other and to the base material.

The fused coating may be suitably finished by grinding for use as a wear-resisting coating or used, as fused, where the coated article is to be used as a hone or lap, the sharp edges of the carbide inclusions constituting the abrading or cutting edges.

EXAMPLE 20

Titanium is coated with nickel as described in Example 1 to produce a powder having a particle size between 100 and 325 mesh and containing 10 to 50% nickel based on the titanium.

The nickel protects the titanium from oxidation during storage and when spraying.

Upon spraying in the manner described in Example 1, on a base material prepared by grit-blasting, the nickel and titanium combine in the flame to form a corrosion-resistant coating.

EXAMPLE 21

A niobium powder is coated with nickel in the manner described in Example 1 so as to form a composite nickel-clad flame spray powder having a particle size between 100 and 325 mesh and containing 5 to 40% by weight of nickel based on the niobium.

The nickel protects the niobium from oxidation during storage and when spraying.

Upon spraying in the manner described in Example 1 on a base material prepared by grit-blasting, the nickel and niobium combine in the flame to form a corrosion-resistant material.

EXAMPLE 22

A molybdenum powder was coated with nickel in the manner described in Example 1 so as to produce a nickel-clad flame spray powder having a particle size between 100 and 325 mesh and containing 5 to 40% nickel based on the molybdenum.

The nickel protects the molybdenum from oxidation during storage and when spraying.

Upon spraying in the manner described in Example 1 on a base material prepared by grit-blasting, the nickel and molybdenum combine in the flame to form a corrosion-resistant material.

EXAMPLE 23

A titanium boride powder was coated with nickel so as to form a flame spray powder having a particle size between 100 and 325 mesh and containing 20 to 50% nickel based on the titanium boride.

The nickel protects the titanium boride during the spray.

Upon spraying in the manner described in Example 1, on a base material prepared by grit-blasting, a securely bonded nickel-titanium boride composite coating is achieved.

EXAMPLE 24

A silver powder is coated with nickel so as to form a nickel-clad flame spray powder having a particle size between 100 and 325 mesh and containing 30 to 70% nickel based on the silver.

Upon spraying in the manner described in Example 1, on a base material prepared by grit-blasting, the nickel and silver combine in the flame to produce a new material which is securely bonded to the base and is excellent for use as electrical contacts or the like.

During the spraying heat was evolved upon the combination of the nickel and silver, increasing the thermal economy of the process.

EXAMPLE 25

An aluminum powder is copper-plated so as to form a copper-clad flame spray powder having a particle size between 100 and 325 mesh and containing 85 to 98% or 8 to 20% copper based on the aluminum.

Upon spraying in the manner described in Example 1, on a base material prepared by grit-blasting, the copper and aluminum combined in the flame to form a harder, corrosion-resistant alloy.

EXAMPLE 26

A silicon powder was coated with copper so as to form a copper-clad flame spray powder having a particle size between 100 and 325 mesh and containing 50 to 80% by weight of copper based on the silicon.

Upon spraying in the manner described in Example 1, on a base material prepared by grit-blasting, the copper and silicon combine in the flame to form coatings of a material considerably more inert than copper.

EXAMPLE 27

Telleurium powder was coated with copper so as to form a composite having a particle size between 100 and 325 mesh and containing 50 to 80% copper based on the tellurium.

Upon spraying in the manner described in Example 1, on a base material prepared by grit-blasting, the copper and tellurium combine to form a new material.

During the spraying heat was evolved upon the combination of the copper and tellurium, increasing the thermal economy of the process.

EXAMPLE 28

Tin powder is coated with copper so as to form a copper-clad composite flame spray powder having a mesh size between 100 and 325 mesh and containing 75 to 95% copper based on the tin.

Upon spraying in the manner described in Example 1, upon a base material prepared by grit-blasting, the copper and tin combined in the flame to produce a ductile, corrosion-resistant coating.

EXAMPLE 29

Lead powder is coated with copper so as to form composite flame spray powder having a particle size between 100 and 325 mesh and containing 50 to 90% copper based on the lead.

Upon spraying in the manner described in Example 1, upon a base material prepared by grit-blasting, an excellent, leaded copper material is deposited which is suitable for use as a bearing.

EXAMPLE 30

The nickel-clad flame spray powder of Example 1 is mixed with about 20% by weight of low pressure polyethylene powder and molded at a temperature of about 212° F. into the form of a rod of ⅛" diameter. The rod is sprayed, using a conventional wire-type flame spray gun sold by Metco, Inc. of Westbury, Long Island, N.Y., as the Metco-type 4E Gun. The spraying is effected with acetylene at a pressure of 15 p.s.i. and a flow rate of 37 cu. ft./hr. with oxygen as oxidizing gas at a pressure of 38 p.s.i. and a flow rate of 75 cu. ft./hr.; with air as a blast gas at a pressure of 40 p.s.i. and a flow rate of 25 cu. ft./min. The end coating produced is similar to the coating produced in Example 1.

EXAMPLE 31

The nickel-clad flame spray powder of Example 10 is compacted and sintered in the form of a rod .125" in diameter. The rod is sprayed, using a conventional wire type flame spray gun sold by Metco, Inc. as the Metco-type 4E Gun. The spraying is effected with acetylene at a pressure of 15 p.s.i. and a flow rate of 37 cu. ft./hr. with oxygen as the oxidizing gas at a pressure of 38 p.s.i. and a flow rate of 75 cu. ft./hr. Air is used as a blast gas at a pressure of 55 p.s.i. and a flow rate of 30 cu. ft./min. The end coating produced is similar to the coating produced in Example 10.

EXAMPLE 32

A wire is formed by encasing a core of aluminum in a tube of nickel and drawing to a size of .125" in diameter plus or minus .002. The wire contains 82 to 84% by weight of nickel based on the aluminum.

The wire is sprayed, using a conventional wire type flame spray gun sold by Metco, Inc. of Westbury, Long Island, N.Y., as the Metco-type 4E Gun. Spraying is effected with acetylene at a pressure of 15 p.s.i. and a flow rate of 37 cu. ft./hr. with oxygen as the oxidizing gas at a pressure of 38 p.s.i. and a flow rate of 75 cu.t ft./hr. Air is used as a blast gas at a pressure of 55 p.s.i. and a flow rate of 30 cu. ft./min. After initiation of the exothermic combination reaction at the melting wire tip, the flow of fuel and oxidizing gas may be drastically reduced, thus utilizing the heat of reaction to aid in melting the spray material and contributing to the over-all economy of the process. The end coating produced is similar to the coating produced in Example 1.

Similar results are also obtained using 55–90% by weight of nickel in the wire.

EXAMPLE 33

A composite wire is formed by winding individual wires of nickel and aluminum and drawing the same to a thickness of .125" plus or minus .002". The wire contains 82 to 84% by weight of nickel based on the aluminum. The wire is sprayed in the manner described in Example 32, with identical conditions and coating resulting.

EXAMPLE 34

A self-fluxing silver-solder powder containing 15% silver, 5% phosphorus and 80% copper, is coated with copper so as to form a composite flame spray powder having a particle size between 100 and 325 mesh and containing 20 to 50% copper based on the silver-solder.

Upon spraying in the manner described in Example 1, on a base material prepared by light grit-blasting, an excellent, low melting point, self-fluxing alloy is deposited.

EXAMPLE 35

Example 34 is repeated except nickel is used in place of the copper. Similar results are obtained.

EXAMPLE 36

A simple mixture of powders containing 10 to 25% of the composite nickel—nickel phosphorus powder described in Example 5 and 75 to 90% of copper or copper alloy powder of the kind known as "Everdur" is sprayed with the gun and spray conditions described in Example 1.

The coating as described is mechanically bonded to the base material and slightly porous by nature. It may be subsequently fused by torch or furnace heating to form a homogenous, pore-free coating welded to the base material. After fusion the coating is a fairly hard, corrosion-resistant, welded bronze overlay.

EXAMPLE 37

Example 36 is repeated, using, however, the composite nickel—phosphorus powder described in Example 11 in place of the nickel—nickel phosphorus powder.

Comparable results are obtained.

EXAMPLE 38

A simple mixture of powders containing 69% of the composite powder as described in Example 6 and 31% pure copper powder in the particle size range −140 and +325 mesh is sprayed with the gun as described in Example 1.

The coating as applied may be subsequently fused without atmosphere control, to form a homogenous alloy fused to the base material, which corresponds in characteristics to Monel.

EXAMPLE 39

A simple mixture of powders containing 81% of the composite powder as described in Example 6 and 19% of pure chromium powder in the particle size range −140 and +325 mesh is sprayed with the gun as described in Example 1.

The coating as applied may be subsequently fused without atmosphere control, to form a homogenous alloy fused to the base material, which corresponds in characteristics to Nichrome V.

EXAMPLE 40

Example 9 is repeated except in place of the nickel, nickel phosphorus was used containing 6 to 12% of phosphorus. A similar coating resulted upon spraying, which however, was self-fluxing. Fusion bonding of particles to each other and to the base was accomplished by fusing the applied coating.

EXAMPLE 41

The coated diamond powder of Example 9 is mixed with nickel-coated silver solder powder of Example 19 in the proportion of 50 to 75% diamond to 25 to 50% materix material.

The mixture was sprayed in the manner described in Example 1 and the deposit subsequently fused.

The resultant coating was a dense, pore-free coating fused to the base material in which the diamonds were securely anchored by the low melting point, self-fluxing matrix metal.

EXAMPLE 42

Example 14 is repeated except in place of the nickel, nickel phosphorus is used containing 4 to 12% of phosphorus. A similar coating resulted which, however, was self-fluxing.

EXAMPLE 43

A silicon powder having a particle size between 140 and 325 mesh is coated with molybdenum in the known manner and a composite powder is formed containing about 35 to 39% by weight of silicon and about 61 to 65% by weight of molybdenum, and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting, in the manner described in Example 1.

The molybdenum coating and the silicon base combine in the heat of the flame, forming a molybdenum silicon inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at elevated temperatures and will protect the base material from oxidation.

EXAMPLE 44

A molybdenum powder having a particle size range between 140 and 325 mesh is coated with silicon in the known manner and a composite powder is formed containing about 35 to 39% by weight of silicon and about 61 to 65% by weight of molybdenum, and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting. The spraying is effected at about five inches from the plate, using a powder type plasma flame-spray gun sold by Metco, Inc. of Westbury, Long Island, N.Y., under the trade name of Type MB Plasma Flame Gun. The spraying is effected at a rate of six to nine lbs. of powder per hour, using argon gas as the plasma gas at a pressure of 100 p.s.i. and a flow rate of 110 cu. ft./hr., using argon as the powder carrier gas at 100 p.s.i. and a flow rate of 11.5 cu. ft./hr., using a No. 3 (pointed) electrode and

No. 3R argon nozzle, and using arc current of 550 amperes at 45 volts.

The molybdenum base and silicon coating combine in the heat of the flame, forming a molybdenum silicon inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at high temperatures and will protect the base material from oxidation.

EXAMPLE 45

A silicon powder having a particle size between 140 and 325 mesh is coated with chromium in the known manner, and a composite powder is formed containing about 48 to 85% chromium and 15 to 52% silicon by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting in the manner described in Example 1.

The chromium coating and the silicon base combine in the heat of the flame, forming a chromium-silicon inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at elevated temperatures and will protect the base material from oxidation.

EXAMPLE 46

A chromium powder having a particle size between 140 and 325 mesh is coated with silicon in the known manner, and a composite powder is formed containing about 48 to 85% chromium and 15 to 52% silicon by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting. The spraying is effected at about five inches from the plate, using a powder type plasma flame-spray gun sold by Metco, Inc. of Westbury, Long Island, N.Y., under the trade name of Type MB Plasma Flame Gun. The spraying is effected at a rate of six to nine lbs. of powder per hour, using argon gas as the plasma gas at a pressure of 100 p.s.i. and a flow rate of 110 cu. ft./hr., using argon as the powder carrier gas at 100 p.s.i. and a flow rate of 11.5 cu. ft./hr., using a No. 3 (pointed) electrode and No. 3R argon nozzle, and using arc current of 550 amperes at 45 volts.

The chromium base and silicon coating combine in the heat of the flame, forming a chromium silicon inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at high temperatures and will protect the base material from oxidation.

EXAMPLE 47

A zirconium powder having a particle size between 140 and 325 mesh is coated with chromium in the known manner and a composite powder is formed containing about 47%, zirconium and 53% chromium by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material in the manner described in Example 1.

The chromium coating and the zirconium base combine in the heat of the flame, forming a chromium zirconium inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at high temperatures.

EXAMPLE 48

A titanium powder having a particle size range betwen 140 and 325 mesh is coated with chromium in the known manner and a composite powder is formed containing about 35% chromium and 65% titanium by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting in the manner described in Example 1.

The chromium coating and the titanium base combine in the heat of the flame, forming a chromium titanium inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at high temperatures.

EXAMPLE 49

A titanium powder having a particle size range between 140 and 325 mesh is coated with silicon in the known manner and a composite powder is formed containing about 35 to 65% titanium and 35 to 65% silicon by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting. The spraying is effected at about five inches from the plate, using a powder type plasma flame-spray gun sold by Metco, Inc. of Westbury, Long Island, N.Y., under the trade name of Type MB Plasma Flame Gun. The spraying is effected at a rate of six to nine lbs. of powder per hour, using argon gas as the plasma gas at a pressure of 100 p.s.i. and a flow rate of 110 cu. ft./hr., using argon as the powder carrier gas at 100 p.s.i. and a flow rate of 11.5 cu. ft./hr., using a No. 3 (pointed) electrode and No. 3R argon nozzle, and using arc current of 550 amperes at 45 volts.

The titanium base and silicon coating combine in the heat of the flame, forming a titanium silicon inter-metallic which deposits on the base as a dense, high quality coating which exhibits excellent resistance to oxidation at high temperatures and will protect the base material from oxidation.

EXAMPLE 50

A dysprosium powder having a particle size between 140 and 325 mesh is coated with aluminum in the known manner and a composite powder is formed containing 60 to 75% dysprosium and 25 to 40% aluminum by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by light grit-blasting in the manner described in Example 1.

The aluminum coating and the dysprosium base combine in the heat of the flame with a strong exothermic action, forming a dysprosium aluminum inter-metallic compound which deposits on the base as a dense, high quality coating which exhibits excellent properties at high temperatures.

EXAMPLE 51

A lanthanum powder having a particle size between 140 and 325 mesh is coated with aluminum in the known manner and a composite powder is formed containing 70 to 75% lanthaum and 25 to 30% aluminum by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by grit-blasting in the manner described in Example 1.

The aluminum coating and the lanthum base combine in the heat of the flame with a strong exothermic action, forming a lanthanum aluminum inter-metallic compound which deposits on the base as a dense, high quality coating which exhibits excellent properties at high temperatures.

EXAMPLE 52

A chromium powder having a particle size between 140 and 325 mesh is coated with aluminum in the known manner and a composite powder is formed consisting of 60 to 62% chromium and 38 to 40% aluminum by weight and a size of 100 to 270 mesh.

The powder thus formed is flame-sprayed on a base material which has been prepared by grit-blasting in the manner described in Example 1.

The aluminum coating and the chromium base combine in the heat of the flame with a strong exothermic action, forming a chromium aluminum inter-metallic compound which deposits on the base as a dense, high quality coating of very high melting point and excellent oxidation-resistance.

EXAMPLE 53

Example 52 is repeated except that the composite powder is formed with an aluminum core and chromium coating. Identical results are obtained.

EXAMPLE 54

The nickel-clad aluminum composite powder of Example 1 is mixed with cobalt bonded tungsten carbide particle powder having a particle size range of −140 mesh +10 microns, and preferably −140 +325 mesh in proportions of:

(a) 80 weight percent tungsten carbide to 20 weight percent of the composite,
(b) 20 weight percent of the carbide to 80 weight percent of the composite, and
(c) preferably 50 weight percent each of the tungsten carbide and composite.

The powder mixtures are each flame-sprayed on a mild steel plate which has been surface cleaned by grinding or very light sand-blast cleaning. The spraying is effected at about 8–9 inches from the plate, using a powder-type flame-spray gun as described in U.S. Patent 2,961,335, issuing November 22, 1960, and sold by Metco, Inc. of Westbury, Long Island, N.Y., under the trade name of "Thermo-Spray" powder gun. The spraying is effected at a rate of 6 to 10 lbs. per hour using acetylene gas as the fuel at a pressure of 12 p.s.i. and a flow rate of 20 to 30 cubic feet per hour and oxygen as the oxidizing gas at a pressure of 14 p.s.i. and a flow rate of 30 to 40 cubic feet per hour.

The nickel-aluminum composite powder in the mixture reacts exothermically in the flame to provide the self-bonding properties of the mixture and, being fully molten on impact with the subtrate, becomes the matrix which securely binds the tungsten carbide particles together in the coating.

Used as sprayed, or finished by proper grinding procedure, the resultant coating is of a highly wear-resistant coating material, applicable to virtually any base material and not subject to the limitations of the previously used self-fluxing alloy matrix materials which must be fused at approximately 1900° F.

EXAMPLE 55

Example 54 is repeated except that in place of the grade of tungsten carbide cobalt powder grains used, cobalt-bonded tungsten carbide grains with lower cobalt content and sharp, angular shape are used.

The powder was sprayed in the manner described in Example 54. The sharp, angular edges of the initial tungsten carbide particles were retained in the coating.

The deposited coating may be suitably finished by grinding for use as a wear-resisting coating or used as deposited where the coated article is to be used as a hone or lap, the sharp edges of the carbide inclusions constituting the abrading or cutting edges.

EXAMPLE 56

Example 55 is repeated except that in place of the cobalt-bonded tungsten carbide grains described, the nickel-clad tungsten carbide grains described in Example 10 were substituted.

EXAMPLE 57

The nickel-clad aluminum composite described in Example 1 is mixed with a columbium (niobium) powder of size between −120 mesh and +10 microns and preferably −140 +325 mesh in the proportions of 60 weight percent of the nickel-aluminum composite.

The powder mixture is sprayed in the manner described in Example 54. The resultant coating is self-bonding to a wide variety of substrate materials and when properly finished, by grinding or other means is a highly wear-resistant, hard coating.

EXAMPLE 58

The nickel-clad aluminum composite described in Example 1 is mixed with a molybdenum powder of a size between −120 mesh and +10 microns and preferably −140 +325 mesh in the proportions of 65 weight percent molybdenum to 35 weight percent of the nickel-aluminum composite.

The powder mixture is sprayed in the manner described in Example 54. The resultant coating is self-bonding to a wide variety of substrate materials and when properly finished by grinding or other means presents a highly wear-resistant, hard surface.

EXAMPLE 59

Example 54 is repeated except in place of the tungsten carbide, other carbides such as titanium carbide, tantalum carbide, columbium carbide, chromium carbide and mixtures of the various carbides are used.

EXAMPLE 60

The nickel-clad aluminum core composite from Example 54 is mixed with aluminum powder in the mesh size range −100 +325 mesh, and preferably in the −170 +325 mesh size range in the proportions of 80 weight percent nickel aluminum composite to 20 weight percent aluminum.

The mixture was sprayed in the manner described in Example 54. The coating as deposited consists of an intimate mixture of the flame-reacted nickel aluminide and aluminum securely bonded to the base and particle to particle within the coating.

Upon heat treating in the temperature range 1250° F. to 1500° F. in reducing atmosphere, dry hydrogen for instance, the nickel aluminide and aluminum combine to form a dense, homogenous coating fused to the base material which can be used for "cathodic" protection of iron and steel subject to water and salt water corrosion.

EXAMPLE 61

The nickel-clad aluminum composite powder of Example 54 is mixed with Monel powder of a size between −100 mesh and +10 microns, and preferably between −140 and +325 mesh in the proportions 35 weight percent composite to 65 weight percent Monel.

The powder mixture was sprayed in the manner described in Example 54. The resultant coating is self-bonding to a wide variety of substrate materials and the inclusion of the nickel-aluminum composite, the components of which combine exothermically in the flame to provide the self-bonding ability of the mixture, considerably increase the particle to particle bonds within the coating and decrease the permeability of the coating.

EXAMPLE 62

Example 61 is repeated except that nickel and stainless steel powders are substituted for the Monel.

EXAMPLE 63

Example 61 is repeated except that chromium is substituted for the Monel.

The resultant coating when properly finished by grinding or other means shows high resistance to abrasion, wear, and galling by other metals, and is an excellent bearing surface.

As may be noted from the foregoing the flame spraying of synergistically-acting composites in accordance with the invention is effected in the conventional manner, using the conventional flame spray equipment and utilizing conventional surface-preparation, though in certain instances wherein the spray coating has self-bonding characteristics, special surface-preparation other than a good cleaning, is not critical.

The synergistic composites in accordance with the invention may be sprayed in conjunction with or in addition to other flame-spray materials conventionally used in the art, or may be sprayed in combination with or in conjunction with each other. Thus the synergistically clad powders in accordance with the invention may be sprayed in admixture with other conventional spray powders or mixtures of two or more of the composite powders in accordance with the invention may be sprayed.

In case of powders comprised of synergistically clad particles the components of which exothermically react forming an inter-metallic compound, the spraying in admixture with other composites or with other conventional spray materials offers many advantages.

The use of these composite powders, such as nickel-coated aluminum particles, will generally improve the bond of the total sprayed mixture and thus of the other component or components to the substrate making the mixture self-bonding. The particle bond will also be improved so that the porosity of the coating may be decreased. The use of the composites in admixture with conventional spray powders may thus be used to improve the characteristics and properties of the materials or, conversely, the properties of the composites, such as the nickel-aluminum deposits may be enhanced or other new or better properties may be obtained.

In general as little as 20% by weight of the composite containing exothermically reacting components will be sufficient to substantially improve the bonding characteristics and decreases the porosity of other flame-spray powders such as conventional metal or alloy powders. There is, of course, no upper limit on the amount as the composites may be sprayed per se, but generally about 20% by weight of the other component is required in order to have a pronounced effect on the characteristics of the coating. When, for example, using a mixture of a nickel clad aluminum powder as for instance, is shown in Example 1, with tungsten carbide, titanium carbide, tantalum carbide, chromium carbide, molybdenum, niobium and tantalum amounts of 20% to 80%, and preferably 25% to 50% by weight of the composite may be used. The mixtures are self-bonding as sprayed and form abrasion and wear-resistant coatings. When the same composite is sprayed in mixture with Monel, stainless steel, nickel, chormium, etc., amounts of 25% to 75% by weight of the composite, and preferably 30% to 40% by weight of the composite are used. When sprayed in admixture with aluminum as little as 5% of the aluminum will vary the characteristics of the coating, though preferably up to 25% of the aluminum is used. The composite as mentioned may also be sprayed in admixture with iron, nickel, or Nichrome or produce a self-bonding mixture which produces a coating of lower permeability. It is of course, impractical to list all of the materials which may be sprayed in conjunction or admixture with the composites in accordance with the invention, but the selection of such materials for specific purposes is within the skill of the artisan in light of the disclosure.

While the invention has been described in detail with reference to certain specific embodiments, various changes and modifications which fall within the spirit of the invention and scope of the appended claims will become apparent to the skilled artisan. The invention is therefore only intended to be limited by the appended claims or their equivalents wherein we have endeavored to claim all inherent novelty.

We claim:

1. A flame spray powder in the form of individual, synergistically clad particles of a size between about 60 mesh and plus 3 microns comprising a nucleus and at least one coating layer of a material differing from said nucleus, one of said coating layer and nucleus comprising a refractory selected from the group consisting of refractory oxides, refractory carbides, and diamond, the other a bonding matrix for said refractory material selected from the group consisting of nickel and cobalt matrices.

2. A flame spray powder according to claim 1 in which said nucleus comprises a refractory material and said coating comprises a bonding matrix for the material of said nucleus.

3. A flame spray powder according to claim 1 in which said coating layer is nickel and said nucleus is a refractory material.

4. A flame spray powder according to claim 1 in which said coating layer is nickel and said nucleus is a carbide.

5. A flame spray powder according to claim 4 in which said carbide is tungsten carbide.

6. A flame spray powder according to claim 1 in which said coating layer is nickel and said nucleus is aluminum oxide.

7. A flame spray powder according to claim 1 in which said coating layer is nickel and said nucleus is diamond.

8. A flame spray powder according to claim 1 in which said powder is bonded in the form of a wire.

9. A flame spray powder according to claim 1 including at least one additional coating layer differing from said nucleus and first mentioned coating layer and synergistically active with at least one of said nucleus and first mentioned coating layer in flame spraying.

10. Flame spray powder according to claim 1 in which said refractory material is a refractory oxide.

11. Flame spray powder according to claim 10 in which said refractory oxide is a member selected from the group consisting of alumina and zirconia.

12. Flame spray powder according to claim 1 in which said refractory material is a refractory carbide.

13. Flame spray powder according to claim 12 in which said refractory carbide is tungsten carbide.

14. Flame spray powder according to claim 1 in which said refractory material is diamond.

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