United States Patent

[11] 3,561,399

[72] Inventor **Alfred P. Federman**
Chesterland, Ohio

[21] Appl No **836,832**
[22] Filed **June 26, 1969**
Division of Ser. No. 379,965, July 2, 1964, Patent No. 3,468,695.
[45] Patented **Feb. 9, 1971**

[73] Assignee **Homer W. Giles**
University Heights, Ohio

[54] **METAL COATING APPARATUS**
1 Claim, 3 Drawing Figs.

[52] **U.S. Cl.** **118/65,** 118/405; 164/86
[51] **Int. Cl.** **B05c 11/00**
[50] **Field of Search** ..... 118/404, 405, 58, 65, 64; 117/113—115, 51, 128, 131, 231; 164/86, 281, 275, 87, 85; 29/91.6, 183.5, 196.2

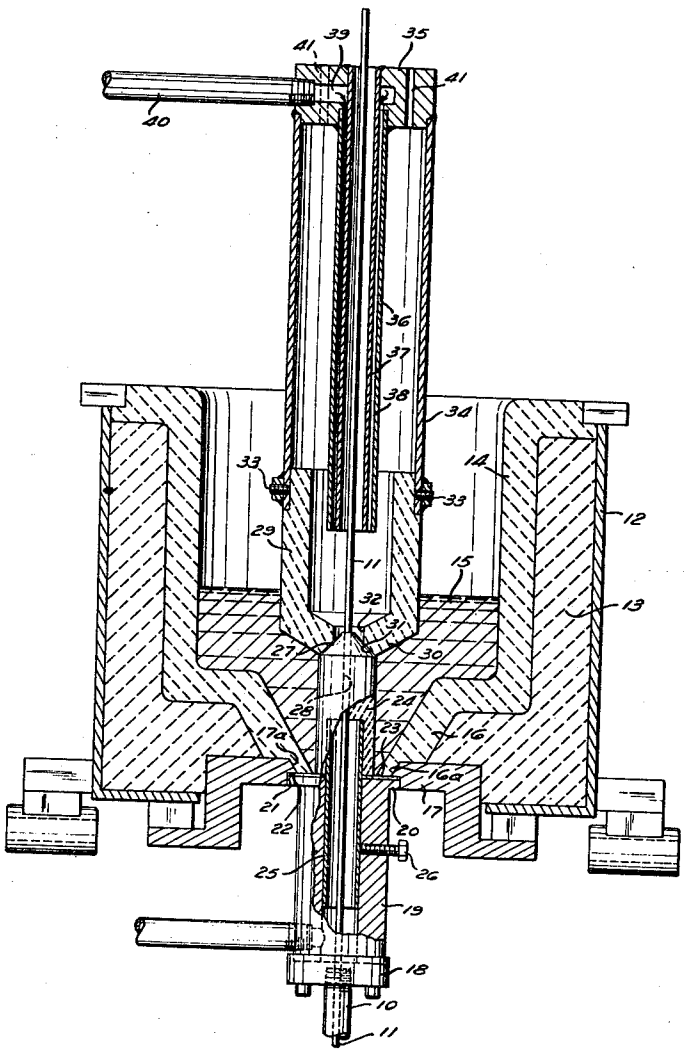
[56] **References Cited**

UNITED STATES PATENTS

867,659	10/1907	Hoopes et al.	164/275
2,111,853	3/1938	Fourness et al.	118/405X
2,231,142	2/1941	Schultz	164/275
3,209,723	10/1965	Schrodersecker	118/404X
3,227,577	1/1966	Baessler et al.	118/405X

Primary Examiner—Morris Kaplan
Attorney—Ely, Golrick & Flynn

ABSTRACT: Apparatus for casting a thick coating of aluminum on steel wire. A lower refractory member presents a vertical wire passage with an exit opening inside a crucible for holding molten aluminum. An upper refractory member extends down into the crucible and is releasably engageable sealingly with the lower member around the latter's exit opening to provide a valve controlling the flow of molten aluminum into contact with the wire passing up through the exit opening.



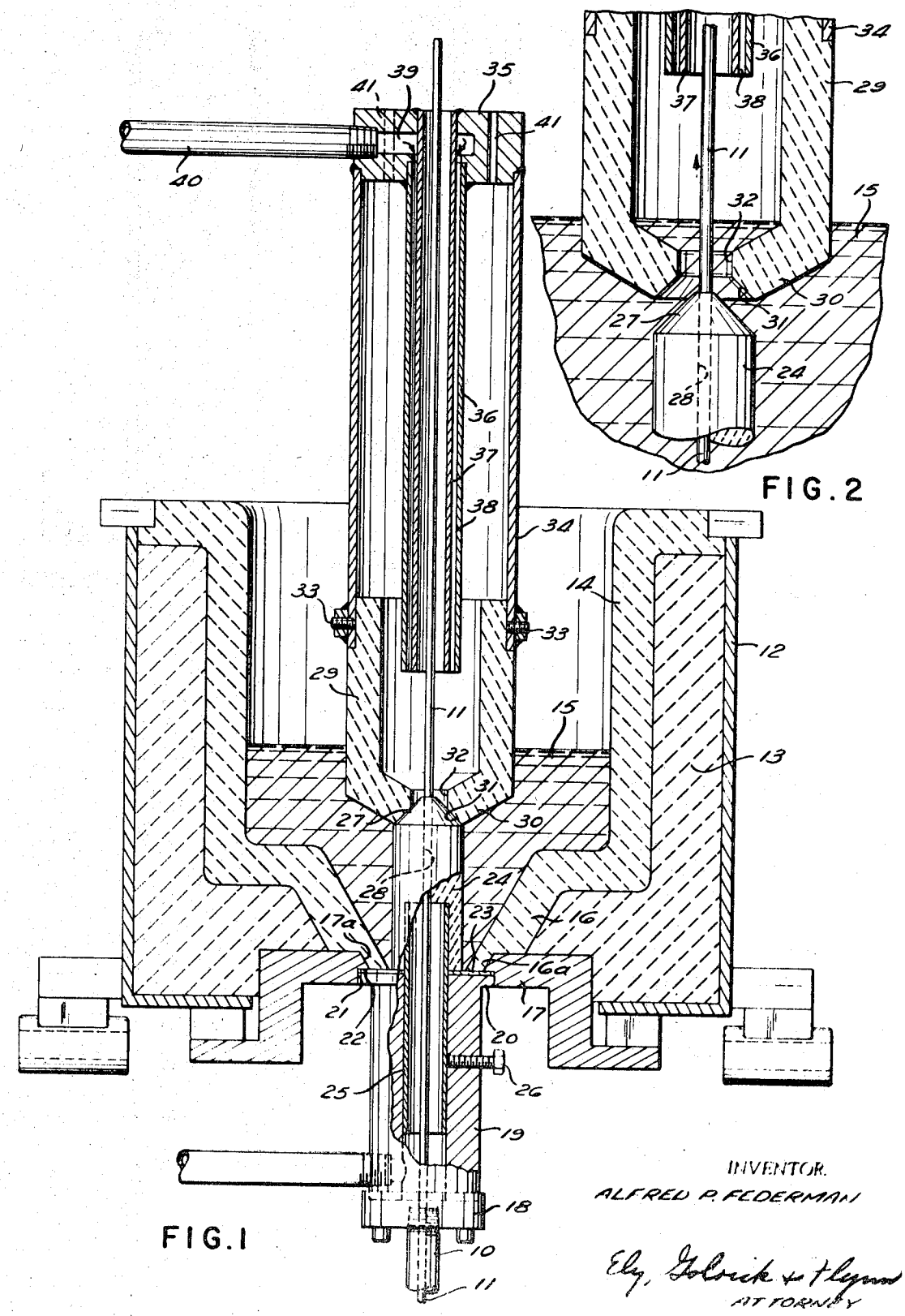


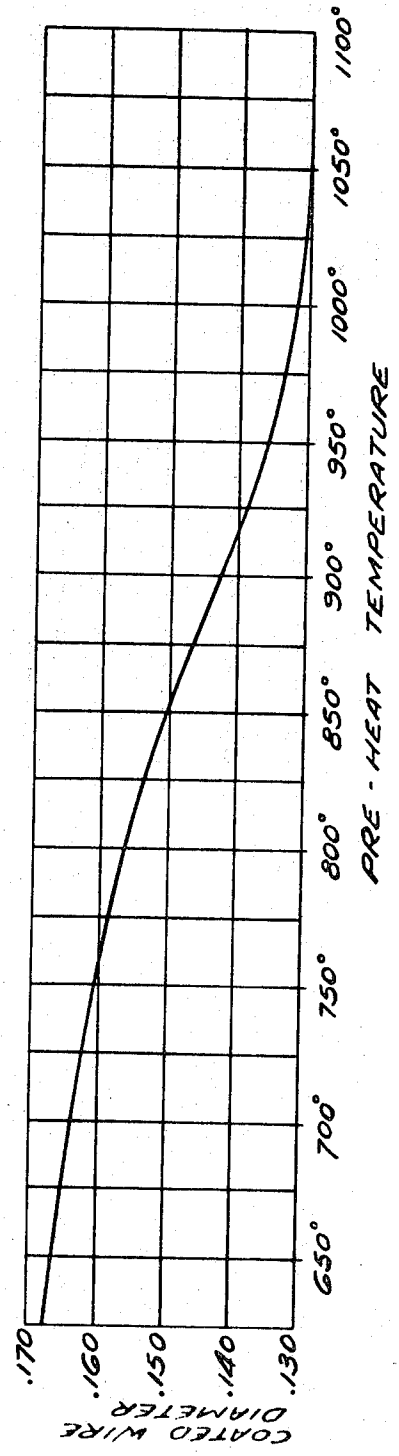
FIG. 2

FIG. 1

INVENTOR.
ALFRED P. FEDERMAN

Ely, Golrick & Flynn
ATTORNEY

FIG. 3



INVENTOR
ALFRED P. FEDERMAN

Ely, Golnick & Flynn
ATTORNEY

METAL COATING APPARATUS

This application is a division of my copending application, Ser. No. 379,965, filed Jul. 2, 1964 and now U.S. Pat. No. 3,468,695.

This invention relates to apparatus for casting a metal coating on a metal base, particularly an aluminum coating on steel wire. By "aluminum" as used herein is meant substantially pure aluminum and also various aluminum alloys, preferably those which have high electrical conductivity and/or corrosion resistance.

Prior to the present invention, various difficulties and disadvantages have been encountered in the application of a thick aluminum coating to steel wire on a commercially practical, mass production basis. In accordance with the present invention, the difficulties and disadvantages of prior efforts are substantially overcome by a novel apparatus for casting a thick, smooth surfaced aluminum coating onto steel in a novel and advantageous manner. By "thick" is meant substantially greater than .002 inch. The aluminum coating preferably is bonded to the steel base at an aluminum-steel interfacial alloy layer which may be intermittent or continuous over the entire surface of the steel base and which has a thickness throughout its extent of less than .0007 inch. Alternatively, the interfacial alloy layer may be substantially or completely absent and the thick aluminum coating may not be firmly bonded to the steel base, so that subsequent mechanical working and/or heat treatment will be necessary to bond the coating tightly to the base.

Aluminum-coated steel wire produced by the present apparatus is characterized by an exceptionally smooth and concentric thick aluminum coating which has a controllable thickness.

A principal object of this invention is to provide a novel and improved apparatus for casting a thick, smooth, uniform thickness metal coating onto metal base.

Another object of this invention is to provide a novel and improved apparatus for casting a thick, smooth substantially oxide-free, corrosion-resistant, electrically conductive, aluminum coating of substantially uniform thickness on a steel wire.

Further objects and advantages of this invention will be apparent from the following detailed description of a presently-preferred embodiment of the present apparatus and of exemplary embodiments of the process in which the apparatus is used, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a vertical axial section, with certain parts broken away for clarity, through the coating apparatus of the present invention with the valve arrangement therein closed;

FIG. 2 is an enlarged fragmentary section of this apparatus with the valve arrangement open; and

FIG. 3 is a graph showing the coating thickness plotted against preheat temperature for a particular uncoated wire size, wire speed and coating bath temperature in a process using the present apparatus.

The following detailed description is directed specifically to the use of the present apparatus in casting of a thick aluminum coating on a solid steel wire of circular cross section By a "thick" coating is meant an aluminum coating substantially greater than .002 inch in thickness, and preferably having a cross-sectional area of at least 7 percent of the total cross-sectional area of the coated wire. This coating is substantially thicker than that produced by hot-dip processes of the prior art, in which the aluminum is molten when the steel wire leaves the aluminum bath and remains on the wire only due to its own surface tension. Typically, such hot-dip coatings are 0.002 inch or less in thickness and the aluminum coating is not substantially free of dissolved iron. The aluminum coating produced by the present apparatus is appreciably thicker than that of hot-dipped coatings and the thickness of this coating enables the coated wire to be used for purposes different from those of the hot-dipped wire of the prior art, for example as electrical conductors. In addition the coating deposited by the present apparatus is substantially free of dissolved iron.

Before the aluminum coating is cast on, the steel wire preferably is thoroughly cleaned. While the present invention is not limited to the following details of the cleaning operation, successful results have been obtained with the following sequence of cleaning steps:

1. subject the steel wire to a stream of shot or abrasive to remove any drawing compound on the wire;
2. immerse the wire in an alkaline cleaning solution, with or without electrolytic action;
3. rinse the wire in cold tap water;
4. pickle the wire in a pickling solution heated to a temperature between 140° F. and 150° F. and agitated by an ultrasonic transducer;
5. rinse the pickled wire in cold tap water; and
6. finally, rinse the wire with hot distilled or de-ionized water.

The cleaned steel wire then is passed through a preheat furnace which is part of the apparatus of the present invention. This furnace includes an elongated tubular housing **10**, whose upper end only appears in FIG. 1. The wire **11** extends centrally longitudinally through this housing. The preheat furnace housing **10** is filled with a suitable gaseous oxygen-deficient or reducing atmosphere, such as hydrogen or carbon monoxide. This gas is maintained at above atmospheric pressure by pumping in a continuous stream of the gas and permitting it to leak out of the lower end of the housing **10**. The escaping gas preferably is ignited as a safety measure. A suitable heat source, such as gas burners or an induction heating unit, is positioned in proximity to the housing **10** to heat the wire **11** to a suitable preheat temperature, as explained hereinafter. A series of thermocouples or optical pyrometers, not shown, are provided at intervals along the length of the housing **10** to sense the wire temperature, and suitable controls, not shown, may be provided for regulating the wire preheat temperature.

After being preheated, the steel wire **11** immediately passes vertically up through a casting furnace in accordance with the present invention.

Referring to FIG. 1, this casting furnace includes a crucible comprising a fixedly supported, generally cup-shaped outer shell **12** of steel or other suitable metal which supports a first refractory ceramic liner **13**. Liner **13**, in turn, supports a generally cup-shaped, refractory, ceramic inner liner **14**, which receives a pool or bath **15** of molten aluminum. At its lower end, the inner liner **14** has an inwardly offset, inwardly and downwardly tapering annular portion **16**, which rests on a thick metal base member **17** of the casting furnace. This lower end portion **16** of the inner liner **14** terminates in a tapering annular nose portion **16*a*** disposed inside a complementary opening **17*a*** in the base member **17**.

The upper end of the preheat furnace housing **10** is threadedly received in an annular steel flange **18**, which is bolted to the lower end of a steel sleeve **19**. An enlarged annular flange **20** on the upper end of this sleeve is snugly received in a complementary, downwardly-facing recess **21** formed in the bottom of base member **17**. Base member **17** presents a downwardly-facing annular shoulder **22** at the intersection of its recess **17*a*** and **21**, this shoulder being coplanar with the bottom face of the lower nose portion **16*a*** on the inner liner of the furnace. A flat, annular, refractory washer **23** is engaged between the top face of flange **20** and shoulder **22** and the bottom face of nose portion **16*a***.

A refractory ceramic tip **24** extends vertically upward within, and spaced from, the inner ceramic liner **14** of the casting furnace. A stainless steel tube **25** is rigidly secured in the ceramic tip **24**, such as by being cast in place therein. Tube **25** extends down into sleeve **19** coaxial therewith. A plurality of bolts **26** clamp the tube **25** within sleeve **19**. The ceramic tip **24** terminates at its upper end in an upwardly-facing, frustoconical surface **27** which forms part of a valve assembly in the present apparatus. The tip **24** has a central longitudinal passage **28** which snugly, but slidably, receives the steel wire **11**. In one practical embodiment, for wire having a diameter of .128 inch, the diameter of this passage **28** was .139 inch.

The other part of this valve assembly is constituted by a vertically disposed, annular, refractory ceramic member **29** having a laterally inwardly turned lower end **30** terminating in a downwardly-facing frustoconical surface **31**, which is complementary to, and sealingly engageable with, the surface **27** on the upper end of the ceramic tip **21**. Member **29** has a central, vertical opening **32** extending upward from this sealing surface **31**.

Ceramic member **29** is attached by screws **33** to the lower end of a metal sleeve **34**. The upper end of this sleeve is closed by an end cap **35**. End cap **35** supports a pair of spaced, depending, concentric, vertically disposed metal tubes **36** and **37**. The annular space **38** between the outer tube **36** and the inner tube **37** communicates with a cavity or recess **39** formed in the end cap **35**. A pipe **40** communicates with recess **39**. The upper end of the inner tube **37** is open to the atmosphere at the top of the end cap **35**. The end cap itself has a plurality of narrow vent openings **41**.

When the apparatus is in operation, a suitable gas, preferably nitrogen or argon, is introduced at pipe **40** and flows under pressure down through the space **38** between the outer and inner tubes **36** and **37**, filling the space within the ceramic member **29** and sleeve **34** and escaping to the atmosphere through the open upper end of the inner tube **36** and through the vent openings **41** in end cap **35**.

The unitary assembly of ceramic member **29**, metal sleeve **34**, end cap **35**, tubes **36**, **37**, and pipe **40** is mounted for movement vertically up and down to selectively position the frustoconical sealing surface **31** on ceramic member **29** either in sealing engagement with the top surface **27** on the ceramic tip **24**, as shown in FIG. **1**, or spaced upward therefrom, as shown in FIG. **2**. Thus it will be seen that the ceramic members **24** and **29** together constitute a valve which controls the flow of molten aluminum from the bath **15** into the interior of ceramic member **29**.

Before the casting operation, the ceramic member **29** is in its "down" position, with its surface **31** sealingly engaging the top surface **27** of tip **24**. Before there is any molten aluminum **15** in the furnace, or before molten aluminum in the furnace reaches the level of the seal between ceramic member **29** and ceramic tip **24**, the interior of ceramic member **29** and sleeve **34** is purged of air by continuously circulating nitrogen or argon under pressure through it. When the molten aluminum bath **15** is provided, the molten aluminum is prevented from flowing up into the interior of ceramic member **29** by the seal between the valve faces **27** and **31**.

The cleaned and preheated steel wire **11** is fed up through the passage **28** in ceramic tip **24** and thence up through the interior of ceramic member **29** and up through the inner tube **37** and out through the top end cap **35**. Any suitable wire feeding mechanism may be provided for this purpose. Preferably, the wire feed is maintained at a closely regulated, uniform speed.

When coating of aluminum onto the steel wire is to begin, the unitary assembly of ceramic member **29**, metal sleeve **34**, end cap **35**, pipe **40** and tubes **36** and **37** is raised up to permit molten aluminum in the bath **15** to flow up between the valve surfaces **27** and **31** into the interior of ceramic member **29** to the same level as the main portion of the bath. The molten aluminum which has flowed up into member **29** is substantially free of oxides because this flow has taken place from below the level of the main bath **15**. Even though the top surface of the main bath **15** is exposed to air and may be contaminated with oxides, there is substantially no oxide contamination of the molten aluminum below the surface. The molten aluminum which enters the ceramic member **29** remains oxide-free and uncontaminated because of the presence of the non-reactive gas in member **29**.

As the steel wire **11** moves up out of the ceramic tip **24** and up through the molten aluminum inside the ceramic member **29**, it picks up a uniformly thick, concentric coating of aluminum which adheres to, and solidifies on, the wire. The clearance or sliding fit of the steel wire **11** in the tip passage **28**, the surface tension of the molten aluminum and the relatively low pressure head of the molten aluminum above the tip **24** are such that there is substantially no leakage or flow of the aluminum down the passage **28**.

Preferably, the vertical depth of the molten aluminum bath above the top of the ceramic tip **24** is from about five-sixteenth inch to 3 inches. The wire speed is in excess of 50 feet per minute, preferably 100 feet per minute or higher. With a bath depth of three-fourths inch and a wire speed of 100 feet per minute the steel wire is exposed to molten aluminum for .0375 second.

The bath **15** is replenished intermittently or continuously by adding more aluminum to the melt, so as to maintain substantially uniform the depth of the bath through which the wire must pass.

Specific examples of the wire preheat temperature, wire speed and coating bath depth are given in my aforementioned U. S. Pat. application Ser. No. 379,965.

FIG. **3** shows a plot of coated wire diameter versus preheat temperature for 1,080 steel wire (0.80 percent carbon) having an original diameter of .128 inch, and pure aluminum as the coating metal. The coating thickness is a maximum at about 625° F. preheat. At this point the aluminum coating has a cross-sectional area of about 41 percent of the total cross-sectional area of the coated wire.

At temperatures below 625° F. the coating thickness of pure aluminum is not significantly greater than this, and the interfacial alloy layer is substantially absent, as already explained and the aluminum coating is not firmly bonded to the steel wire.

At a preheat temperature of about 860° F., in the case of this particular size and composition of the steel core wire, the pure aluminum coating has a cross-sectional area of about 25 percent of the total cross-sectional area of the coated wire.

At a preheat temperature of about 960° F., the pure aluminum coating has a cross-sectional area of about 10 percent of the total cross-sectional area of the coated wire.

For wires of different steel compositions and sizes, different compositions of the coating bath, different preheat and coating bath temperatures, and different periods of immersion of the core wire in the coating bath, the specific values of aluminum coating thickness for different wire preheat temperatures will differ from the particular values of the FIG. **3** curve, but the curve will be generally similar, with the coating thickness reaching a maximum at the minimum preheat temperature at which a smooth, continuous, concentric coating will be deposited, and declining gradually at progressively higher preheat temperatures up to about 1,200° F. At preheat temperatures substantially above 1,200° F. the aluminum coating is thin enough to be comparable to the coatings obtained by prior hot-dip coating processes.

In the passage of the steel wire up through the aluminum bath, it appears that almost the complete thickness of the aluminum coating solidifies on the steel wire in the first few millimeters of the wire's travel through the bath. The preheated steel wire acts as a heat sink, absorbing heat from the molten aluminum in the bath to enable the aluminum to solidify onto the wire. The higher the temperature to which the wire is preheated, the less capacity it will have to absorb heat from the molten aluminum and, consequently, the thinner will be the solidified aluminum coating as shown by FIG. **3**. Over a preheat temperature range from about 500° F. to 1,200° F., if the time of immersion is short enough there appears to be no substantial remelting of the solidified aluminum within the bath as the steel core heats up, and as the wire emerges from the bath the aluminum coating is already substantially completely solidified thereon. This is in contrast to prior hot-dip processes in which the aluminum is largely still molten as the wire emerges from the bath and the molten aluminum is clinging to the wire primarily because of surface tension, with solidification of the aluminum taking place largely after the wire has emerged from the bath.

While a presently preferred embodiment of the present casting apparatus has been described in detail and illustrated in the accompanying drawing with reference to the casting of

aluminum on steel wire, it is to be understood that the invention is susceptible of other embodiments and that various modifications, omissions and refinements which depart from the disclosed embodiment may be adopted without departing from the spirit and scope of this invention. For example, the apparatus may be used for casting a metal other than aluminum on a steel or other metal base, such as copper on steel.

I claim:

1. An apparatus for casting a metal coating on a wire comprising:

a preheat furnace having a wire passage therethrough;

a crucible for holding molten coating metal;

a heat-resistant first member extending up into said crucible, said first member having a wire passage therein shaped and dimensioned to pass the wire snugly and leading to an exit opening at its upper end and communicating with said passage in the preheat furnace, said first member at its upper end presenting a frustoconical upwardly-facing sealing surface surrounding said exit opening and disposed below the latter;

means for maintaining an oxygen-deficient, nonreactive atmosphere in said wire passages in said preheat furnace and said first member;

and a hollow, heat-resistant second member extending down into said crucible and having a bottom opening which receives the upper end of said first member at said exit opening therein, said second member having a frustoconical downwardly-facing sealing surface surrounding said bottom opening therein and extending downward therefrom and sealingly engageable with said sealing surface on said first member;

said first and second members being movable apart to separate said sealing surfaces and permit molten coating metal to flow from the crucible up between said sealing surfaces on the first and second members and into said second member above said exit opening in the first member to contact the wire immediately as it emerges from said exit opening; and

means for maintaining an oxygen-deficient, nonreactive atmosphere in said second member above the level of the molten coating metal.