This invention relates to the art of the deposition of metals. More particularly, it relates to the plating of metals on continuously moving wire and the apparatus for carrying out the process.

Deposition of thin films of protective metal such as nickel, cobalt, tungsten and metal alloys upon stationary objects has been accomplished in the past by enclosing an object to be plated in a chamber, charging the chamber with a decomposable metal-bearing gas and heating the object to the decomposition temperature for said gas.

In the only process of which applicants have knowledge wherein an object is moved in the plating zone, the material is thin metal sheet. This flat material is brought to the gas decomposition temperature by resistance heaters placed adjacent the underside of the sheet.

The upper side of the sheet is exposed to the decomposable gases.

This metal sheet is brought into and out of the plating chamber by passing the sheet through a water bath which acts as a seal for the gas chamber.

Neither of these systems is commercially feasible for the plating of wire. The size of the wire is such that it is not heated evenly by radiant heaters. Secondly, the wire will not form a partition shutting off access of the gas to water in which the gas is soluble, in any reasonably proportioned system. Thirdly, wire is not evenly plated in a chamber where it is not kept in constant motion.

Thus, the plating of wire presents two major problems, heating the wire and sealing the chamber against leakage of poisonous gases while continuously passing the wire through the chamber, for which the earlier processes offer no solution.

It is an object of this invention to overcome the disadvantages and limitations of the processes known heretofore.

It is also an object of this invention to provide a continuous process for plating wire.

It is a further object of this invention to provide small compact apparatus of high wire plating capacity.

It is another object of this invention to provide a process wherein wire is preliminarily coated, heat treated for increased adhesion, and given a finish plating in succeeding steps without a time lag therebetween.

It is also an object of the present invention to provide apparatus for rapid passage of the wire therethrough.

It is a further object of this invention to provide apparatus having provision for conducting electricity to wire so that the wire will heat due to its own internal resistance.
Carbon dioxide, helium, nitrogen, hydrogen, the gaseous product of controlled burning of hydrocarbon gases free of oxygen, and the like, have been utilized as a carrier medium or inert gas medium.

In some instances the use of hydrogen is preferred, as for example, in the cleaning anneal chamber where its ability to act as a reducing agent may be put to advantage to remove the oxide film or rust from iron wire.

Metals to be deposited may be introduced as gaseous metal carbonyls or vaporized solutions of certain of the metal carbonyls in readily vaporizable solvents (for example, petroleum ether), also nitroxy compounds, nitroxy carbonyls, metal hydrides, metal alkyls, metal halides, and the like.

Illustrative compounds of the carbonyl type are nickel, iron, chromium, molybdenum, cobalt, and mixed carbonyls.

Illustrative compounds of other groups are the nitroxylics, such as copper nitroxy; nitroxy carbonyls, for example, cobalt nitroxy carbonyl; hydrides, such as antimony hydride, tin hydride; metal alkyls, such as chromyl chloride; and carbonyl halogens, for example, osmium carbonyl bromide, ruthenium carbonyl chloride, and the like.

Each material from which a metal may be plated has a temperature at which decomposition is complete. However, decomposition may take place slowly at a lower temperature or while the vapors are being raised in temperature through some particular range. For example, nickel carbonyl completely decomposes at a temperature in the range of 375°F. to 400°F. However, nickel carbonyl starts to decompose slowly at about 375°F. and therefore decomposition continues during the time of heating from 300°F. to 380°F.

A large number of the metal carbonyls and hydrides may be effectively and efficiently decomposed at a temperature in the range of 350°F. to 450°F. When working with most metal carbonyls we prefer to operate in a temperature range of from 375°F. to 425°F.

In order to deposit coatings on the wire, it is necessary that the wire be at a temperature in the general decomposition range of the volatile compounds.

If the wire is, for example, hot drawn wire, the hot wire upon cooling to the plating temperature range may be led directly to plating chambers of the hereinafter described apparatus, with or without an annealing stage therebetween. If an anneal is desired, the operation within the apparatus may be carried out in a manner similar to that used when starting with cold wire.

Cold wire is raised to and maintained at desired temperatures by causing the wire to conduct electricity or by induction heating.

The voltage required will vary depending upon the type of wire. Iron wire, for example, heats to a plating temperature with a lower voltage or lower frequency than, for example, copper wire.

When annealing temperatures, which are considerably higher than plating temperatures, i. e., in the range of 500°F. to 1200°F, are to be used the operation generally consists of impressing upon terminals contacting the wire a voltage sufficient to bring the wire to a red heat.

The lower temperature of the plating area is then accomplished by placing an electrical shunt in parallel with the plating zone. In this way the amount of current passing in the wire in the plating zone is reduced and as a result its temperature quickly reduces to a desirable range.

Preparatory to coating the wire the metallic material may be cleaned by employing conventional methods used in the art, comprising electro-chemically cleaning by moving the same through a bath of alkali or acid electrolyte wherein the wire is made the cathode or anode.

Pickling of the metal with hydrochloric, sulfuric or nitric acid, or a combination of acids may also be made as a part of the cleaning process and the wire thoroughly rinsed or washed prior to introduction into the plating apparatus.

However, if the wire is in good condition a cleaning anneal may suffice, in which event the wire may be heated just prior to entering the plating chamber.

In a cleaning anneal any grease and the like will be burned away by bringing the wire to red heat.

The invention will be more clearly understood from the following description of one embodiment of the apparatus and its mode of operation.

In the drawings:

Figure 1 is a diagrammatic illustration of a complete plating unit.

Figure 2 is an enlarged sectional view diagrammatically showing the seal used at either the inlet or outlet end of the tubular unit; and

Figure 3 is a sectional view diagrammatically illustrating the partition unit separating the tubular unit into segments.

Referring to Figure 1, there is shown a base 10 upon which is mounted a tubular unit 11 composed of five sections 12 to 16 supported by holder brackets 17 which in the instant illustration are set to support partition units 18 dividing unit 11 into sections or compartments.

Wire to be plated is mounted on a spool or reel 19 and enters unit 11 through a seal 20, passes through the partition units 18 and is drawn out through a seal 21 of construction similar to seal 22.

Plated wire is wound on a spool 22 driven by suitable power means 23 such as an electric motor.

Seal 20 is more fully illustrated in Figure 2. Seal 20 consists of a base cup 25 of material which is preferably a non-electrical conductor. This cup is adapted to be substantially filled with a fluid, such as mercury, low melting point eutectic fusible alloys, or equivalent fluid. Mounted on the base cup 25 is a support 26. Support 26 carries three small pulleys 27, 28 and 29 mounted on ball bearings for free action.

Support 26 is composed of a vertical section 30 bored as at 31 and adapted to extend into the mercury bath. Head section 32 of support 26 is bored as at 33. Bore 33 is adapted at the lip 34 to receive a partition element 18 to be described later in detail and has an enlarged portion 35 adapted as a chamber in which the pulley 27 is enclosed.

Partition element 18 is preferably of conducting material and consists of a block 40 which is horizontally bore, to have a leftwardly direction as at 41 and parallel thereto in a rightwardly direction as at 42.

Bore 42 is tapered as at 43 and ends in a small diameter aperture 44 in the rightwardly wall of block 40. Below and adjacent the aperture 44,
block 40 is provided with an extension 45 adapted to support a mercury contact 46 for use when the wire is to be a conductor.

Bore 42 is provided with a port 47 whose axis is disposed at 90° to the axis of the bore in the wall block 40, which is of the same diameter as bore 42 and adapted to receive a tubular member.

Bore 41 is provided with a port 49 whose axis is disposed at 90° to the axis of the bore adapted to receive a tubular member.

Conduit 50 is joined to the block 40 by suitable means 51, such as welding, screws and the like.

When unit 18 is used as an end piece, a tubular member 43 is provided for bore 42 and port 47 is closed by suitable means.

Tubular member 48 is adapted for gas tight engagement with seal 20 through suitable means 53 such as a gasket.

The unit 18 is joined to a tubular section, for example section 12, through flexible tube means 54.

When unit 18 is used as an intermediate connector, tubular member 49 is positioned in port 47 and flexible tube means 55 is provided forming a gas tight seal between unit 18 and, for example, tubular section 13.

In brief, the operation of the apparatus is as follows:

Wire on the reel 19 moves through seal 20 by passing over pulley 29 and down through the mercury. The wire turns upward after passing below pulley 28 and passes over pulley 27. The wire then traverses tubular member 40 and bore 42 and passes through aperture 44. The wire is energized by meeting the mercury contact 46.

The wire passes through tubular unit 11 and its partition element 18 until it emerges through the outlet seal 21. The coated wire is then accumulated on reel 22.

Gas flow in this apparatus is counter-current to the direction of travel of the wire in each compartment.

Further, the gas in each compartment may be fed from separate systems, or, under certain circumstances, the plating compartments 13 and 15 may be connected in series and chambers 12, 14 and 16 connected in series.

Accordingly, each chamber receives gas through tubular member 49a depending from partition element 10 and is removed through tubular member 48 of the next succeeding partition element 18.

In this apparatus, copper wire and steel wire, such as No. 36 iron wire SAE 1010 have been successfully plated at rates of wire movement in the range of 10 to 30 feet per minute and generally at rates of 1 foot per minute per foot of plating chamber, with nickel, chromium and like metals deposited from decomposable volatile compounds such as nickel carbonyls and hydrides.

When using a segment or compartment apparatus described in connection with the drawing, plating gases were excluded from the non-plating sections or compartments by passing through these compartments inert gas at rates in the range of 10 to 20 cubic feet per hour.

In the plating chambers gas flow of mixed gas containing inert gas such as nitrogen mixed with volatile metal compounds is at a gas rate in the range of 2 to 5 cubic feet per hour.

In the plating of nickel upon No. 36 iron wire SAE 1010 the following conditions were maintained:

- Wire rate 18 feet per minute.
- Temperature of the wire in the anneal compartments 1,000° F.
- Temperature of the wire in the plating compartments approximately 395° F.

Rate of flow of carbon dioxide gas through the three annealing compartments in series approximately 14 cubic feet per hour.

Rate of flow of gas through the plating compartments approximately 3 cubic feet per hour, with nickel carbonyl vapors being present in the ratio of approximately 5½ ounces of carbonyl per cubic foot of carbon dioxide gas.

It will be understood that while the method and apparatus disclosed and described herein illustrate a preferred form of invention, modifications can be made without departing from the spirit of the invention, and that modifications that fall within the scope of the appended claims are intended to be included herein.

We claim:

1. The method of plating metal wire of continuous length which comprises continuously moving the wire therealong from a source of supply through a plurality of chambers including a gaseous metal plating chamber, heating said wire as the same is continuously moved along to a temperature sufficient to decompose a heat-decomposable gaseous metal compound brought in contact therewith, said moving hot wire being maintained in a non-oxidizing atmosphere, moving said heated wire into said plating chamber and subjecting the same to a continuously moving gaseous mass at least a portion of which comprises a heat-decomposable gaseous metal compound, said wire being heated to a temperature sufficient to cause decomposition of said heat-decomposable gaseous metal compound which is circulated in contact therewith and deposition of the metal constituent thereof on the surface of the wire as the same is continuously moved therealong, and maintaining a differential in gaseous pressures between said plating chamber and preceding and succeeding chambers, said pressures within the chambers adjacent the plating chamber being slightly higher than that within said plating chamber to prevent leakage of said gaseous metal compound from said plating chamber.

2. The method of plating metal wire of continuous length which comprises continuously moving the wire therealong from a source of supply through a plurality of chambers including a gaseous metal plating chamber, heating said wire as the same is continuously moved along to a temperature sufficient to anneal said wire and in the range of about 800° F. to 1200° F., said moving wire being maintained in a non-oxidizing atmosphere, lowering the temperature of the wire to a temperature sufficient to decompose a heat-decomposable gaseous metal compound brought in contact therewith, moving said heated wire into said plating chamber and subjecting the same to a continuously moving gaseous mass at least a portion of which comprises a heat-decomposable gaseous metal compound, said wire being heated to a temperature sufficient to cause decomposition of said heat-decomposable gaseous metal compound which is circulated in contact therewith and deposition of the metal constituent thereof on the surface of the wire as the same is continuously moved therealong, and maintaining a differential in gaseous pressures between said plating chamber and preceding and succeeding chambers, said pressures within the chambers adjacent the plating chamber being slightly higher than that within said plating chamber to prevent leakage of said gaseous metal compound from said plating chamber.
gaseous pressures between said plating chamber and preceding and succeeding chambers, said pressures within the chambers adjacent the plating chamber being slightly higher than that within said plating chamber to prevent leakage of said gaseous metal compound from said plating chamber.

3. The method of plating metal wire of continuous length which comprises continuously moving the wire therealong from a source of supply through a plurality of chambers including a gaseous metal plating chamber, heating said wire under non-oxidizing atmospheric conditions as the same is continuously moved along to a temperature sufficient to anneal said wire and in the range of about 800° F. to 1200° F., said annealing being effected by passing electric current through said wire to cause said wire to be heated to the annealing temperature, lowering the temperature of the wire by shunting a portion of the electric current passing through said wire whereby said wire is heated to a lower temperature, and moving said heated wire into said plating chamber subjecting said lower temperature wire to a continuously moving gaseous mass at least a portion of which comprises a heat-decomposable gaseous metal compound, said wire being heated to a temperature sufficient to cause decomposition of said heat-decomposable gaseous metal compound which is circulated in contact therewith and deposition of the metal constituent thereof on the surface of the wire as the same is continuously moved therealong, and maintaining a differential in gaseous pressures between said plating chamber and preceding and succeeding chambers, said pressures within the chambers adjacent the plating zone being slightly higher than that within said plating chamber to prevent leakage of said gaseous metal compound from said plating chamber.

4. The method of plating metal wire of continuous length which comprises continuously moving the wire therealong from a source of supply, heating said wire under non-oxidizing atmospheric conditions as the same is continuously moved along to a temperature sufficient to anneal said wire, said annealing being effected by passing electric current through said wire to cause said wire to be heated to the annealing temperature and in the range of about 800° F. to 1200° F., lowering the temperature of the wire as the same is moved along to about 350° F. to 450° F. by shunting a portion of the electric current passing through said wire whereby said wire is heated to a lower temperature, moving said heated wire through a plating zone and subjecting said lower temperature heated wire while in said zone to a continuously moving gaseous mass at least a portion of which comprises a heat-decomposable gaseous metal compound, said wire being heated to a temperature sufficient to cause decomposition of said heat-decomposable gaseous metal compound which is circulated in contact therewith and deposition of the metal constituent thereof on the surface of the wire as the same is continuously moved therealong, and maintaining a differential in gaseous pressure between said plating zone and preceding and succeeding zones, said pressures within the zones adjacent the plating zone being slightly higher than that within said plating zone to prevent leakage of said gaseous metal compound from said plating zone.

5. The method of plating metal wire of continuous length which comprises continuously moving the wire therealong from a source of supply through a plurality of chambers including a gaseous metal plating chamber, heating said wire under non-oxidizing atmospheric conditions as the same is continuously moved along to a temperature sufficient to decompose a heat-decomposable gaseous metal compound brought in contact therewith, moving said heated wire into said plating chamber subjecting said wire to a continuously moving gaseous mass comprising carbon dioxide and nickel carbonyl, said wire being heated to a temperature sufficient to cause decomposition of said nickel carbonyl and deposition of the nickel on the surface of the wire as the same is continuously moved therealong, and maintaining a differential in gaseous pressures between said plating chamber and preceding and succeeding chambers, said pressures within the chambers adjacent the plating zone being slightly higher than that within said plating chamber to prevent leakage of said gaseous metal compound from said plating chamber.

6. The method of plating metal wire of continuous length which comprises continuously moving the wire therealong from a source of supply, heating said wire under non-oxidizing atmospheric conditions as the same is continuously moved along to a temperature sufficient to anneal said wire, said annealing temperature being effected by passing electric current through said wire to cause the same to be heated said distance to the passage of electric current to the annealing temperature and in the range of about 800° F. to 1200° F., lowering the temperature of the wire as the same is moved along by shunting a portion of the electric current passing through said wire whereby said wire is heated to a lower temperature, moving said heated wire through a plating zone and subjecting said lower temperature heated wire while in said zone to a continuously moving gaseous mass comprising nickel carbonyl, said wire being heated to a temperature sufficient to cause decomposition of said nickel carbonyl and deposition of the nickel on the surface of the wire as the same is continuously moved therealong, and maintaining a differential in gaseous pressure between said plating zone and preceding and succeeding zones, said pressures within the zones adjacent the plating zone being slightly higher than that within said plating zone to prevent leakage of said gaseous metal compound from said plating zone.

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