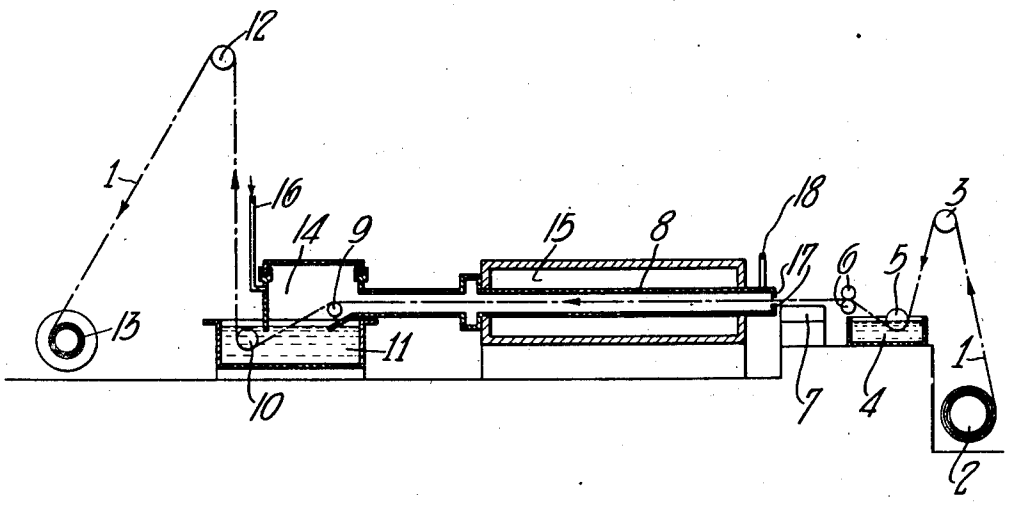
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METAL COATING

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METAL COATING

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This invention is particularly concerned with continuously coating steel strip with molten metal of the class consisting of zinc, tin, aluminum and their alloys, but certain of its features may be applicable to coating in a manner other than continuously.

The accompanying drawing schematically illustrates a specific example of the invention in operation.

More specifically, this drawing shows steel strip 1, which may be of any chemical composition, gauge and width suitable for coating with molten metal of the class described, this strip being upwardly fed continuously from a coil 2 around a roller 3 and downwardly into a tank 4 containing a water solution of ammonium chloride, otherwise called sal ammoniac, the strip being dipped into the solution in this tank by a sinking roller 5 in such a fashion that both sides of the strip become thoroughly wet with the solution. The ammonium chloride concentration of this solution may vary from 1 to 10% by weight, the balance being water.

Leaving the ammonium chloride solution in the tank 4, the strip next travels between squeegee rollers 6 pressed against both sides of the strip and having surfaces proper for squeegeeing such as soft rubber, the squeegeeing action being adjusted to leave the strip wet on both sides with thin smooth films of sal ammoniac solution. The water from these films is then evaporated, by the strip next passing over a heater 7, so as to leave its surfaces coated with dry ammonium chloride. The heater 7 may be of the open gas-flame type since the temperatures to which it heats the strip are not critical beyond the limits required to thoroughly dry its surfaces, by evaporation of the water, but, since the purpose in mind is to provide the strip with uniformly distributed layers of ammonium chloride, it is important that the temperature of the strip is not raised so high as to cause vaporization of the ammonium chloride.

With its dried coatings of ammonium chloride, the strip next enters and passes through a horizontal enclosure or muffle 8 from which it leaves over a roller 9, this roller 9 and the squeegee rollers 6 guiding the strip so it travels through the muffle as a free span, the strip then bending downwardly around this roller 9 and going around and under a sinking roller 10 so as to dip into the described molten coating metal in a pan 11, the strip traveling upwardly from the sinking roller 10 over a roller 12 and downwardly to a

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coiler 13, the latter pulling the strip under tension from the coil 2.

The end of the muffle 8 opens into a box 14 completely covering the top of the coating metal, into which the strip dips, the roller 9 and the strip itself, the idea being to completely enclose the strip from the time it enters the muffle 8 until it leaves the coating metal. To this end, the edges of the box 14 dip into the top of the metal in the pan 11, the box being made gas-tight and connecting in a gas-tight manner with the muffle 8.

A considerable portion of the muffle 8 is surrounded by a heating chamber 15 designed to put sufficient heat into the muffle to raise the temperature of the strip traveling through it to from 1000° F. to higher temperatures, the maximum temperature being fixed by the fact that it must not be so extreme as to melt the strip. The portion of the muffle thus heated is that portion toward the end of the muffle where the strip enters it, and a sufficient length of the muffle at its other end is left exposed to the air to provide for cooling the strip to temperatures required for the hot-dip coating application, it being understood that the different metals in the class described require different temperatures depending on the peculiarities of the parficular metal involved. Generally speaking, the prior art is familiar with the temperatures required, in the case of any of the metals described, for the proper alloy-bonding responsible for the adherence of the coating to the strip. In all cases the length of the muffle enclosed by the furnace so it functions as a heating zone, and the length left exposed to the atmosphere so that it functions as a cooling zone, may be determined by any skilled furnace designer, due consideration being paid respecting the gauge of the strip, its traveling speed, and the temperature to which it is desired to be raised in the heating portion of the muffle.

A gas inlet 16 is provided in the box 14 at its end remote from the muffle 8 and, preferably, quite close to the top of the coating metal enclosed by this box, hydrogen being introduced through this inlet under sufficient pressure to cause the hydrogen to flood the box 14 and flow through the muffle 8 counter the traveling direction of the strip, the strip-entering-end of the muffle being preferably provided with a seal 17 and a little stack 18 close to the seal 17, the stack 18 providing a gas exit for the muffle and also serving to provide an indication that the hydrogen is flowing through the furnace, since the exiting gases may be lit at this stack to indicate

the presence of the hydrogen by continued burning of a flame. In such cases the flame should burn continuously since this assures the passage of hydrogen through the muffle, the hydrogen functioning to make the atmosphere in the muffle reducing throughout its length including that portion that is heated.

In operation, the strip carrying its coatings of dried ammonium chloride enters the muffle and soon acquires a high enough temperature to cause vaporization of the ammonium chloride, thus continuously introducing ammonium chloride to the muffle at its strip-entering-end. The chlorine in the ammonium chloride vapor, thus formed in the muffle, functions to condition the strip for the coating step, it being the chlorine that apparently is effective in carrying out this conditioning and it being possible to introduce chlorine in other forms to the muffle, such as by the injection of hydrogen chloride or, for that matter, chlorine gas somewhere near its strip-entering-end. However, the introduction of the ammonium chloride in the manner described is very advantageous in that it is continuous and permits easy and exact control of the amount of ammonium chloride introduced. It may be mentioned at this point that if too thin ammonium chloride layers are formed on the strip prior to its entering the muffle, as by the use of too low an ammonium chloride concentration in the water solution or by too tightly adjusting the squeegee rollers, that then there will not be enough ammonium chloride to provide for effective conditioning for application of the coating, experience best indicating the minimum amount needed but it being suggested that in actual practice the amount should not drop below around .002 pound per hundred square feet of strip surface area. On the other hand, too heavy a coating of ammonium chloride produces a roughly coated product, experience again best serving to indicate when too much ammonium chloride is used. Generally speaking, the amount should not exceed .015 pound per hundred square feet of the strip surface.

Now if the ammonium chloride vapor concentration in the muffle is sufficient to properly condition the strip for its ultimate coating with the molten metal, of the class described, the iron of the strip is attacked by the chlorine. That is to say, to perform its function the chlorine concentration, whether provided as ammonium chloride, hydrogen chloride, or chlorine, must be sufficient to form compounds with the iron of the strip. This is disadvantageous as an ultimate result since it represents an iron loss and causes complications during the application of the molten coating metal. Furthermore, in commercial work it is ordinarily desirable to make the muffle out of a ferrous material, and this muffle is subject to chemical attack when the chlorine concentration of the muffle atmosphere, through which the strip is being passed, is sufficient for its intended purpose.

In addition to the above, if the chlorine contacts the molten coating metal in the pan 11 it forms chlorine compounds with the coating metal which is disadvantageous to the coating application. This is particularly true in the case of certain of the coating metals described, an alloy of zinc and a little aluminum, such as is commonly used to provide a zinc coating of maximum adherence, introducing particular difficulties in this respect. In the case of zinc alone, zinc chloride is one of the fluxes used in ordinary zinc coating practices, but this requires a thick layer of the flux and it has been found that when the flux is not used, and the chlorine contacts the zinc, that the thin layer of zinc chloride that then forms introduces roughness to the ultimately coated product.

All of the foregoing disadvantages, connected with the use of chlorine in the muffle, are eliminated in the case of the present invention by the introduction of hydrogen through the inlet 16 to the box 14, the flow rate and pressure of the hydrogen being adjusted to keep a barrier of the hydrogen between the surface of the metal in the pan 11 and the ammonium chloride, or other chlorine-containing atmosphere, in the muffle, this barrier consisting of hydrogen alone in the box 14 and at least an adjacent part of the cooling portion of the muffle 8, and then gradually becoming mixed with the ammonium chloride in the heated portion of the muffle.

Now in all instances the hydrogen must be sufficient to render the atmosphere throughout the heated portion of the muffle reducing respecting the formation of the compounds that would otherwise form between the chlorine and the iron of the strip under treatment. When this is done, iron-chlorine compounds either do not form or are immediately reduced, and by keeping the atmosphere reducing, throughout the length of the muffle, respecting the formation of compounds that would otherwise be formed in the absence of the hydrogen between the chlorine and the iron of the strip, and of the muffle itself if this is made of ferrous metal, all the difficulties described are avoided. At the same time, it has been found that the chlorine, regardless of its form, conditions the strip for reception of the molten coating metal in the pan 11 as effectively under reducing conditions as under any other condition. It also follows that after the strip is conditioned, and during its cooling to a temperature permitting application of the molten coating metal, it is continuously bathed in a reducing atmosphere.

It is to be understood that it is unnecessary to use pure hydrogen, it being possible to introduce a mixture of hydrogen and a comparatively inert gas, such as nitrogen, to the inlet 16. However, in all instances there must be sufficient hydrogen to maintain the atmosphere throughout the muffle reducing in nature respecting the formation of the iron-chlorine compounds that would form otherwise.

After the strip has passed through the reducing atmosphere of hydrogen and ammonium chloride, or hydrogen and chlorine, and is cooled, by passing through the cooling portion of the muffle, it then enters the molten coating metal and emerges therefrom with a properly bonded coating, the roller 12 being arranged sufficiently high to permit complete freezing of the metal. It may be desirable to wipe the strip, as it leaves the coating bath, to more uniformly distribute the coating.

Although 1000° F. has been set as the minimum temperature to which the strip must be heated, this applies mainly to the continuous process specifically disclosed. But it may be that the principles of the invention might otherwise be used advantageously as by discontinuous methods providing longer treatment times than are possible with practical continuous methods. In such instances the temperature of the work while it is being treated in the atmosphere containing

the chlorine and hydrogen may be dropped as low as 660° F., this being at least academically operative assuming that adequate time is permitted. When the strip is on the move, as it is in a continuous process, it has not been found posisble to drop below around about 1000° F., and 1050° F. may be taken as a completely safe working minimum temperature in any event.

It is to be noted that in all instances it is possible to use a treating temperature below the recrystallization temperature of cold-worked steel strip and, likewise, well below the critical temperature of ordinary steel strip. Therefore, dead-soft box-annealed steel strip may be coated with metal in the manner described without its being subjected to the equivalent of a normalizing heat treatment, whereby it largely retains its dead-soft characteristics. On the other hand, full-hard cold-rolled strip may be coated without substantial loss of its full-hard characteristics. At the same time the temperatures may be raised well above the 1000° F. minimum, applicable to the continuous process, so as to effect normalizing or annealing of full-hard cold-rolled strip as a part of the metal coating process, whereby to combine the heat treatment and metal coating of cold-reduced steel strip into one process.

The product resulting from the present invention has exceptionally good adherence between its metal coating and the steel strip forming the base, the adherence being equivalent to that obtained by the old method of hot-dipping sheets singly. Furthermore, the steel may vary in its composition to a greater extent than has ever before been possible, commercially satisfactory adherence between zinc and the steel strip being attained even when the strip is made from rimmed steel with its characteristically nearly pure iron surfaces that have always caused poor zinc adherence heretofore.

We claim:

1. A ferrous metal coating method comprising wetting the ferrous metal with a water solution of ammonium chloride, drying the metal so it retains a coating of ammonium chloride, heating the metal to temperatures ranging from 660° F. to higher temperatures insufficient to melt the ferrous metal in an atmosphere containing sufficient hydrogen to make it reducing respecting the formation of iron compounds by the ammonium chloride, and subsequently coating the ferrous metal with molten metal selected from the group consisting of zinc, tin, aluminum and their alloys.

2. A continuous ferrous metal strip and wire product coating method comprising continuously passing the product through a water solution of ammonium chloride, drying the product so it retains a coating of ammonium chloride, continuously passing the thus coated product through an enclosure containing hydrogen at temperatures of from 1000° F. to higher temperatures insufficient to melt the product, and subsequently continuously coating the product with molten metal selected from the group consisting of zinc, tin, aluminum and their alloys.

3. A continuous steel strip and wire product coating method comprising continuously passing the product through a bath of a water solution of ammonium chloride to wet the product therewith, drying the product so it retains a coating of ammonium chloride, continuously passing the thus coated product through an enclosure while heating the product in the product entering end of the enclosure to temperatures of from 1000° F. to higher temperatures insufficient to melt the product so as to vaporize its said coating and produce an atmosphere of ammonium chloride vapor in the enclosure, coating the product at the product exiting end of the enclosure with molten metal selected from the group consisting of zinc, tin, aluminum and their alloys with the molten coating metal exposed to the enclosure atmosphere, and continuously introducing hydrogen to the product exiting end of the enclosure to protect the coating metal from the ammonium chloride and so the hydrogen flows to the product entering end of the enclosure and mixes with the atmosphere there to maintain it reducing respecting the formation of compounds of iron and chlorine at the temperatures described.

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