July 2, 1957 T. SENDZIMIR 2,797,476

PROCESS AND APPARATUS FOR TREATING METALLIC STRIPS

Filed June 17, 1952 3 Sheets-Sheet 1

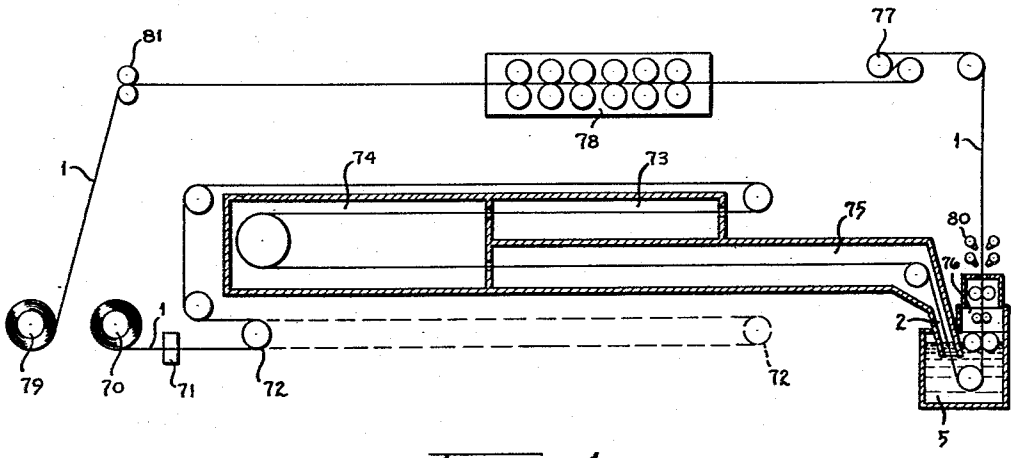


FIG. 1

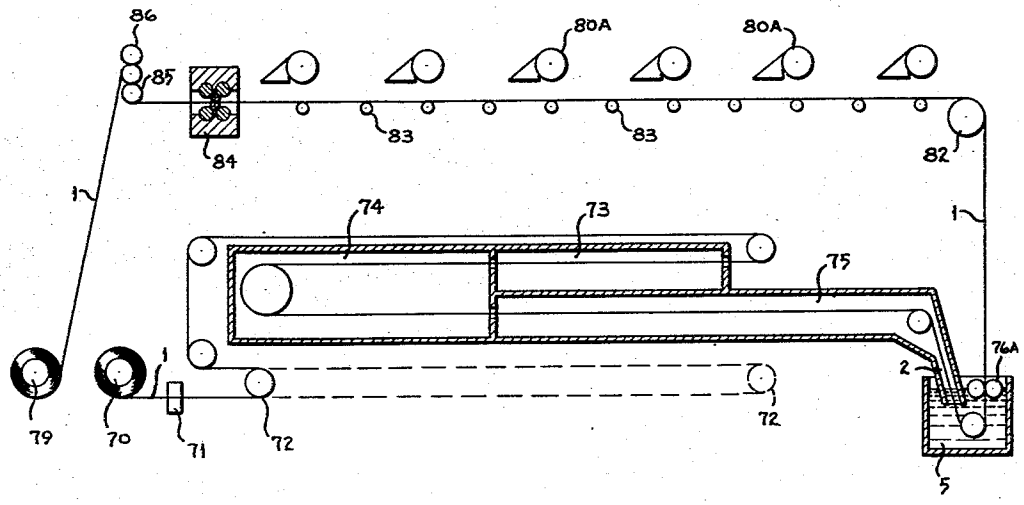


FIG. 2

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Filed June 17, 1952 3 Sheets-Sheet 2

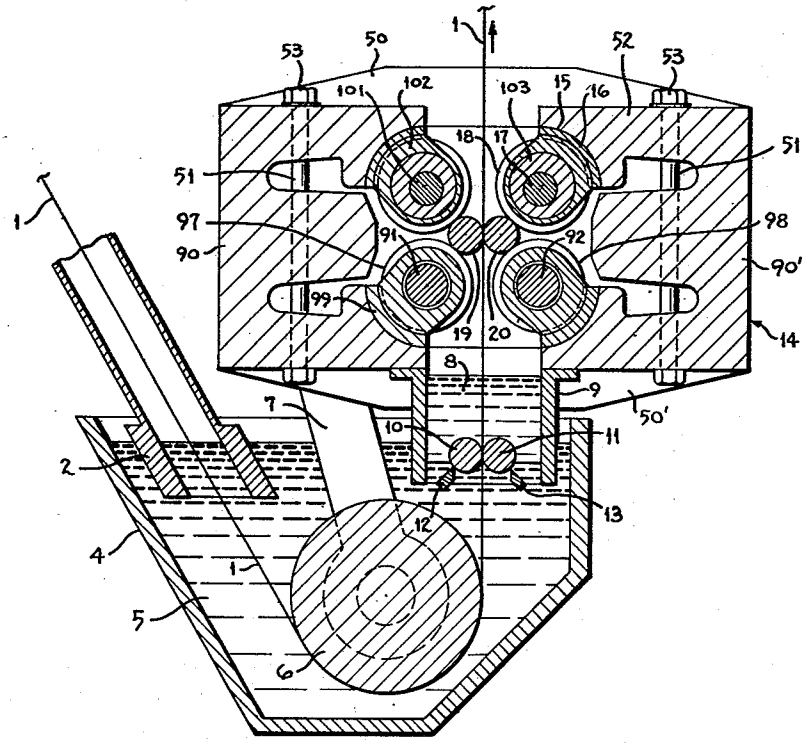


FIG. 3

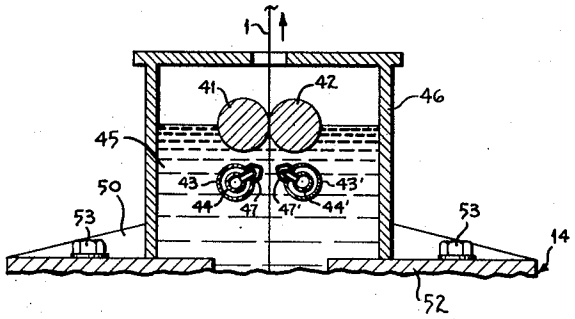


FIG. 3A

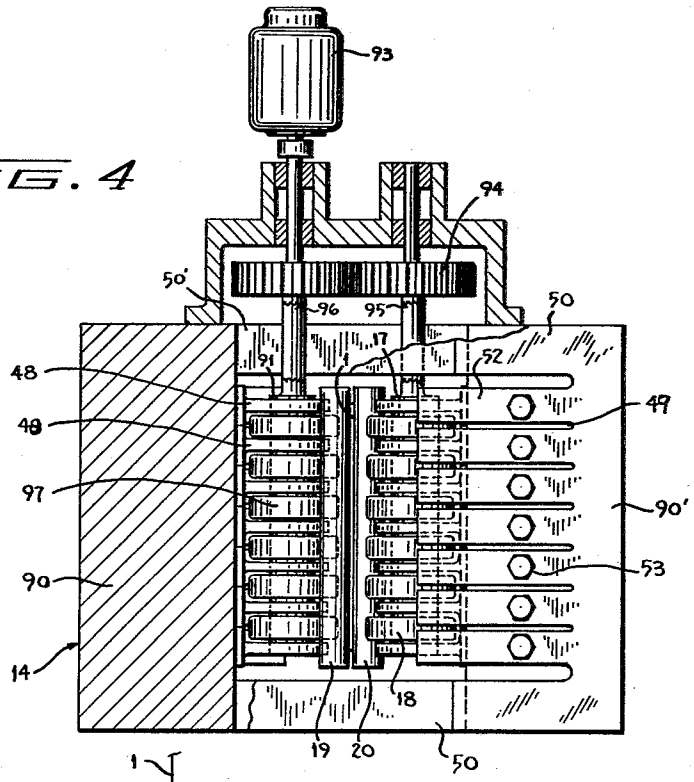
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PROCESS AND APPARATUS FOR TREATING METALLIC STRIPS

Filed June 17, 1952 3 Sheets-Sheet 3

FIG. 4



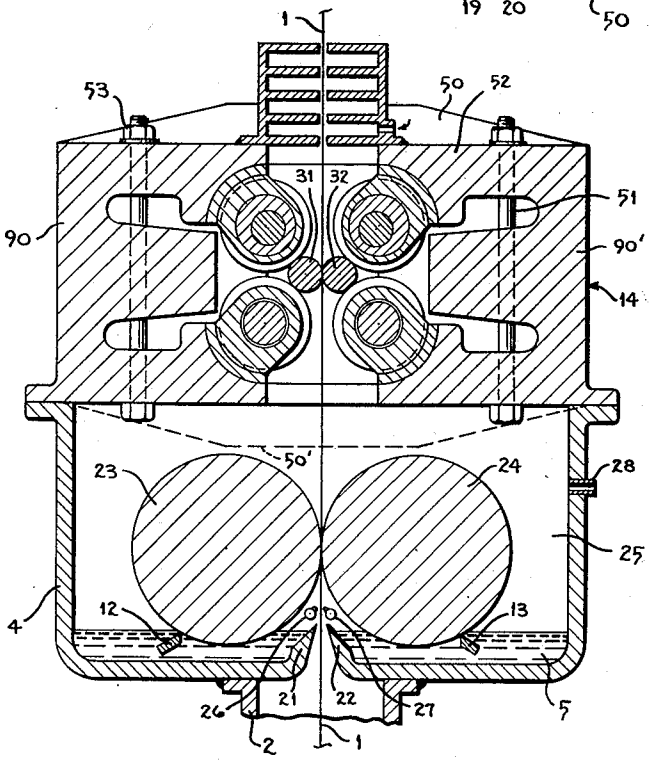


FIG. 5

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2,797,476

PROCESS AND APPARATUS FOR TREATING METALLIC STRIPS

Tadeusz Sendzimir, Middletown, Ohio

Application June 17, 1952, Serial No. 294,107

11 Claims. (Cl. 29—528)

In the process as described in my U. S. Patent 2,110,893, cold rolled steel strips are passed in succession through an oxidizing-cleaning unit, an annealing unit with reducing atmosphere, a cooling chamber, also with a neutral or reducing atmosphere, then, without getting in contact with the outside atmosphere, into the hot-dip metal bath, and out through a suitable exit roll or other exit mechanism to control the weight of the coating metal and its distribution. The strip is further passed in the free air under cooling conditions over other pulleys, back and forth, until it can be wound up on a coiler, in a ready annealed and coated condition.

This process represents a big advancement over prior art but it is still subject to inconvenience in that the finished strip, whether coated or only annealed, is very difficult in further handling as it cools down because on even slight bending over pulleys and on the winder it has a tendency to "flute," that is, instead of bending uniformly around the pulley, it bends very sharply in one place and remains straight in other places. Such "flutes" are in many cases impossible to remove from a sheet and it may even become unusable for some applications. They are usually less visible on galvanized or aluminized sheets where the coating is heavy but become particularly objectionable on simple bright annealed strips or on tin-coated where the coating is very light.

The present invention completely remedies the situation in providing a mill capable of taking a slight reduction on the strip, as a part of the process and from the point where such cold reduction has taken place, the strip is no longer susceptible to "fluting."

To give an example, an annealed but not cold rolled strip can be passed over pulleys the diameter of which is not less than two thousand times the thickness of the strip, whereas after such reduction, much smaller pulleys can be used.

It is a standard practice in the industry to temper roll annealed material either in strip or in sheet form as a means to get rid of fluting. It also has been tried on my continuous coating process units according to the patent above referred to, to include a roller leveller so as to give the material some cold working, but for all material except galvanized, the coil breaks or "flutes" left by such roller leveller are sufficiently pronounced to make the appearance of the strip objectionable.

I believe the idea to be new, to incorporate a regular cold rolling mill capable of temper rolling the strip, right in such processing equipment and thereby not only save the extra operation with the incidental storage of semi-finished materials between the two operations but with the added benefit of avoiding damage and "fluting" to the material since it is so delicate in handling before temper rolling. There is also a considerable saving in the cost of the equipment because the material handles more easily and all the pulleys and winders can be of smaller diameter and the supporting elements and rollers need not be so close together.

The combination of the annealing line with a temper pass mill also gives a substantial saving in capital investment, mainly through the fact that the strip tensioning equipment required in conjunction with the temper pass mill represents a big proportion of the cost of such installation and a tensioning equipment is also required in the annealing or annealing and metal coating line, for the purpose of guiding the strip and also for the purpose of stretch-levelling it during the annealing cycle. Although the requirements of such tensions do not quite coincide, a compromise is possible particularly with a temper rolling instrumentality as hereinafter described. A combined unit using a single strip tensioning system represents a considerable saving over the cost of two separate installations.

Ordinarily, whether the process is used for bright annealing only or for bright annealing followed by a metallic coating, I prefer to first cool the strip down considerably before it is led through the temper rolling unit, but in certain cases I prefer to do the temper rolling right at the exit from the metal coating bath and, in fact, use the temper rolling rolls as one pair of the exit roll system of the coating unit, the object of which is to control the weight, distribution and finish of the coating. This pair of rolls can either do the whole amount of temper rolling required by specification, in one operation or only a part of it, to be followed by another temper rolling step at a point where the strip is already much cooler.

I found that if a temper rolling is done at higher temperatures such as approximately the temperature of the molten zinc or even molten tin coating bath, certain physical properties of the strip, mainly elongation, are liable to suffer slightly. I found that I can improve these conditions, especially when the metallic coating is skimmed down to be very thin, by chilling or cooling the strip down very rapidly right as it leaves the rolls, such as by a cool or even refrigerated air blast or by passing over an internally cooled roll or other equivalent device.

The fact that it has never been suggested or attempted to combine continuous strip cleaning and annealing with temper rolling, in one single process, is easily explained by the fact that conventional rolling equipment does not lend itself to such operation. Cleaning, annealing and/or coating lines such as described in the U. S. patent above mentioned are long high-production lines and the length of strip and consequently the weight of metal at any time comprised in such unit is considerable. Therefore, for economical operation, it is indispensable that they be run continuously without stoppage, day in and day out and month in and month out, and ordinarily continuous long runs are registered, except where a strip breaks at a weld between consecutive coils by accident, when a unit has to be stopped and then, of course, all the material comprised in the unit is scrapped.

Rolling mill equipment, on the other hand, does not lend itself to such treatment. Each coil is an entity by itself and the mill is always stopped and a new coil set in. After a few hours' operation, the rolls of such mills become worn out to the extent that a roll change is necessary and that usually takes half an hour or more during which the operation is stopped. Moreover, while the annealing and coating lines are large and expensive units, usually running over a million dollars each, their speed is moderate and uniform. Temper rolling equipment is also expensive, but its speed is not subject to such limits and in order to use it to its full advantage and compensate for the work stoppages between coils and for roll changes, such mills are invariably provided with variable speeds that permit to take the pass at much higher velocity than would be practical for the continuous annealing and coating lines.

While not excluding the possibility of use of conventional rolling equipment, such as a two-high or four-high mill, in conjunction with the present invention, I have found that I can obtain a great advantage by the use of the mill type described in Patents 2,170,732 and 2,479,974, and more particularly in Fig. 4 with details on Figs. 5 and 6 of the first-named patent. These are very light weight mills compactly built and involving only a small capital investment, as compared to four-high mills. They use small work rolls of high grade alloy steel such as, for instance, a steel containing 12% chromium and 2.2% carbon, which have a very high abrasion resistance and therefore last long. Moreover, roll changes on such mills can be made very rapidly, say, in half a minute, and therefore only a short piece of a strip which passes through the unit during such roll change will not receive a temper pass; the unit, however, would not be stopped.

The big difference between cold rolling steel strips for reduction in gauge and cold rolling for temper passing lies in the fact that in rolling to reduce gauge, say, from a low carbon hot rolled strip .080" x 32" to tinplate gauges such as .010" x 32", very heavy rolling passes are taken and the heavier the mill is the stronger its bearings and the smaller the rolls, the easier it takes such heavy passes. With temper passing, on the contrary, the physical specification calls for a certain percentual reduction that must be attained so as to remove the danger of coil breaks or "fluting," but which must not be exceeded because the strip will become too hard and lose some of its drawing qualities and other characteristics.

For this reason, only mills with relatively large diameter rolls were heretofore considered as acceptable for temper rolling because such rolling is performed upon material in its annealed state in which the first few percent of cold reduction are obtained with very little pressure. A conventional four-high mill if fitted with small diameter work rolls would be totally unsuitable for temper passing, because the rolls would sink into the strip too easily and never produce a uniform elongation.

It has been surprising to find that the mill of the type described in the two patents mentioned which in itself is at the other end of the scale in that it can be equipped with work rolls much smaller in diameter than those of a four-high mill, has proved to be quite dependable as a temper pass mill, for entirely a different reason: because of its almost absolute rigidity and its extreme precision in the support of the work rolls. Under the ordinary load as encountered in temper passing, the elastic deflection of the mill housing is practically nil and the deflections of the inside rotating elements are firstly, extremely slight and secondly, distributed very uniformly over the width of the strip.

These mills have been intended for taking very heavy reductions and have proved themselves invaluable especially when reducing very tough and hard metals and therefore it is important to find that they can be so applied. But since they can, the consequences that appeared to me are enormous because here we have not a large mill structure weighing several hundred tons, say, to roll 40" wide steel strip, but a small rigid steel housing weighing ten tons or less, doing the same work but physically so dimensioned that it can be conveniently placed and operated in conjunction with such unit.

There are other important advantages connected with the use of this process which will become apparent from the detailed description on hand, of figures of which:

Fig. 1 shows in diagram a complete installation of one embodiment of the invention.

Fig. 2 shows in diagram a complete installation of another embodiment of the invention.

Fig. 3 represents, in vertical cross section, a part of the installation including a bath of molten tin in which is submerged the exit portion of the cooling chamber and the skimming and temper rolling mill.

Fig. 3A shows, in vertical cross section, a modification at the top of the temper rolling mill of Fig. 3.

Fig. 4 shows the plan view of Fig. 3, partly in cross section.

Fig. 5 represents, in vertical cross section, another embodiment of the invention involving a modified tin pot combined with the temper rolling mill.

The schematic view in Fig. 1 shows an unwinder **70** for paying off the strip **1** into the unit. Strip **1** passes, in succession through: welder **71** for joining consecutive strips end to end, a looper **72** to provide enough strip **1** to the unit while the strip end is being welded. From the looper, strip **1** proceeds over suitable supports into the oxidizing part **73** of the furnace where it is preheated by waste heat of the cooling chamber **75** while its impurities are burned off and a light iron oxide coating is formed, annealing furnace **74** where strip **1** is heated to annealing temperature under deoxidizing conditions, and cooling hood **75** in which strip **1** is cooled to a temperature approaching the temperature of the metal coating bath **5** under non-oxidizing conditions. Strip **1** then passes through said coating bath **5** in the sealing bell **2**, all above substantially as described in U. S. Patent 2,136,957, Fig. 1, and upwardly through the skimming and temper rolling mechanism **76**, the rapid cooling unit **80**, the tensioning device **77**, the cleaner **78**, and is finally wound upon coiler **79** while pinch rolls **81** serve to propel the strip when a ready coil is taken off the coiler and a new one is started.

Fig. 2 is identical with Fig. 1 up to the point where strip **1** leaves the molten metal coating bath **5**. An "exit" or "skimming" mechanism **76A** is provided which controls the coating but does not temper roll the strip. Strip **1** is then passed over a large diameter pulley **82** and over closely spaced roller supports **83** disposed along its horizontal path, to avoid damage through fluting, and is subjected to the action of cooling fans **80A**. It is then passed through the temper rolling mill **84** and through a tensioning device **85** of smaller diameter, supplemented by pinch roll **86** to propel the strip during coil change on coiler **79** identical with the one of Fig. 1. My invention including temper pass with bright anneal does not necessarily have to be combined with the step of metal coating and applies to bright anneal and subsequent temper pass without a metal coat. The metal coating step can be omitted, say, by using the installation as shown in Fig. 2, and simply omitting to put a liquid metal bath in the pot **5** and providing a suitable seal at the exit of bell **2**. The cooling hood **75** will in this case, of course, have to be extended so as to provide enough coling for the metal strip **1**, under non-oxidizing condition, so that it first contacts outside atmosphere after it has already cooled down sufficiently, so as not to become oxidized on contact with said atmosphere.

In Figs. 3 and 4 representing the vertical cross section and top view, respectively, of one embodiment of the invention, the strip **1** passes from the cooling hood **75** (not shown) through sealing bell **2** which guarantees a gas-tight seal preventing contamination of the reducing, or at least neutral, atmosphere inside the hood. The pot **4** contains molten tin **5** or other suitable coating metal. Pot **4** is heated by a means such as gas burners or electrical resistors, not shown, to begin operation, but it is not necessary to heat it to maintain operation since the strip enters the tin bath at a slightly higher temperature than the bath itself and the heat it gives away to the bath is sufficient to maintain the temperature of the bath execpt to the extent that heating or cooling means, not shown, may be used to control the temperature of the bath within close limits, as is required for successful operation.

A hilly roll **6** is totally submerged in the tin bath, around which the strip turns on its way upward to the exit mechanism. The billy roll is not driven and its

necks are mounted on two bearings 7, one at each end, all substantially as described in the aforementioned Patent 2,136,957.

A palm oil or equivalent bath 8 is floating on the top of the molten tin and is contained in a housing 9 which housing also comprises bearings for the first pair of exit rolls 10 and 11, partially submerged in molten tin and partly in oil and preferably contacted by scrapers 12 and 13 to continuously clean and condition their surface. Temper rolling mill 14 is bolted to the housing 9 but it is mounted on separate pedestals, not shown, with which it is connected by supporting screws making it possible to slightly tilt said mill 14 in case it is necessary to slightly adjust its position out of horizontal, which adjustment may assist in guiding the strip through the unit.

The mill 14 comprises four identical parallel bored channels 15 which serve as bases for spaced supports 16 which in turn serve to give a continuous and accurate support to four parallel shafts 17 carrying caster rollers 18 which directly support, over their whole working length, the two work rolls 19 and 20. These rolls perform the dual function of controlling the thickness of the coating metal and also of temper rolling the strip itself as described in detail in the two rolling mill Patents 2,170,732 and 2,479,974 above cited.

If the treated material is tinplate strip, and a complete temper pass is to be produced, a reduction of 1 to 5% in the temper mill will suffice in most cases as is well known in the art. If only a partial temper pass is to be effected by the skimming rolls 19 and 20, the cold reduction required may be only a few tenths of 1%, when followed by another temper roll pass preferably while the strip is cooler or, if necessary, in an entirely different operation.

For the skimming operation, rolls 19 and 20 rely solely on the pressure exerted by them on the work piece 1 which pressure controls the thickness of the film of the molten tin and the tin iron alloy which adhere to the strip 1. Ordinarily, rolls 19 and 20 will do nothing but that, as far as the coating itself is concerned, since their relatively high chromium content will not permit them to be "wetted" on their surface by the molten tin. In cases where the appearance of the tin coating of such strip is dull and not acceptable commercially, another pair of wetted rolls similar to rolls 10 and 11 of Fig. 3 but disposed above rolls 19 and 20 may be used as a final finishing operation on the strip. The strip may be reheated again by high-frequency induction coils or similar means, just beyond the melting point of tin, as is well known in the electrolytic tinning industry, in order to produce a bright finish; this operation may later be followed by a light spray of atomized palm oil or equivalent to produce a surface that will not scratch too easily. This latter operation is also well known in the art.

The modification shown in Fig. 5 also comprises strip 1 passing vertically upwards through the sealing bell 2 where lips 21 and 22 of the tin pot 4 in conjunction with end seals, not shown, of the tinning rolls 23 and 24 form a gas tight seal to safeguard its neutral atmosphere.

As rolls 23 and 24 turn in the molten tin bath 5 in which they are partially submerged, they become wetted or coated with tin which is carried in the space between the rolls where their surfaces meet and contact strip 1. The molten tin forms an inverse meniscus in the bite between the rolls, owing to the co-action of capillary attraction and surface tension forces and since, at this stage, the strip 1 is perfectly free of oxide and its surface is ready to accept the tin, its surface becomes immediately wetted with tin which it carries upward through space 25, within the pot 4 and above the molten metal bath 5 which is hermetically sealed and also provided with a neutral atmosphere. This hermetic seal is effected by tightly bolting to pot 4 the housing 14 of the combined temper pass and skimming mill which is identical with the mill described in Fig. 3.

A neutral atmosphere such as helium or nitrogen or even combinations of gases such as are not capable of oxidizing molten tin at temperatures close to its melting point, protect the molten tin 5 as well as molten tin on the surface of wetted rolls 23 and 24 and on the surface of strip 1 from being covered with ashes and such ashes from gradually accumulating on the rolls. Whatever little impurities may attach themselves to the surface of the rolls, are scraped off in conventional manner by lightly touching scrapers 12 and 13.

Palm oil or equivalent could be used on the surface of the tin bath with this embodiment but I prefer not to use it for fear that its vapors might contaminate the absolutely neutral atmosphere inside bell 2. Moreover, I prefer the use of a neutral atmosphere within the space 25, even though the presence of palm oil would not make it absolutely indispensable, because even palm oil oxidizes readily and under protective atmosphere conditions, operation becomes very much cleaner and the consumption of palm oil decreases. Neutral atmosphere gas is delivered into space 25 through tubes 26 and 27, each having a plurality of little jets directed toward strip 1 but so inclined that the gas currents created have a direction towards the edges of the strip. This is for the purpose of blowing away any excess tin that may be running down strip 1 back into the pot 4 and prevent it from falling into bell 2. The neutral atmosphere gas has to be supplied in excess of the losses through seals so as to maintain space 25 under slight pressure over atmospheric so as to prevent infiltration of air through seals. In order to give the gas jets sufficient velocity for the purpose of blowing away tin as above described, said gas has to be recirculated and for this purpose it has to be taken out of space 25, for instance, through tube connection 28 and recirculated in a closed circuit by a suitable pump, not shown, with addition of fresh gas to compensate for seal losses as above explained.

The selection of correct gases for such protected atmosphere is important and in certain cases an active reducing gas may be required, in a certain proportion, such as hydrogen or carbon monoxide. This selection depends chiefly on the analysis of the coating metal and of course on the bath temperature which is closely connected with it. Wherever, for the purpose of obtaining clean coatings it is found necessary to keep the partial pressure of oxygen extremely low, I prefer to use, in connection with the gas recirculating system above described, a device that I have patented in my U. S. Patent 2,136,957, Figs. 2, 7, 8 and other, and which I originally developed for use in a cooling chamber in order to refine the reducing atmosphere in contact with the steel strip immediately preceding the application of a molten metal coating. However, I see that for the purpose of neutralizing atmospheric action in space 25 or in functionally comparable spaces in other embodiments of the present invention, i. e. where the atmosphere is essentially in contact with the molten coating metal, the use of this patented refinement will give, after the strip has passed through the coating bath, fine practical results in making the coating smoother and more free from blemishes and even in increasing the useful life of exit rolls 23 and 24.

The device referred to essentially consists in providing, within the recirculating system, another molten metal bath containing certain metals having high affinity to oxygen. If the recirculated atmosphere is for instance blown in bubbles through such metallic bath as shown in Fig. 8 of the Patent 2,136,957 above referred to, any oxygen present therein will combine with the metal of the bath and form an oxide floating on the top of it. This explanation of the action of the bath may or may not be complete but it is as clear as I can see it. However, I notice that big practical improvements are connected with its use. Although in the aforesaid patent, I am providing a condenser to separate metal vapors that said recirculated gas may carry, after having been bubbled

through said molten metal bath having a high affinity for oxygen, it is possible that any metal vapors that may still remain in the gas may be responsible for a cleaner and better coating.

In what concerns the instrumentality used for the purpose of temper rolling, with or without simultaneously performing the other function, namely regulating the thickness of the metallic coating, any of the mills as shown in the above specified Patents 2,170,732 or 2,479,974 can be used because they all fulfill the essential characteristics of being of relatively light weight and very small physical size. Such mills fit in with continuous furnaces and coating lines where ordinary four-high mills could not conveniently be employed. In such mills, the work rolls are extremely small in diameter and therefore they can be, firstly, changed very rapidly so as to hardly cause any interruption in work of the unit that must be kept running constantly and, secondly, a wide selection of materials is permissible for such rolls, the one most widely used and which I prefer in many cases being the 12% chromium 2.20% carbon alloy steel of extremely long-wearing characteristics. Especially such arrangements as Fig. 8 in Patent 2,170,732, Fig. 2 in Patent 2,479,974 and also the instrumentalities as are described hereunder, permit the choice of even harder but rather brittle materials since the driving torque can be transmitted through the backing elements and no torque through the work rolls. Such materials as tungsten carbide, sapphire or even quartz are applicable, the last one of course for rather light pressures where the skimming and controlling of the metal coating is the prime objective and only little or no temper rolling is accomplished. The above named materials do not in themselves form an alloy, for instance, with molten tin, but the alloy steel above referred to would form an alloy, for instance, with molten zinc or aluminum. In all cases where such alloy is not formed, the roll itself is not wetted by the coating metal and therefore it controls the thickness of the film of coating metal that is permitted to remain on the strip, only by the pressure it exerts upon said strip. Wherever such alloy is formed, the factor which controls the thickness of the coating metal is, by and large, the surface tension of the coating metal that forms a negative meniscus within the roll bite, as is well known in the art. However, for the purposes shown, either variety may be used within its limitations except that, in some cases, it is desirable, after the weight of the coating has been determined by the pair of rolls **31** and **32** of Fig. 5 to either follow immediately with another pair of wetting rolls that only need to touch the surface of the metal very slightly but do form the aforesaid meniscus in the roll bite and thereby produce a smooth mirror-like coating, or else permit the coating metal to become solid and then, in a further step of the operation but before coiling up the strip, to refloat said coating by heating it and then cooling again.

In case of tin coatings, I find that I can obtain very satisfactory and smooth coatings by subdividing the temper passing operation into two and by having the mill rolls **31** and **32** of Fig. 5 or rolls **19** and **20** of Fig. 3 perform essentially the skimming or coating control function only, coupled with substantially no rolling action but followed up by a similar instrumentality disposed at the portion of the installation where the strip is much cooler to perform most of the required temper rolling reduction of the strip. The work rolls of this last-named instrumentality should preferably be kept with a mirror-like finish which finish they readily impart to the strip.

Where the temper rolling step of the process is accomplished in one operation such as in the mill **14**, Fig. 3, the roll pressure exerted on the strip is of such high order that the coating produced would be too thin to meet most technical specifications. In this case, I prefer, as shown in Fig. 3A, to use another pair of skimming or exit rolls **41** and **42** as a skimming step subsequent to the skimming by temper rolls **19** and **20** and extend the oil bath to fill the whole cavity of the mill **14** and the hood **46** so as to even leave rolls **41** and **42** partially submerged in the palm oil or equivalent. Since the use of a second pair of skimming rolls **41** and **42** is alternative, the whole superstructure of hood **46** and its associated elements may be removed from the top of temper rolling mill **14**. The upper portion **45** of the oil bath is vigorously recirculated, by pumps, not shown, capable of exerting relatively high pressure and passing the oil through tubes **43** and **43'**, parallel with rolls **41** and **42**, one opposite each face of strip **1**, discharging oil at high velocity through flattened jets **47** and **47'**, perpendicular to or at slight angle to said strip **1**. Inside said jets **47** are other jets connected to tubes **44** and **44'**, each disposed inside the oil tubes **43** and **43'** through which is supplied molten tin, as a secondary application. This molten tin, supplied in strictly measured quantities, is atomized by the high velocity oil streams passing through said jets **47** and **47'** and impinges against the face of the strip **1** merging with its existing but inadequately heavy coating. Since rolls **41** and **42** are of the wetting type, that is, they are completely covered with tin, they spread evenly such coating and impart unto it a high lustre. They also equalize slight irregularities in the amount of tin deposited across the strip by the individual jets **47** and **47'** but they do not control the thickness of the coating and substantially do not hold back and reject any tin from said coating, said quantity of tin being regulated as above said, by the quantity of tin admitted through tubes **44** and **44'**.

Although rolls **41** and **42** do not require in the ordinary operation the use of conventional scrapers, such use may be indicated with certain analyses of exit roll materials.

An alternate method of applying a measured quantity of molten coating metal as addition to the already wetted strip surface but where such coating is not sufficiently thick involves omission of the tin spraying jets above described and provision of suitable trays under skimming rolls **41** and **42** to hold molten tin so that the rolls are partially submerged in molten tin, as is well known in the art. As the rolls **41** and **42** turn, molten tin will be carried into their bite and provide a negative meniscus, as between the surface of each roll and each face of strip **1**.

I devised a ready means of exactly controlling the weight of the supplementary coating metal deposited on the strip which consists in providing a controllable speed drive for said rolls **41** and **42** and driving them at a speed other than the speed of strip **1**. If a skimming roll **42** is driven at a lower surface speed than the speed of the strip, the amount of molten coating metal which it carries into the meniscus will be less than if it were driven at synchronous speed and therefore a lighter coating can be produced, as required. If such speed of the roll is greater than the speed of the strip within limits of overfilling the meniscus, the opposite happens and heavier coatings are obtained.

I can also control the speed of each of the skimming rolls **41** and **42** individually and thus produce a different weight coating on each face of strip **1**. The same effect can also be produced when using the tin spraying apparatus **44** and **44'** hereinabove described, by feeding a different amount of tin to sprays **47** than to sprays **47'**.

The above two methods of providing a supplementary coating metal supply to the strip, after it has been wiped so tight that the metal surface is barely wetted by molten coating metal are shown by way of example only, the principle being to first wipe the strip tight without regard to coating weight and being at liberty to use pressures high enough to temper roll the strip itself and also obtaining other advantages, and then, in a separate opera-

tion, supply from outside the required quantity of additional coating metal.

Wetted exit rolls as used, for instance, in the in-plate industry, that is, without the preliminary overskimming and subsequent addition of coating metal, are limited in the weight of coating they produce in that they cannot produce a coating under a certain minimum weight which is too heavy for many purposes. Moreover, they are limited to rather low speeds, say, between 30 and 100 feet per minute, whereas a unit as herein described is capable of running at speeds of 1000 feet a minute or more.

As can be noticed from the few mentions herein above, the design of the temper rolling instrumentalitiy follows closely the two rolling mill patents mentioned, except that certain further improvements make the mill embodiments described in the present application much more suitable for temper rolling and for the combined function of temper rolling the strip and skimming the metal coating. Firstly, there is a cast steel housing of the mill **14** in Figs. 3, 4 and 5 which is preferably altered in shape and proportions which alterations make it much more suitable for conditions peculiar to temper rolling. Whereas the cold reduction mill described in the two patents above referred to, is provided with a housing practically as rigid as can be, I have found that I gain particular advantages, for a temper pass mill mounted directly in an annealing and coating line, if I incorporate in it certain elastic characteristics of a nature that can be provided only with this type mill and which it is impossible to provide with conventional mills. If a conventional, e. g. a four-high mill, is to be designed so as to permit a greater degree of elasticity, its objectionable features become so much more prominent and the deflection of the work rolls at the center of the strip remains or even becomes more than on four-high mills designed for heavy reductions. This is counteracted ordinarily by crowning the rolls but, with variable pressure, such crowning adversely affects the shape of the strip and produces a strip with loose edges whenever the pressure increases. Temper rolling mill **14** as shown in Figs. 3 and 4 comprises essentially a rigid one-piece housing, the frame of which consists of two heavy beams **90** and **90'** connected by columns **50** and **50'**, so that the type of deflection as described practically does not exist, for the relatively light roll pressures as encountered in temper rolling. I have found, however, that I can readily overcome very annoying problems affecting, amongst others, the shape or "flatness" of the finished temper rolled strip, if I so shape the housing of the mill **14** as to give it certain specified characteristics of elasticity. The problem essentially lies in the fact that the strip **1** being so treated, may have come from any mill and the characteristics of its cross section, including the difference in thickness as between the center and edges of the strip, the difference in thickness between one edge and the other, as well as general gauge discrepancies along the strip such as caused by acceleration and deceleration of the rolling mill that has produced the strip and the variations in its tension control, make is preferable to provide a temper mill that can adapt itself to the shape of such strip and elongate it evenly by the prescribed small percentage required for temper rolling and never let its shape become worse than it already is but improve it to the extent it is possible. I have found that this requirement is further complicated by the fact that in the design and operation of combined annealing and temper rolling units which may or may not involve the step of metal coating, it is not easy to reconcile the close tension control characteristics required by the temper pass mill, both ahead and after the work rolls, with the slightly different tension characteristics required by the annealing and/or coating unit itself. In most cases, the compromised result is that the temper rolling operation has to be satisfactorily performed under somewhat lower tensions applied to the strip than would be the case with a temper mill not connected with any annealing line. The improvements hereunder described make this temper rolling mill quite suitable for such difficult tension conditions.

I accomplish this by providing deep slots **49** in the housing beam, between each two bearing elements **48** and also so as to leave each bearing element or "saddle" supported by one of the cantilever beams **52** between the last bearing element and the mill column **50**. This measure alone would permit the roll backing elements **48** to spread apart like C-clamps, away from the work rolls they are backing and thereby increase the total deflection of the mill under the working load but in such way that this added deflection would be uniform over the entire length of the work rolls, since these cantilever supporting members **52** all deflect uniformly and since the load is uniformly distributed over the entire width of the strip which is substantially the same as the entire length of the work rolls. This in itself would already solve the problem since the work rolls are relatively of a small diameter and therefore are flexible, and in this way they are able to adapt themselves to the shape of the strip whereas the backing elements support them uniformly along their length and thus permit them to exert uniform pressure all over the strip irrespective of the fact that such strip may have a crown section or a wedge section or may differ in thickness from one place to another along its length.

But I prefer not to entirely rely on this automatic means of compensation which I found I can so readily build into this mill but also provide for the operator of the unit ready means of manual control to further influence the elastic characteristics of the mill across the strip, to compensate for the inherent wear of the rolls and backing elements, difference in heat expansion of the mill and other operating conditions. In the embodiment as in Figs. 3 and 4, I provide for this purpose a plurality of bolts **51**, one for each pair of opposite beams **52**, each provided with a head and with a nut **53**, by adjusting which the operator can partly suppress the elasticity of any of the elements or groups of backing elements he may desire to so control. In this way, if during the operation it is noticed that the issuing strip shows some defects, for instance one of its edges becomes wavy, the operator can quickly adjust this condition by increasing or decreasing the pressure where he needs.

Certain means to accomplish this end on heavy reduction mills as per the patents above referred to, have been incorporated in them but these were designed to correct undesirable elastic deflections whereas the present improvement on the contrary gives the mill a relatively high elasticity to completely adapt itself to the shape of the strip it rolls and yet makes it possible to increase or decrease roll pressure wherever it may be necessary to influence it.

Referring again to Figs. 3 and 4, the two lower shafts **91** and **92** are rotating shafts and are driven from a combined motor and gear box **93**, through conventional pinion stand **94** and spindles **95** and **96** provided with flexible couplings. The final backing elements in this case are rings **97** and **98** which are shrunk on the above named shafts **91** and **92** in fixed evenly spaced positions. Bearings **99** are provided in the spaces between each pair of rings **97** and **98** for such shafts **91** and **92**, uniformly across their lengths.

Work rolls **19** and **20** are therefore driven by friction by the plurality of the final backing elements **97** and **98**. On the contrary, the two upper shafts **101** and **17** have similar rings **18** mounted on them at intervals spaced exactly as indicated of rings **97** and **98** on the lower shafts **91** and **92**, with the exception that such rings are not shrunk on said shafts but are mounted over suitable roller bearings permitting the shafts to be stationary while said rings **18** support the work rolls **19** and **20**. Bearings

or "saddles" **102** supporting said shafts **101** and **17** carry eccentrics **103** keyed onto said shafts so that by adjusting their angular position, the distance between rolls **19** and **20** can be altered at will which corresponds to so-called "screwdown" on conventional mills, substantially as explained in the two above-named rolling mill patents.

I claim:

1. The process of treating an extensive length of work-hardened steel strip, which comprises continuously moving said steel strip lengthwise and simultaneously applying to successive portions of said steel strip the continuous steps of: bright annealing; cooling under non-oxidizing conditions; and temper rolling while maintaining said steel strip under tension to take up the elongation of said steel strip resulting from said temper rolling.

2. The process of claim 1 wherein the portion of said steel strip which has been cooled under non-oxidizing conditions is passed through a molten metal coating bath prior to being temper rolled.

3. The process of claim 1 wherein the portion of said steel strip which has been cooled under non-oxidizing conditions is passed through a molten metal coating bath and then said portion with the molten metal coating is temper rolled thereby limiting the weight of said coating on said portion and simultaneously elongating said steel strip.

4. The process of claim 3 wherein the portion of said steel strip which has been temper rolled is cooled to solidify the molten metal coating thereon and then is heated to remelt and float the metal coating on said portion of said steel strip.

5. The process of claim 3 wherein the portion of said steel strip which has been temper rolled is further coated with molten metal.

6. The process of claim 5 wherein the portion of said steel strip which has been further coated is cooled to solidify the molten metal coating thereon and then is again temper rolled.

7. The process of metal coating a steel strip, which comprises applying a molten metal coating to said steel strip and temper rolling said steel strip with said molten metal coating.

8. The process of claim 7 wherein the coated steel strip after being temper rolled receives a further application of molten metal coating.

9. The process of metal coating a steel strip, which comprises passing said steel strip through a molten metal coating bath, wiping off part of the molten metal coating on said steel strip, temper rolling the thus coated steel strip, and applying additional molten metal coating to the temper rolled steel strip.

10. Unitary apparatus for producing a metal coated, temper rolled steel strip, which comprises means for applying a molten metal coating to a steel strip, and a pair of parallel, slender rolls for temper rolling the metal coated steel strip, each of said rolls being backed up by two rows of casters mounted on parallel shafts having spaced supports in a beam provided with a lengthwise cavity to permit elastic deflection of said beam when said rolls are forced apart by the metal coated steel strip passed therebetween.

11. The apparatus of claim 10 wherein the means for applying a molten metal coating to a steel strip comprises a pan provided with a bottom slit for passing said steel strip therethrough, said pan having up-turned lips around said slit to retain a bath of molten metal coating in said pan, and a pair of rotatable, parallel rolls disposed in said pan on opposite sides of said slit to contact the opposite faces of said steel strip and to dip in said bath of molten metal coating.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,797,476 July 2, 1957

Tadeusz Sendzimir

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 52, for "coling" read --cooling--; line 73, for "hilly" read --billy--; column 9, line 3, for "in-plate" read --tin-plate--; line 60, for "make is" read --make it--.

Signed and sealed this 5th day of November 1957.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents