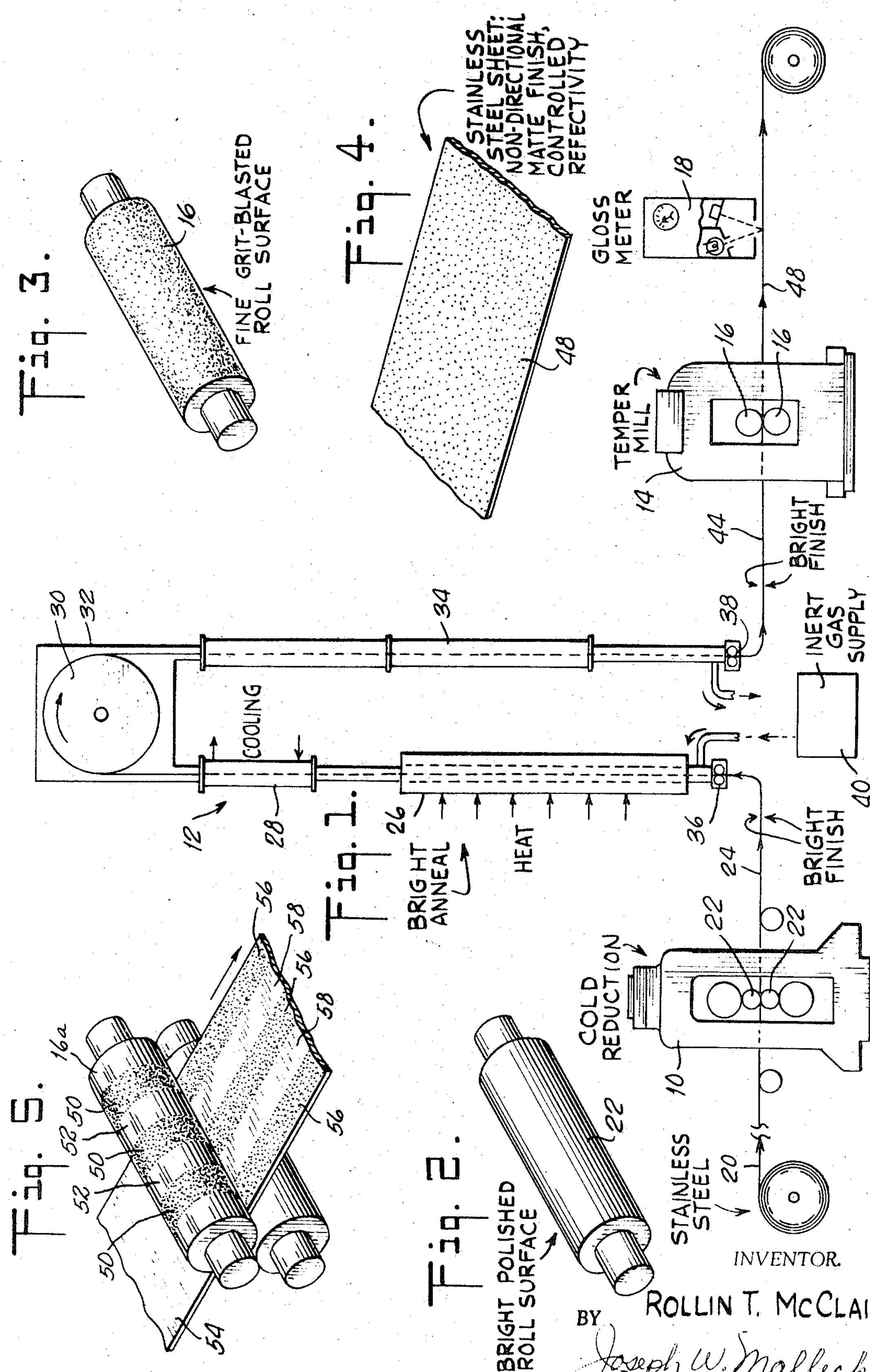
METAL ARTICLES WITH CONTROLLED FINISH

Filed Aug. 1, 1967

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United States Patent Office

3,556,874

Patented Jan. 19, 1971

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3,556,874

# METAL ARTICLES WITH CONTROLLED FINISH

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Filed Aug. 1, 1967, Ser. No. 657,562
C22c 39/20
U.S. Cl. 148—37 9 Claims

## ABSTRACT OF THE DISCLOSURE

Stainless steel sheet, e.g. strip, of unusual matte finish having a subdued luster of completely non-directional character is achieved by cold rolling the strip to final gauge with a bright mirror-like finish, then annealing the strip while maintaining the bright surface unimpaired, as by bright anneal in an inert atmosphere, and thereafter subjecting the mirror-like sheet to temper rolling with essentially zero elongation, using matte-surfaced rolls prepared by polishing followed by grit blasting or etch treatment, the matte roll surfaces having a substantial profile depth and a fine, random, relief distribution of indentations of the same grain count or peak density in all directions. Being measurable by a simple reflectivity test, the matte surface on the strip can be produced to any desired standard by control of the rolling pressure and number of passes in the temper rolling stage. The resulting new sheet product has a highly attractive, non-directional finish, is reproducible, and has good corrosion resistance and durability in fabrication for many uses, affording a sum of qualities not previously attained in special-finish stainless steel. The process is applicable to many stainless steels, including the 200, 300 and 400 grades.

## FIELD OF THE INVENTION

This invention relates to the production of rolled metal articles having a matte finish and in an important specific sense is concerned with the manufacture of cold-rolled stainless steel sheet which has excellent metallurgical properties and which on at least one surface carries a non-directional matte finish that may be of an unusual, lustrous character.

The invention is thus directed to cold-rolled metal products, i.e. wherein the final and substantial reduction of the stock to finish gauge is achieved by cold rolling, and an important object is to afford novel, economical and easily controlled procedure for producing such articles from any of a wide variety of stainless steels and with equipment that is readily available, so as to achieve the described matte finish while affording full realization of other desired properties.

The invention thus attains, in a highly practical way, a novel and unusually attractive finish for stainless steel sheet products that are suitable for essentially all uses, either in the flat or for fabrication by bending, roll forming, stamping, drawing, shearing or the like. More specifically, a new and heretofore unobtainable stainless steel material, having a surface treatment of exceptional utility, is made available to designers, architects, engineers, and others for a variety of applications.

As stated, the improvements are primarily concerned with sheet products, the term sheet being used herein (unless otherwise expressly limited (to include the conventional designation of strip in a variety of gauges as produced by rolling operations, and likewise articles similarly finished to size by cold rolling and having extended, opposed surfaces, whether known as sheet or sometimes by other identification as plate or the like.

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## DESCRIPTION OF THE PRIOR ART

In the production of stainless steel strip, conventional practice includes reducing suitable strip or sheet stock by one or a succession of two or more cold rolling passes to a finish gauge, whereupon the work is annealed at a temperature appropriate for the particular alloy composition, and may thereafter be given a temper or skin pass for suitable hardness and other properties of the surface or surface region. Effective techniques have been developed to produce strip with a very high gloss or mirror finish, often called a bright finish, as by employing cold reduction passes with rolls of increasing smoothness, the final such pass being effected with very highly polished rolls. The strip is then subjected to a so-called bright anneal, in an inert atmosphere, and may finally receive a temper pass with rolls polished to maintain the mirror-like reflectivity that was preserved through the annealing step.

Where a matte or other dull surface, however, is desired on stainless steel strip, present-day techniques are notably less satisfactory than for bright finishes. Thus one conventional mode of manufacture has been to roll the product to finish gauge, and then, following a suitable anneal, to impart a dull or frosty finish by pickling, of ordinary or electrolytic character, or by other chemical etching. The finishes so produced, while uniform, are usually characterized by a dull or whitish, non-lustrous appearance, and are highly susceptible to mechanical damage, as by abrasion or the like, especially since it is impossible to use a temper or skin pass on the strip without impairing the dull finish. Experience indicates that the pickling or etching effect tends to be spotty or irregular unless the anneal has been such as to produce a coating of scale; but because scale formation tends to deplete the chromium at the surface (by preferential oxidation), or because of the absence of a temper pass, or for both reasons, the etched-surface product tends to have less corrosion resistance than bright strip.

An alternative way of achieving a dull or non-gloss surface is by a surface grinding as with abrasive rolls or bands operating lengthwise of the strip, but the resulting finish, having a brushed appearance, is highly directional in its reflecting properties and is of correspondingly limited utility. Like effects appear when an effort is made to achieve a matte or non-mirror finish by use of rough-ground or like surfaced rolls in the cold reduction of the strip; indeed mechanical arrangements or operations aimed at providing a dull surface have generally resulted in a marked directionality of finish, or an absence of regularity or uniformity, or other deficiency that sharply curtails the use of the product. While various operations have been employed or proposed for producing dull or roughened surfaces on sheets of ordinary steel, e.g. carbon steel, as for instance to provided a non-slipping surface for aid in deep drawing of automobile shapes that are ultimately to be painted, there has been no effective, practical way of providing a pleasing and attractive matte finish of high quality and completely non-directional and uniform nature on stainless steel strip that has all other desired properties, nor does there seem to be any known practice which has been found or would appear to be applicable for producing such result.

The choice of stainless steel as a corrosion-resistant material for fabricating various articles and structures is often dictated by its decorative appearance, but where a mirror-like surface is not desired, it has not been possible to realize full potentiality of this metal. As indicated above, a major difficulty in certain dull finishes has been a marked directionality of appearance, in that total light reflection and reflection of highlights is seen to be different when the metal surface is viewed in directions at right angles to each other, as for example crosswise and lengthwise of the direction of travel which the metal strip followed in rolling or processing. Such directionality creates undesirable contrasts in fabricated articles since they do not look the same from different directions, and the difficulty becomes acute in making articles from more than one piece of metal and in assembling panels side-by-side for covering large areas. It is seldom convenient or feasible to align all pieces so as to have a common optical effect, and even then a selected luster or dullness may be achieved when the surface is viewed in one direction but not in another. Predeterminable and non-directional characteristics of a matte or reduced luster finish are also sought for other than artistic reasons alone, as for instance in the fabrication of various fixtures, elements of trim, and the like for automobiles where a minimization of glare or sharp reflection is required, yet a pleasing, durable surface and maximum corrosion resistance are demanded.

Although dull surfaces produced by etching the sheet are non-directional and have some uses, the finish is of limited desirability, and there are other limitations on the properties of the product as explained above. Since the surface of the metal must remain in the annealed state, some types of forming may have effects that are undesirable where appearance is paramount, for example, in the occurrence of so-called Luder lines upon shaping or other treatment that involves stretching.

## SUMMARY OF THE INVENTION

To the foregoing and other ends it has been discovered that a non-directional, lustrous matte finish on stainless steel can be produced in a controllable and reproducible manner by the following, novel sequence of operations. Stainless steel strip is first brought to finish gauge by cold rolling operations involving substantial reduction of thickness of the initial stock, while attaining a high mirror-like gloss on one or both surfaces, as in conventional procedure for production of a fully bright finish. Thus where there are successive cold passes, they are preferably effected with work rolls of successively increasing smoothness, and in all cases the final reducing pass is achieved with rolls of a mirror-like polish. The resulting bright strip, which thus in effect has reached finish gauge, is then annealed, as it must be for utility of the material in fabrication, and such annealing operation is effectuated so as to maintain the bright mirror finish. For example, a so-called bright anneal, in an inert gas atmosphere is particularly effective, in delivering the strip with its bright surface essentially unchanged. Thereafter the annealed strip, on which a high-gloss, mirror-like finish has been carefully prepared and maintained as if for production of bright sheet, is subjected to a specially controlled temper rolling operation with work rolls that have been specially figured or textured with a matte surface in relief, as by grit blasting to a substantial depth of profile and with a fine, random, covering distribution of indentations or depressions having substantially the same grain count or peak density in all directions. By this series of operations, including the defined temper or skin rolling, without appreciable elongation of the strip, a sheet product is produced having the desired, non-directional matte surface, e.g. of unusual subdued luster, and meeting a high standard of other properties desired for stainless steel.

A further important feature of the process is that the character of the matte finish on the strip, e.g. as to luster or non-reflectivity, can be readily controlled to any desired extent, permitting maintenance of the precise, selected finish not only throughout a given length of strip, but for successive lengths or quantities, with correspondingly unusual uniformity of production. Such control, governed for example by simple test or tests of reflectivity at the beginning of each rolling pass or set of passes through the temper or skin-pass mill, is attained by adjustment of the roll pressure and by selecting the number of such passes, e.g. whether one, two or more.



In consequence of these operations, which depart from conventional modes of obtaining dull or similar finishes on stainless steel, but nevertheless utilize standard equipment without extended supplemental treatments of the material, it has been found possible to obtain an exceptionally satisfactory matte surface which is fully non-directional in its optical effects, and likewise to achieve the stated control and reproducibility of a selected finish, for assured uniformity of production, as to the needs of a particular use or a particular customer.

The sheet product of stainless steel, e.g. as resulting from presently preferred practice of the process, appears to be novel and distinctive, in comparison with products heretofore available. The surface has a fine matte appearance but is characterized by a basic luster in that it may exhibit a very minor degree of specular reflectivity, ranging from a mere vestige to an effect of somewhat greater depth, which is nevertheless far short of full mirror reflection. This controlled or subdued luster is not the same as that of a darkened, cloudy or milky mirror, where dim but sharp images of even very distant objects may be seen; the modified reflectivity, when appears to constitute the luster, is such that very near objects may be imaged in a detectable though limited way but even moderately remote things are wholly diffused. In general, the surface is characterized by minute roughness, preferably having a reflectivity in a given range (measurable as a reading of gloss with an appropriate instrument), a significant depth of profile, and a grain count or peak density of at least a given minimum, as further explained below.

A further advantage of the procedure is that it is effective with a wide variety of stainless steel compositions, e.g. any of the 200, 300 or 400 series, thus allowing good metallurgical selection of product grades. High corrosion resistance is readily achieved, as in strip of a normal bright finish. The surface is free of processing streaks or the like while its lustrous and uniform character is such as to permit good quality control inspection; any surface defects that might represent metallurgical deficiency are not camouflaged.

In addition, the selected degree of finish is not only reproducible for uniformity of a single product but can be accurately reproduced on a wide range of gauges, permitting the user to achieve a desirable match of appearance where material of different thicknesses must be assembled. The novel surface is unusually resistant to marking, abrading, staining or fingerprinting; although it is easily adapted to hold lubricants during drawing or forming steps, such materials and indeed other liquids or substances on the surface can be readily cleaned away. As indicated, the products are relatively insensitive to changes or surface disfiguration, such as Luder lines, that sometimes result from stretching or forming.

It is conceived that basic features of the procedure described are applicable to a variety of metal products and shapes, including sheet or other members of other steels, and indeed articles of other metals, and the basic steps can be carried out by other means, an important proviso being that the impression of the abrasive-blasted or like surface on the bright-finished metal surface be in effect directly downward, with essentially no other relative movement between the surfaces such as might impart optical directionality to the desired finish.

## THE DRAWING

By way of example, a schematic illustration of the method in a system of apparatus for practicing it, and related features of the invention, are shown in the accompanying drawing, wherein:

FIG. 1 is a schematic view of representative major elements in the stated system, indicating the principal steps of the process;

FIG. 2 is a representation of a work roll used in the final reduction pass;

FIG. 3 is a representation of a work roll used in the temper pass or passes;

FIG. 4 is a representation, characterized briefly by the applied legend, of a sheet product of the invention; and

FIG. 5 is a simplified view illustrating the temper rolling stage of a modification of the process.

## DETAILED DESCRIPTION

Referring to the drawings, a presently preferred set of operations for carrying out the invention involves first, cold rolling the metal as schematically indicated by the mill stand **10** in FIG. 1, to yield the described bright finish stainless steel strip of desired gauge, then subjecting the strip to annealing operation as represented by the continuous, bright anneal furnace **12** and thereafter subjecting the strip to temper or skin rolling, designated by the temper mill **14**, utilizing one or both work rolls having an appropriately treated surface as indicated by the roll **16** in FIG. 3. The operation of the temper rolling is controlled, for example as to roll pressure or number of passes or both, in accordance with suitable test of reflectivity of the issuing strip, for instance as schematically indicated by the glossmeter **18** (shown in disproportionate size, for clarity).

The cold reduction stage, effected by any suitable arrangement of mill or mills such as the 4-high mill **10**, or a Sendzimir mill or other rolling equipment, may involve appropriate total cold reduction of the previously hot rolled strip or other stock of selected composition (e.g. supplied as indicated at **20**), for instance, as usual and necessary to reach the desired finish gauge. In such operation, a series of passes can be employed, as through successive mills or by change of rolls through the same mill, whereby the surface of the strip is progressively converted to a bright, glossy finish. The work rolls of the final pass, as indicated at **22** in FIGS. 1 and 2, should have a suitable bright or mirror finish, produced by grinding or polishing with abrasive or grit of appropriate fineness, i.e. grit finer than 150 by the standard numerical designation of grade for grits employed in surface grinding or polishing. Thus the work roll surface in the final cold reduction pass can be defined as having a brightness or gloss resulting from finish with grit of at least the fineness of No. 180 and very preferably finer than 200 grade (e.g. grit No. 220), superior results being attained where the roll has been surfaced with grit No. 280 or finer, even up to No. 400. As will be understood, preceding rolling passes in the cold reduction can employ work roll surfaces of substantially less smoothness, but are preferably progressively smoother in the series to the final pass.

In any case, the strip **24** issuing from the final pass, having the desired gauge as for example in the range of 0.008 to 0.125 inch, is characterized by a fully bright or mirror-like finish at one or both of its surfaces. Such finish can be defined by the character of the final rolling treatment, and specifically by the fineness of abrasive with which the roll or rolls in such pass have been polished.

As for most uses the work-hardened character of the immediate product of cold rolling is undesirable, an annealing operation is utilized, most appropriately with an inert-gas, bright anneal treatment as indicated at **12**. Conventional equipment of this sort has various forms, of which one example is shown, including a tall, upright heating chamber **26**, followed by cooling passage structure **28**, the strip thereafter traversing a turning roll **30**, in an enclosed region **32**, and then descending through a long, enclosed passage **34**. The entire course of the strip through the furnace, including the further passages and spaces, is totally enclosed and sealed, the entrance and egress of the work being respectively effected through appropriate roll seals as indicated at **36**, **38**. Heat is suitably applied, as by gas burners or heated gases in a jacket surrounding the enclosed strip passage at the section **26**, with cooling at the section **28** as by contact of cool inert gas or by other heat exchange, while the entire interior of the assembly is maintained in an atmosphere of inert gas supplied from an appropriate source **40**.

The annealing operation thus indicated at **12** may be such as is conventional for bright finish stainless steel strip. The inert gas is likewise selected as will be well known, examples being hydrogen, argon, mixtures of nitrogen and hydrogen, and the like. A convenient gas is so-called cracked or dissociated ammonia, being a relatively inexpensive product, of 25% nitrogen and 75% hydrogen by volume, produced in the source **40** by high temperature treatment of pure anhydrous ammonia. In view of the known character of the bright anneal equipment, supplementary elements are not shown, such as entry and exit looping towers, uncoilers, degreasers, recoilers, and the like. The product strip **44** from the bright anneal has the same clean, bright, mirror finish as it had at **24**, but is now in an annealed state suitable for many fabricating operations.

Instead of treating the strip by a temper pass with high gloss rolls, the present invention employs the temper mill **14** to modify the strip surface in a controlled and reproducible fashion and thus to deliver a strip product **48** having the new matte finish, of selected, subdued luster. That is to say, an essential feature of the present process for producing a non-mirror, matte surface on stainless steel, and of the special advantages of the process and of the resulting rolled finish, is that the strip is first produced and indeed carried through the annealing stage, in such fashion as to provide and maintain a fully bright, mirror-like finish. Thereupon the temper rolling stage, which should involve essentially no appreciable reduction in gauge, is effectuated with one or both work rolls **16** that have a special, selected matte character.

Notably effective results are achieved where each such roll **16** is prepared and characterized as follows: The roll is of appropriate steel composition, prepared and treated to have suitable hardness, for example as is well known in preparing bright-surfaced work rolls for a temper pass on stainless steel. Thus for special advantage the roll should be made to have a scleroscope hardness (D scale) over 90, preferably about 95. The roll is advantageously first finished to a bright mirror surface, e.g. at least approximately equal to that of the bright steel work rolls of the final cold reduction pass or to that of the bright finish, annealed strip itself. This is attained by polishing with grit finer than 150 grade, and more particularly with grit finer than 200 grade; specially preferred results are attained with grit No. 280, and indeed grit of No. 400 fineness has been employed to good advantage. Thereafter the roll surface is subjected to an abrasive-blasting treatment, e.g. a high velocity blast carrying appropriate grit particles, directed essentially normal to the roll surface, for imparting a fine, non-directional matte configuration.

Any appropriate arrangement may be employed for this treatment, suitable techniques being known and available for producing matte-surface rolls, as where the roll turns slowly past a jet, or row of jets, carrying grit particles in air, disposed to strike the surface along a line parallel to the axis of the roll, whereby the surface is finely pitted or indented by the impinging particles. The ultimate grain or fineness, and depth of profile of the roll surface, can be achieved at the desired values given below, by suitable control or adjustment of the quantity and size of grit, and velocity and duration of blast, all in a manner which is fully understood in abrasive-blasting techniques and need not be detailed here. Suitable grit sizes, for instance, are those in the range of numbers G25 to G80, one very appropriate size being number G40 with an average particle size of about 0.01 inch, although in some instances finer particles, or even coarser ones, e.g. down to grit number G18, can be usefully employed. These grit numbers are given and employed herein according to the standard (S.A.E.) designation of grit sizes for particles used in abrasive blasting.

The resulting roll surface should for most purposes be characterized by a peak density, i.e. the grain of the random pitted or indented surface, measured linearly (by or with the aid of suitable instruments) in each of the circumferential and axial directions, of at least about 100 peaks per linear inch. Especially suitable results have been achieved with fineness of grain or roughness in the range of 200 to 400 peaks per linear inch. For special purposes departures from these ranges are conceivable, but in all cases the roll surface is characterized by a covering, random distribution of minute irregularities or pits, sufficiently close to constitute a matte appearance and usually obliterating at least 90% or essentially all of the polished cylindrical contour. The depth of profile of the grain or texture of the surface should be such as to permit the roll to achieve its matte-finishing function. Thus as measured by a profile meter or the like, profile depth readings of about 15 RMS or more (meaning a root-mean-square measure of peaks and valleys, in microinches) are suitable, particularly advantageous results being achieved with profile values of 30 to 40 RMS (microinches). Somewhat larger values are presumably attainable, but are not presently regarded as necessary; indeed the abrasive-blasting operation is probably self-limiting, in that grit particles cannot be allowed to be embedded, and prolonged non-embedding treatment may well only remove surface metal without increasing profile depth.

It is critical that the matte surface on the roll be non-directional, and to that end it is ordinarily desired that the profile depth be substantially the same in both longitudinal and circumferential directions of the roll surface, and likewise the fineness of grain of the random pitted or indented texture, e.g. the value of peak density, per unit of length. Stated more generally, the grain fineness and depth should each be approximately the same in all directions.

For some purposes, the random-grained matte surface of the work roll **16** can be produced by an etching rather than a blasting operation, as for example with electrolytic or straight chemical etching, employing acid compositions suitable for imparting an etched finish on polished steel of the character employed.

As stated, upon subjecting the bright-finish strip to the temper rolling operation using the described matte-surfaced rolls **16**, and controlled to produce no significant reduction or elongation of the work, the product strip **48** is given the desired, non-directional matte finish. If only one such surface is wanted, only one correspondingly textured roll **16** is used, and operations on the other surface can provide a finish of bright character (using a polished roll **16**) or of other nature as desired. The temper rolling can be effected with roll pressure in a range conventionally employed for tempering or skin hardening purposes on stainless steel, and should be less than any pressure which would cause appreciable elongation of the strip. For finishes in a higher luster range, a single pass through the mill **14** will often suffice, being basically effective to produce a matte surface of relatively fine grain having subdued and entirely non-directional reflectivity. If a lower luster, i.e. markedly lesser reflectivity, is desired, two or more passes are utilized, the effect of multiple passes being cumulative in enhancing the degree of matte appearance, while maintaining the pleasing effect and essential non-directionality of the finish.

As explained, a very simple control of the process and product has been found effective, namely by utilizing a single reflectivity measurement, preferably one related to specular reflection, as of a type measuring the amount of light, from a standard source, which is specularly reflected in a defined path, or of a type measuring that proportion of the total reflected light (from an incident beam) which follows a path of specular reflection. Thus for example, useful results have been achieved with an instrument of the first type, namely a so-called Gardner 20° glossmeter, indicated at **18**. Such device produces a reading, on a standardized scale, of a specularly reflected ray of light having angles of incidence and reflection of 20° to the normal. The standard scale of such meter has a range from zero to 100, the instrument being normally calibrated or adjusted so that the upper limit corresponds to a surface that has substantially less than the complete specular reflection of a true mirror. For instance, the bright finish strip supplied to the temper rolling stage normally has a reading which is far above scale, while the preferred products of the invention have such reading in the range from about 100 downwards, e.g. most usefully 10 to less than 100. Reflectivity readings, as by such instrument, have been found to afford a sufficient characterization of the extent of treatment and of the character of the surface, for actual control in processing, and for grading the product.



The process control is conveniently exercised by adjustment of roll pressure in the mill **14**, or by selection of number of passes, or by both factors. In so doing, reflectivity readings may conceivably be taken on the issuing strip as it moves, or by momentarily arresting it at any time, but it is ordinarily sufficient to start the feed through the mill slowly, stop the strip, examine the initial portion of the impressed surface with the meter, and then proceed with rolling after such adjustment (e.g. in roll pressure) as may be required to attain a selected reading of the meter. In a like fashion, where a greater depth of grain or lower luster of the matte finish is desired, two or more passes through the mill **14** may be utilized, the total effect being again controlled by readings of the glossmeter **18** as necessary.

For example, if test of the treatment at the leading end of the strip shows that a single pass at the highest permissible pressure is insufficient, a second pass can be planned, and if necessary, the pressure may be backed off for the first pass, to avoid the possibility of over-treatment. Then on the second pass, suitable roll pressure can be determined, again by initial test, to achieve the precisely desired value of reduced reflectivity. Hence by conjoint control of rolling pressure and number of passes (involving even more than two passes if necessary), the properties of the finish can be selected, and accurately reproduced, over a continuous range of reflectivity.

The procedure is applicable, and the defined products attainable, with many grades or compositions of stainless steel, particularly comprising all the so-called 200, 300 and 400 grades. In the case of the chromium-nickel compositions (being the 300 grade and also including the 200 grade alloys that are more specifically chromium-nickel-manganese), it presently appears that the annealing step should be a so-called bright anneal (in an inert atmosphere), obviating all formation of scale. With the 400 series, being so-called straight chromium alloys, special advantages are likewise achieved by employing the bright anneal. Useful results, however, can be attained with an ordinary anneal, e.g. of continuous character, followed by a light pickling step sufficient to remove the light scale that is formed; alloys of the 400 series can usually be annealed at a lower temperature than the chromium-nickel grades, so that there is markedly less scale in the presence of oxidizing influences and it can often be removed without appreciable deterioration of the bright finish. If such scale formation, however, would reduce the ultimate corrosion resistance below a required value (by depletion of chromium at the surface), the inert-gas anneal should be used.

As examples of commercial designations of the kind of bright surface (i.e. the nature of brightness) that the strip should most appropriately have for treatment in the matte-finish temper rolling stage of the process, mention may be made of bright sheet Nos. 1, 2 and 2B, in the 400 grades, as for example type 430, whether annealed in a conventional manner or by so-called bright annealing, and likewise in the 200 and 300 series, Nos.

1, 2 and 2B, when bright annealed, a commercial example being type 304.

Considering the sheet products in their presently preferred and distinctly novel embodiments, e.g. the completed strip **48** in FIG. 4, the finish is a matte texture, desirably non-directional in optical properties, and constituted by a random, non-directional distribution of minute elevated and depressed localities, essentially covering the surface. At the same time the surface has a pleasing luster of more or less subdued nature, the degree of matte effect being inversely capable of characterization, and indeed of measurement, by reflectivity as read on a glossmeter or equivalent scale. The contour, in depth and fineness of grain, is determinable by profile depth and linear density of peaks as in the case of the surface of the rolls **16**. Specifically, the profile depth can be from about 8 RMS upward, with particularly good effects in the range of 15 to 30 RMS. The peak density, as measured in each of the lengthwise and crosswise directions, should be such as to provide reasonable coverage of the surface, preferably obliterating at least 90% of the mirror finish and being in most cases at least about 100 peaks per linear inch; presently preferred examples are in the range of 200 to 400 peaks per inch, although it is conceived that surfaces with higher counts may be useful, as for special purposes. For complete and assured avoidance of optical directionality of the finish, each of these measured or determinable properties, including also reflectivity (as in the range of values mentioned earlier above), should be about the same when read or observed in both directions, lengthwise and crosswise, of the rolled strip surface, a convenient definition for each property being that it is approximately the same in all directions.

It is presently believed that the detail structure of the random-peaked matte grain can be likened to the result of a coining operation, in that individual peaks are usually seen to have a rounded contour, as distinguished from a sharp-edged or pointed configuration (when microscopically inspected) such as normally occurs by an etching or like direct treatment of strip or sheet metal surfaces. Indeed the grain configuration can be structurally characterized as a rolled or rolled-in finish. In any event it has been demonstrated that the sheet surfaces of the present invention are less susceptible of damage by subsequent rubbing or like mishandling, or by permanent retention of foreign substances, than etched-matte finishes.

It has been mentioned that the preferred surfaces of the invention have some minor specular or image-forming properties of reflection (the same in all directions), extremely limited as to distance of the imaged object from the surface, in contrast to a true mirror (such as the bright strip **24** or **44** of FIG. 1), which, whether clear or cloudy, images even very remote objects in a discernible manner. Whereas etched-dull sheet surfaces have practically zero specular reflection, it appears that even toward the lower values of luster or reflectivity of presently preferred finishes of the invention, objects up to about one-half inch from the surface have detectable images, and the higher luster products may yield recognizable images of things up to one or two feet; yet in such cases, more remote objects are confused in reflection, e.g. to the extent of effective diffusion of what might otherwise be sharp highlights from sources of illumination or the like.

Although FIG. 1 of the drawing diagrams a continuous path for the strip **20**, **24**, **44** and **48** through successive operations, conventional practice will usually involve recoiling the material (with a protective paper liner if desired) after each stage, and of course, wherever the strip is to have more than one pass through any one mill.

In the following examples of the process and product, the cold-reducing operations included a final pass through a 4-high mill **10** utilizing a pair of work rolls **22** each surfaced to a bright finish, as by polishing with No. 280 grit or finer. The strip was bright annealed in an inert dissociated ammonia atmosphere, with no subsequent pickling, and was subsequently fed to the temper mill **14**, which was a 2-high, 34-inch mill carrying a pair of work rolls **16** that had each been prepared by first polishing to mirror brightness with No. 400 grit and then abrasive-blasting with No. G40 grit to yield a non-directional matte surface indicating a profile meter reading of 38/40 RMS. All profile depth and peak measurements, including those mentioned earlier above, where made with a standard profile meter, being a Physicists Research Company profilometer, which produced peak tracings on a 100-times scale, utilizing a type Q amplifier. Counts of peak density were made by counting the peaks of the tracings or charts on visual inspection. It will be understood that in general the minimum preferred surface characteristics of the matte roll **16** and of the completed matte finish on the strip require at least about 100 countable peaks per inch in both longitudinal and transverse directions of the surface, meaning peaks countable in any significant manner. In the range above this minimum, the number of peaks or the mode of counting is less significant in an absolute sense, the primary criteria being that the peak counts should be about the same in both directions, i.e. with sufficient approximation to avoid directional reflective properties, and the grain or peak or valley positioning throughout the surface should be of a random but completely distributed nature.

In the final cold pass through the mill **10**, the strip in each of the examples was reduced by at least 35%, it being generally important that this bright pass (usually at least 25% reduction) should not only impart the bright mirror surface but should eradicate all streaking, linear scratches or other directional characteristics of the strip. The temper mill **14** was operated so that the elongation (if any) of the strip by each rolling pass was not more than 1%. It will be understood that actual values of roll pressure or load in the latter mill were not generally measured and have no particular significance; in any instance, persons familiar with rolling mill practice can determine, essentially at once, a suitable range of screwdown adjustments for achieving temper rolling without significant elongation of the strip, while for the present process, the screwdown settings to be selected within such range are determinable (without attention to numerical pressure or load values) from simple test of the product, e.g. by glossmeter reading as explained above.

## EXAMPLE 1

In this case, stainless steel strip of grade 304 (chromium-nickel), was supplied with moderately smooth finish to the final cold pass (at **10**) where it was reduced to a finish gauge of 0.031 inch. The strip was recoiled and then, in conventional manner, entered into the line of strip traversing the bright anneal equipment **12**, where it was annealed at a temperature of 1850° F., and cooled, chiefly in the section **28**, to a temperature of 100° F. The recoiled bright strip from the bright anneal was then passed through the matte rolls **16**, **16** of the temper mill **14**. In the first pass, the operation was effected so that the Gardner 20° specular glossmeter **18** afforded a reading of just over 100 (both directions). The appearance at this stage was a very pleasing high luster matte finish, desirable for a number of purposes, the specular reflectance being very much less than the bright mirror finish of the strip entering the mill. Profile depth reading was in the range 17/20 RMS in each direction.

After two more passes between the rolls **16**, the reflectance of the strip was markedly reduced (while maintaining the desired general character of subdued, non-directional luster) to glossmeter readings (both directions) in the range of 25.5 to 27.0. The profile depth reading rose to about 25 to 27 RMS (both ways) and by count with the profile meter charts the peak density was approximately 300 per inch each way.

EXAMPLE 2

In this instance a strip of 201 grade was cold rolled to a bright-surfaced finish gauge of 0.031 inch. Again the material was bright annealed at a temperature of 1850° F., in the furnace **12**, and ultimately the strip was subjected to temper rolling between the rolls **16**. The first pass was adjusted so that a glossmeter reading of just about 100+ (both ways) was achieved in the first pass. Measured longitudinally the profile depth reading was 20/22 RMS and transversely 17/23 RMS, with 222/224 peaks per inch being counted in each direction.

After a second pass in the same rolls, the glossmeter readings were reduced to about 47, while the profile depth readings increased slightly to 22/24 RMS in each direction. The longitudinal surface count was 308/309 and the transverse count 293/301 peaks per inch. Finally, after a third pass through the rolls **16**, the glossmeter reading was reduced to 22, with a small further increase in the profile depth, the latter being 24/27 RMS longitudinally and 23/26 RMS transversely. The peak count per inch rose to 311/316 lengthwise and 306/311 crosswise. This final product had a very subdued though pleasing luster, and a very low reflectivity, for best avoidance of highlight reflections or the like.

EXAMPLE 3

In this instance the operations were essentially the same as previously described, using grade 434 stainless steel strip, cold rolled to a bright finish on both sides, to a finish gauge of 0.025 inch, and bright annealed at a temperature of 1500° F. After one pass of the bright finish annealed strip through the same matte rolls **16**, glossmeter readings were as follows (in contrast to a far off-scale measure on the original bright surface): transverse reading 106/106 and longitudinal reading 120/122, these values being attained by special adjustment of the meter to obtain determinations in a range above the normal maximum of 100. After a second pass the readings (now in the normal range of the scale) were 55/56 and 54/57 while following a third pass the readings became 33/34, 31/33 respectively.

In all of the examples, every surface which had received one or more passes through the matte rolls was absolutely non-directional in optical effects, so far as careful visual inspection could reveal.

Extensive tests were made of the corrosion resistance of the products of these and other, like experimental runs employing the process. So-called dip-dry corrosion tests showed that the corrosion resistance of the matte-finish products of grades 301 and 434 was approximately the same as that of corresponding bright finished material, e.g. strip of the same bright finish and anneal but temper rolled with polished rolls. Utilizing the so-called CASS test (copper-acetic acid-salt spray) in accordance with published standard specifications of major automobile manufacturers (e.g. General Motors Corp.), samples of stainless steel strip produced with a matte finish in accordance with the above procedures exhibited excellent corrosion resistance, equal to that of the standard bright finish strip after temper rolling. These results were obtained with various compositions, including grades 304, 430 and 434.

It will now be seen that the invention affords production of a stainless steel sheet having an unusual, non-directional, matte finish, having a totality of qualities not heretofore attained in special-finish stainless steel, and applicable to new or wider fields of use in fabricating and manufacturing operations, examples being automotive trim and other parts, structural articles, and architectural elements such as curtain wall, finish framing and the like.

The process accomplishes all of the objectives and results explained hereinabove, and is easily controllable for uniformity of production; a selected surface characteristic can be reproduced by simple reflectivity measurement, not only on the same grade and gauge of strip, but indeed with respect to various gauges and grades, with consequent matching of the appearance of the products. Whereas different grades of metal may require different temper mill pressures, results may be equated readily, while using the same rolls for all materials. Although eventually the temper rolls **16** may wear down to a point where resurfacing is required, their life to that point is relatively long in that minor wear can be fully compensated by increasing the roll pressure.



For special purposes the matte configuration, on one or each of the work rolls in the mill **14**, may be applied only to selected areas of the working surface of the roll, as in accordance with a predetermined pattern, and the corresponding matte finish is then produced on the strip only at areas defined by such pattern. For example, as indicated in FIG. 5, the roll **16***a* is grit blasted or otherwise treated to carry the above-described, non-directional distribution of minute depressions over parallel circumferential bands **50**, leaving the intermediate bands **52** in bright polished condition. On passage of the strip **54** through the rolls **16***a*, **16***b* of the temper mill (roll **16***b* providing whatever surface condition is desired to be retained on or imparted to the opposite strip surface), the surface of the strip shown carries longitudinal bands **56** of subdued-luster, non-directional, matte finish, alternating with mirror-bright bands **58**. One use for such product is in fabricating angle or other bent or folded sections required to have a dull finish at one part or face and a bright finish at another. The control of the matte finish, as by its reflectance, is achieved as above described. Any of a variety of patterns are possible, including subtle contrasts achieved by differently grit-blasting different areas of the roll, e.g. as to density, size or depth of indentations. A convenient way of selectively blasting parts of a roll surface is to mask the other areas with appropriate, removable coating or other material, such as thick, tough plastic, or hard metal or like bands, that will protect the underlying surface from grit impact.

The abrasive particles used in the preparation of matte rolls, whethe rover part or all of the surface, are preferably of random angular shapes, exemplified by so-called steel grit, it being understood that abrasive particles of other conventional materials may also be used.

As stated, an important feature of the improved process is the bright rolling of the strip and maintenance of it in bright-finish condition up to the temper rolling stage. Efforts to obtain equivalent results either by matte rolling in the last cold rolling mill stage, or by carrying the cold rolling only to a finish substantially less smooth than the defined brightness and then matte rolling, have failed to yield the desired non-directional matte finish, apparently at least for the reason that the previous directional characteristics of the surface remained to impair the matte grain. Indeed there is some utility to the described process sequence even where the anneal or a consequent pickle may somewhat dull the mirror reflectivity of bright cold-rolled strip, i.e. in that the temper pass or passes with the defined matte rolls will nevertheless yield a product free of optical directionality, and the simplicity and practical features of operation are still realized. It is also conceived that bright finish cold-rolled strip (from the mill **10**) can be subjected to one or more non-reducing passes through the matte rolls **16** without intermediate annealing, to achieve useful impression of matte texture on the strip surfaces; such sequence might be desired, for example, where the resulting matte strip is thereafter subjected to a bright (non-scaling) anneal to yield an especially soft or workable sheet.

It is particularly desirable that in impressing the matte finish on the optically bright, highly reflective metal surface of the workpiece, e.g. the steel strip, the working member, being the work roll, which carries the multitude of random, minute depressions, be brought against the bright surface in an essentially downward direction, with no significant relative movement, as in a lateral manner, that might produce optical directionality, or a directional grain. In this sense a special aspect of the invention may be regarded as involving the forming of a working member to have a surface characterized by randomly distributed depressions which afford a continuous, non-directional appearance, and imprinting said member on the desired surface of a metal article, e.g. of steel, that has been prepared to have a bright mirror finish, such imprint being effected by mutual, forcible contact of the surfaces in a direction essentially perpendicular to each (or at least without movement which would destroy the identity of impression in a directional sense), while the degree of finish thus produced on the article is selected or maintained by controlling or regulating the factors of extent of imprinting force and number of imprinting interengagements.

It is to be understood that the invention is not limited to the specific examples of various steps and features as herein set forth and shown, but may be carried out in other ways without departure from its spirit.

What is claimed is:

**1.** Stainless steel sheet material characterized by an annealed condition of the material and having a temper-rolled surface which carries a rolled-in lustrous matte finish area having a specular reflectivity greater than 10 and substantially less than bright mirror-like reflectivity, as measured by specular glossmeter at 20°, said matte finish area being constituted by random distribution of minute peaks having a linear density in all directions of at least about 100 per inch and a profile depth of at least 8 microinches RMS, the linear peak density and the reflectivity of said surface area being substantially the same in all directions.

**2.** Stainless steel sheet material as defined in claim **1**, in which the linear peak density of the matte finish in each direction has a value in the range between about 200 peaks per inch and about 400 peaks per inch, and the profile depth of the matte finish is at least about 15 microinches RMS.

**3.** Stainless steel sheet material having a surface which carries a rolled-in non-directional lustrous matte finish area having a specular reflectivity greater than 10 and substantially less than bright mirror-like reflectivity, as measured by specular glossmeter at 20°, said matte finish being constituted by random distribution of minute peaks having a linear density in all directions of at least about 100 per inch, and the reflectivity of said surface area being substantially the same in all directions.

**4.** Stainless steel sheet material as defined in claim **3**, in which said matte finish area constitutes a part of said surface, the remainder of said surface comprising an area of uniform finish characteristics different from said matte finish.

**5.** Stainless steel sheet material as defined in claim **4**, in which the remainder of said surface has a bright, mirror-like finish.

**6.** Stainless steel sheet material as defined in claim **3**, in which the matte finish area comprises at least one longitudinal band along the sheet surface, having said matte finish, and the said sheet surface also comprises at least one longitudinal band, adjacent said first band, of bright, mirror-like finish.

**7.** Stainless steel sheet material produced by cold rolling reduction and characterized by an annealed condition of the material, said sheet having a surface which carries a lustrous matte finish area rolled-in without substantial reduction in sheet gauge and having a specular reflectivity greater than 10 and substantially less than bright mirror-like reflectivity, as measured by specular glossmeter at 20°, said matte finish being constituted by random distribution of minute peaks having a linear density in all directions of at least about 100 per inch, and the reflectivity of said surface area being substantially the same in all directions.

**8.** Stainless steel sheet material as defined in claim **7**, in which said matte finish is temper-rolled over a mirror-like finish, to a selected specular reflectivity of at least about 20 as measured by specular glossmeter at 20°.

**9.** Stainless steel sheet material as defined in claim **3**, in which said matte finish has a selected specular reflectivity of at least about 20 as measured by specular glossmeter at 20°.

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U.S. Cl. X.R.

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