May 11, 1948. C. M. O'HARA 2,441,283

APPARATUS FOR CONTINUOUSLY DETERMINING THICKNESS AND HARDNESS OF METALLIC STRIP

Filed Oct. 2, 1945 2 Sheets-Sheet 1

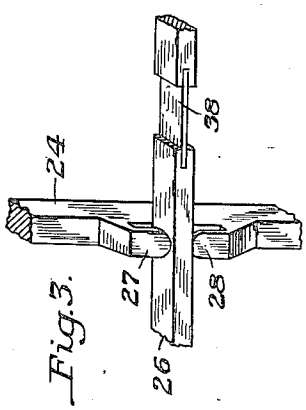


Fig. 3.

Fig 1.

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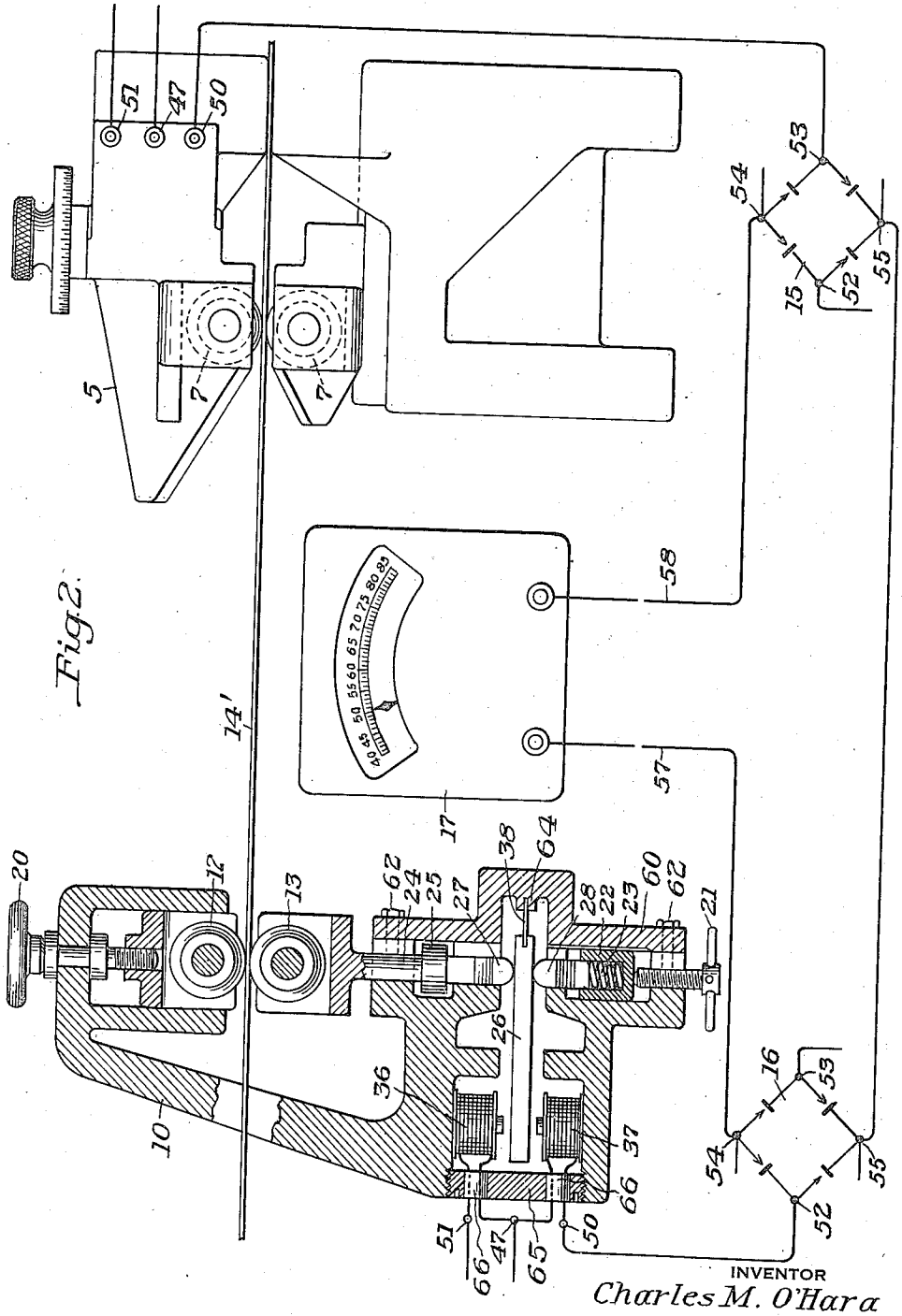


Fig. 2.

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Patented May 11, 1948

2,441,283

UNITED STATES PATENT OFFICE

2,441,283

APPARATUS FOR CONTINUOUSLY DETERMINING THICKNESS AND HARDNESS OF METALLIC STRIP

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Application October 2, 1945, Serial No. 619,881

7 Claims. (Cl. 73—78)

1

In the art of steel making, the term "temper," prior to the advent of cold reduction processes, was used to denote hardness developed by the addition of carbon and heat treatments, and more particularly in the class of carbon tool steels to indicate the carbon content. In connection with strip rolling, however, the term "temper" as applied to the finished product denotes hardness developed by cold rolling, or the ability to resist indentation or flexing.

One of the more common methods practiced to obtain temper in metallic strip is to subject it to a skin pass on a cold rolling mill wherein the metal will be elongated slightly. The degree of temper so obtained is in direct relationship to the amount of elongation, and obviously, therefore, it is necessary to measure elongation to control temper imparted to the material during cold working. Since there is no known method of measuring elongation accurately in a continuous manner, it therefore is necessary to apply spaced-apart markings to the strip and measure it after rolling to determine elongation. This operation may be repeated several times on each coil before the correct roll adjustment is secured to provide the extent of elongation and degree of temper.

As a further check, specimens from the finished material are subjected to deformation tests in order to compare the hardness value with so-called standards, such, for instance, as the Rockwell scale. Such tests, while perhaps not recognized as standard in the stricter sense, serve very well for plant control of the product, and until better methods are devised, will continue to be acceptable. In order to be conclusive, the specimens are indented beyond their elastic limit and the area of deformation measured and translated into terms of hardness. Based upon hardness indicated, material is either accepted as meeting specifications, re-rolled, or reclassified into other temper groups.

The procedure outlined involves endless repetitions which are expensive to practice, and in addition does not include any provision for observing elongation and temper in the material during the continuous rolling process. Elongation is checked only once on each coil processed and variations in gauge of the strip will be reflected as variations in temper, and as result, uneven temper will be created throughout the length of the strip.

The present invention has for one important object the provision of means for continuously measuring and recording temper of rapidly moving strip material as it exists from a cold rolling mill.

2

A further object is to provide a combination of means which can be used for controlling temper of a rapidly moving strip to a degree where the temper will be maintained evenly and continuously throughout the entire strip length during the rolling operation.

Further objects of the invention will become apparent as the description proceeds, and the features of novelty will be set forth in the appended claims. It is to be understood, also, that the specific embodiment of the invention herein illustrated and described is not intended to be any more than an example of one form of apparatus which may be provided for carrying out the objects of the invention, as the principles of the invention are capable of being incorporated into other modifications.

Generally speaking, in order to determine uniformity and degree of temper of a strip as it leaves the final mill pass, the present invention utilizes two somewhat similar gauges located side by side in close proximity to the exit rolls of the mill and extending over the edge of the strip in order that the gauging rolls are positioned a material distance from the edge. One of the gauges measures only thickness of the strip, while the second gauge measures both thickness and hardness, and each is provided with a separate electrical circuit which is caused to function variably in response to mechanical movement of the gauge parts during operation. In practice, as the moving strip passes between the rollers of the respective gauges, the circuit of the first gauge delivers electrical current of a value representative of strip thickness, and the circuit of the second gauge delivers electrical current of a greater value representing both thickness and hardness of the strip. By continuously matching the output of the two circuits against each other in a third circuit, the difference existing between the first two named is readily detected and represents hardness or temper of the moving strip.

The invention will be understood more readily by reference to the accompanying drawings, wherein:

Figure 1 represents a diagrammatic view, partly in section, of one form of apparatus suitable for carrying out the present invention.

Figure 2 is an enlarged view showing the apparatus of Figure 1 operating on the strip, the temper of which is to be determined continuously.

Figure 3 is an enlarged fragmentary perspec-

tive view of a portion of the sectioned left-hand gauge.

Referring more particularly to the drawings, reference numeral 5 represents what is known conventionally as a flying micrometer having opposed contact rollers 7 adapted to engage opposite surfaces of the material being gauged, and is provided with adjustable means for manually setting the micrometer for specific thickness of material. Variations or fluctuations in strip thickness in excess of, or less than, specific thickness, causes relative separating or approaching movement of rollers 7, which movement is indicated on meter 9. This flying micrometer gauge may be of the type described in detail in United States Letters Patent No. 2,007,840, issued July 9, 1935, to Spencer B. Terry, and consequently need not be described here in detail.

Thickness and temper of the strip are obtained by the use of a second gauge 10, which is generally similar to gauge 5 with reference to general design, but in addition to registering variations in thickness simultaneously registers variations in strip hardness or temper also. The contact roll 12 of gauge 10 is provided with adjusting means 20 to adjust the opening between rollers 12 and 13 for specific strip thickness while roll 13 is equipped with means for compressing the strip beyond its elastic limit to determine hardness. Such means comprise screw 21, cup 22, and spring 23. By manually adjusting the screw 21 upwardly, movement is imparted to shank 24 and coacting roll 13. A collar 25, which is integral with shank 24, functions as a stop to prevent overtravel of the latter and resultant damage to armature 26.

As will be apparent from the construction of the gauge 10, roll 12 remains at all times in a vertically fixed position, as determined by the adjustment of the manual adjusting means 20, while roll 13 is capable of relative approaching and separating movement with respect to roll 12 by reason of the fact that roll 13 is supported in the shank 24, which is slidably contained in the gauge housing. The shank 24 is urged resiliently upwardly by spring 23 in response to manual turning of the screw 21, thus establishing the approaching movement of roller 13 to roller 12. The resiliency of spring 23, when properly adjusted, permits controlled downward movement of shank 24 and separation of the rollers 12 and 13 in response to variations of strip thickness and hardness. Corresponding movements of shank 24 are transmitted to the armature 26 by guides 27 and 28 (see Figure 3), which guides are integral with the shank 24 and maintain intimate contact with armature 26, the armature 26 being attached to the gauge housing by a flexible support 38.

The circuits shown in Figure 1 are of generally standard construction, those employed for the gauges 5 and 10 being duplicates and reading directly on United States Letters Patent No. 1,640,464, dated August 30, 1927, and issued to Alfred V. Mershon.

To avoid needless repetition, the following description of the duplicate circuits for gauges 5 and 10 will be confined to the circuit of gauge 10, in which the incoming voltage from power line 30 is regulated to an even value by voltage regulator 31 before being fed into the gauge circuit. One side of the power line is connected at 39 to primary winding of transformer 33, and regulator 31 is connected between the opposite side of the power line and the opposite terminal 40 of the primary winding of the transformer 33. As a result of the combination described, the voltage available for secondary terminals 44 and 45 is stepped down to within safe operating limits, and in addition is maintained at the even value necessary for efficient functioning of the gauge circuit.

The secondary terminal 44 of the transformer 33 is commonly connected at 41 to windings 42 and 43 of a cored inductance 32, and the adjusting arm 46 of potentiometer 34 and secondary terminal 45 of transformer 33 is commonly connected at 47 to respective windings of oppositely disposed electromagnets 36 and 37 positioned on each side of the gauge armature 26 of gauge 10. The discharging terminals 48 and 49 of inductance 32 are connected respectively to the other terminals 50 and 51 of electromagnets 37 and 36, and across potentiometer 34 and rectifier 16 at terminals 52 and 53 on the latter. Thickness meter 29 is connected across the output terminals 54 and 55 of rectifier 16, which converts the alternating current input into direct current output.

The above-described circuits and parts described above are duplicated in the circuit of gauge 5.

In the circuit described above, induced currents are set up in the different branches including windings around electromagnets 36 and 37 within the gauge housing. The intensities of the induced currents in the two branches of the circuit are influenced by the varying distances of armature 26 from the two oppositely positioned magnets 36 and 37, these variations of armature distances being caused by movements of shank 24 in response to variations of strip material being gauged. The variations in current in the two branches connected to terminals 52 and 53 of rectifier 16 function to deflect the pointer of thickness meter 29 connected across the output terminals of the rectifier 16. The potentiometer 34 is used to adjust inductance of the circuit during setting operation of the gauge in order to cause the pointer of meter 29 to register zero.

Temper of the metal being gauged is indicated by a microammeter 17, the two lead wires 57 and 58 of which are connected to output terminals 54 of rectifiers 15 and 16, and the tie-in wire 59 connects the opposite output terminals 55 together. It will be seen from Figure 1 that the meter 17 and the rectifiers 15 and 16 are connected in series, so that any difference in output from rectifiers 15 and 16 will be indicated by a corresponding movement of the pointer of meter 17. Such variations in output of the rectifiers are caused by variations of induced currents delivered to the rectifiers by gauges 5 and 10, which respond sensitively to variations in the metallic strip being gauged.

In operating the system of the present invention, it is necessary first to set the gauges 5 and 10. In the case of gauge 5, the procedure is outlined thoroughly in the aforementioned Terry patent, and needs no further description here. However, it is to be remembered that the gauge 5 measures only variations in strip thickness which are introduced into the circuit of rectifier 15 in the form of induced currents.

In the Terry patent, it is to be understood that the desired setting of the gauge 5 regarding the exact thickness of the material to be gauged is accomplished by the use of a gauge block which is representative of the thickness. After this portion of the setting-up operation is performed, a standard specimen 14 of the exact thickness of

the material to be gauged is inserted between rollers 7, and the pointer of meter 9 should indicate zero. Specimen 14 is left in place during the setting of gauge 10.

To set gauge 10, roller 12 is retracted by operating the screw 20, and the screw 21 is backed out, thus relieving any compressive force against shank 24. The gauge shoe 56 of prescribed thickness is inserted into the position shown, and causes shank 24 to assume a position whereby the coacting guides 27 and 28 will cause the free end of armature 26 to attain a position exactly midway between the poles of the electromagnets 36 and 37. Under the conditions outlined, the pointer of meter 29 should register zero, but if it does not, the desired register may be obtained by moving arm 46 of potentiometer 34, which controls induced current in the circuit between cored inductance 32 and electromagnets 36 and 37.

The screw 21 is now adjusted to a point just short of causing upward movement of shank 24, with consequent unbalancing of the induction circuits and movement of the pointer of meter 29 from the zero register previously attained. The gauge block 56 then is removed and a second standard specimen 14, similar to the one still in gauge 5, is placed between rollers 12 and 13. This latter specimen, in addition to being in exact duplication of the thickness required, must also possess a hardness value required in the finished metallic strip that is to be rolled. The roller 12 is now adjusted by screw 20 until it contacts the surface of the specimen 14, and care must be exercised in making this adjustment so that the separation of the rollers 12 and 13 will be equivalent only to the thickness of the specimen 14. Any overadjustment can readily be detected by movement of the pointer of meter 29 from zero register.

Having set the gauges as described above, it may be said that the circuits thereof are electrically balanced with respect to their output which represents exact thickness value of standard specimens 14. In practicing the method of the present invention, it is proposed to utilize one of the gauges to measure hardness of the strip in addition to thickness, and to accomplish this, gauge 10 will be purposely unbalanced and caused to indicate combined values of hardness (H) and thickness (T) which are in excess of the single value (T) as indicated by the other gauge. By matching the combined values H and T of one circuit against the single value T of the other in a third circuit, it is practical to subtract the smaller from the greater, and obtain the difference, which is H, or hardness.

Continuing the setting of gauge 10 to secure the additional hardness value H, screw 21 is adjusted further in order to overcome resistance of spring 23 and impart upward movement to shank 24, and as a result, upper and lower surface indentations of micro-metric proportion will be imparted to specimen 14 by rollers 12 and 13. Movement of the shank 24 is reflected in correspondingly magnified movement of the free end of armature 26, displacing the latter with respect to the midway or balanced position between magnets 36 and 37 and therefore unbalancing the gauge circuit and altering the value of the output from rectifier 16. Meter 29 responds by indicating the new value of the circuit which, in effect, is actually a measure of hardness and thickness or H and T, as above described. Since the output of rectifier 16 has been increased in value over that of rectifier 15, the difference will be

indicated in the manner previously described, on meter 17.

Movement of the pointer of the meter 17 can be read directly on the graduations, which in the present case conveniently correspond to those of the Rockwell scale for hardness, and when the pointer registers the established known value of standard specimen 14, no further adjustment is required.

The specimens 14 now are removed from the respective gauges and the latter are positioned over the strip edge in the desired location, as indicated in Figure 2. As the moving strip passes between the opposed rollers of the two gauges, the gauge 5 will continuously measure variations in strip thickness as represented in the value of its circuit, while gauge 10 measures combined variations in thickness and hardness as represented in the value of its circuit and the difference in values of the measurements of the two gauges will register continuously on meter 17 as hardness, or temper.

If metallic strip were commercially produced with no variations in thickness, it would be possible to measure hardness continuously by using only gauge 10 and meter 29 of the present invention, in which event lead 59 would be removed and lead 58 of meter 17 would be connected either to terminals 53 or 55 of the rectifier 16. However, since it is still impracticable to produce commercially metallic strip without variations in thickness, it is found to be necessary to include the second gauge to measure thickness variations only of the moving strip and use the same for a reference, as described above.

In Figure 2 there are shown the gauges of Figure 1 in position on a moving strip 14', for taking the measurements of thickness and temper, following the setting of the gauges, as described above. Only enough of the wiring diagram of Figure 1 is included in Figure 2 to show the relationship between the parts of the system, it being understood that the complete wiring diagram is as shown in Figure 1.

It will be seen from Figure 2 that in order to permit access to the interior of the housing of gauge 10 for assembling the parts thereof, the lower portion of the housing is closed on one side by a face plate 60 which is held in position by means of machine screws 62 which pass through holes provided therefor in the face plate, which holes register with similar internally threaded holes in the housing. Also for enabling connection of the leads to magnets 36 and 37, the rear of the housing is provided with a threaded plug 65 having holes therethrough for the reception of insulating bushings 66 through which the leads for the magnets pass. The face plate 60 is a casting having the shape as shown, and is provided with an interior lug 64 having a groove therein for receiving the support 38 for armature 26. The support 38 has sufficient rigidity to maintain the armature 26 in adjusted position, but sufficiently flexible to bend responsively to separating movements between rollers 12 and 13 from their set position.

It will be understood that the invention contemplates variations in detail in the above-described apparatus without departing from the substance and spirit of the invention; and it will be understood that it is intended and desired to embrace within the invention such modification and changes as may be necessary to adapt it to varying conditions and cases within the scope of the following claims.

I claim:

1. Apparatus for continuously measuring gauge and temper of metallic strip, which comprises a pair of micrometer gauges, one of which gauges is adapted to measure thickness of the strip, the second of the gauges being adapted to measure thickness and hardness of the strip, an alternating current circuit for each gauge adapted to receive alternating current from a supply thereof, rectifying means in each alternating current circuit, and means for measuring differences in output of the alternating current circuits, the said differences in output representing temper or hardness of the strip.

2. Apparatus for continuously measuring gauge and temper of metallic strip, which comprises a pair of micrometer gauges one of which gauges is adapted to measure thickness of the strip, the second of the gauges being adapted to measure thickness and hardness of the strip, a first electrical circuit for the thickness-measuring gauge, a second circuit for the second gauge, the circuit for the thickness measuring gauge being adapted to deliver current of a value representative of strip thickness, the second circuit being adapted to deliver current representing both thickness and hardness of the strip, a third circuit connected in series with the said first and second circuits adapted to match current outputs of the first and second circuits, and means in the third circuit for measuring differences in the current outputs of the first and second circuits, the said differences in current outputs representing hardness of the strip.

3. Apparatus for continuously measuring gauge and temper of metallic strip, which comprises a pair of micrometer gauges, one of which gauges is adapted to measure thickness of the strip, the second of the gauges being adapted to measure thickness and hardness of the strip, instrumentalities connected to the second of said gauges for converting thickness and hardness of the strip into electrical current of a value corresponding to the thickness and hardness of the strip, instrumentalities connected to the first of said gauges for converting thickness of the strip into electrical current of a value corresponding to the thickness of the strip, and electrical means connected to both of said instrumentalities for determining difference in values of the said currents, the said difference in current values representing hardness of the strip.

4. Apparatus for continuously measuring gauge and temper of metallic strip, which comprises a pair of micrometer gauges, one of which gauges is adapted to measure thickness of the strip, the second of which gauges being adapted to measure thickness and hardness of the strip, an electrical circuit for the strip-thickness gauge adapted to convert thickness of the strip into an electrical current of a value corresponding to the thickness of the strip, a second circuit for the second gauge adapted to convert thickness and hardness of the strip into electrical current of a value corresponding to the thickness and hardness of the strip, a third circuit connected to the thickness measuring circuit and to the said second circuit, and means in the said third circuit operable responsively to differences in current output of the thickness-measuring circuit and the said second circuit for indicating hardness of the strip.

5. Apparatus for continuously measuring gauge and temper of continuously moving metallic strip, which comprises a pair of micrometer gauges, one of which gauges is adapted to measure thickness of the strip, the second of which gauges is adapted to measure thickness and hardness of the strip, an electrical circuit for the strip-thickness gauge, a second electrical circuit for the second gauge, each of the said circuits having two branches, rectifying means in each of the said circuits, each of the rectifying means having a pair of input terminals and a pair of output terminals, the two branches of each of the said circuits being connected to the input terminals of the respective rectifying means, instrumentalities for inducing alternating currents in both of the said circuits, the induced current in the circuit for the thickness-measuring gauge being of a value corresponding to the thickness of the strip, the induced current in the second circuit being of a value corresponding to the thickness and hardness of the strip, means for initially balancing the currents in both circuits, and a third circuit connected in series to the output terminals of the rectifying means and including a meter graduated in hardness values operable responsively to differences in current input to the rectifiers from the strip thickness-measuring circuit and the said second circuit.

6. Apparatus for continuously measuring gauge and temper of continuously moving metallic strip, which comprises, in combination, a pair of micrometer gauges one of which gauges is adapted to measure thickness of the strip, the second of which gauges is adapted to measure thickness and hardness of the strip, an electrical circuit for the strip thickness gauge, a second electrical circuit for the second gauge, each of the said circuits having two branches, rectifying means in each of the said circuits, each of the rectifying means having a pair of input terminals and a pair of output terminals, the two branches of each of the said circuits being connected to the input terminals of the respective rectifying means, instrumentalities for inducing alternating currents in both of the said circuits, the induced current in the circuit for the thickness-measuring gauge being of a value corresponding to the thickness of the strip, the induced current in the second circuit being of a value corresponding to the thickness and hardness of the strip, means for initially balancing the currents in both circuits responsively to a setting of the gauges on standard specimens of strip, adjustable mechanism in the second gauge actuable responsively to variations in thickness and hardness of the strip being measured to vary the current in the second circuit in amounts corresponding to variations in the strip, and a third circuit connected in series to the output terminals of the said rectifying means and including a meter graduated in hardness values operable responsively to differences in current inputs to the rectifiers from the strip thickness-measuring circuit and the said second circuit.

7. Apparatus for continuously measuring gauge and temper of continuously moving metallic strip, which comprises, in combination, a pair of micrometer gauges, one of which gauges is adapted to measure thickness of the strip, the second of which gauges is adapted to measure thickness and hardness of the strip, an electrical circuit for the strip thickness-measuring gauge, a second electrical circuit for the second gauge, each of the said circuits having two branches, rectifying means in each of the said circuits, each of the rectifying means having a pair of input terminals and a pair of output terminals, the two

branches of each of the said circuits being connected to the input terminals of the respective rectifying means, instrumentalities for inducing alternating currents in both of the said circuits, the induced current in the circuit for the thickness measuring gauge being of a value corresponding to the thickness of the strip, the induced current in the second circuit being of a value corresponding to the thickness and hardness of the strip, means for initially balancing the currents in both circuits responsively to a setting of the gauges on standard specimen of the strip, the second gauge comprising a pair of rolls adapted to engage the strip on opposite sides thereof, one of the said pair of rolls being fixedly mounted relative to the strip, resiliently mounted mechanism acting on the other roll of the pair to continuously urge the said roll against the strip with a predetermined force while enabling the roll to yield responsively to variations in thickness and hardness of the strip, oppositely spaced electromagnets in the second circuit, a resiliently mounted armature positioned between the magnets and movable

relatively thereto in response to movement of the said yieldable roll, thereby varying the current in the second circuit in amounts corresponding to variations in the strip, and a third circuit connected in series to the output terminals of the said rectifying means and including a milliammeter graduated in hardness values operable responsively to differences in current inputs to the rectifiers from the strip thickness-measuring circuit and the said second circuit.

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