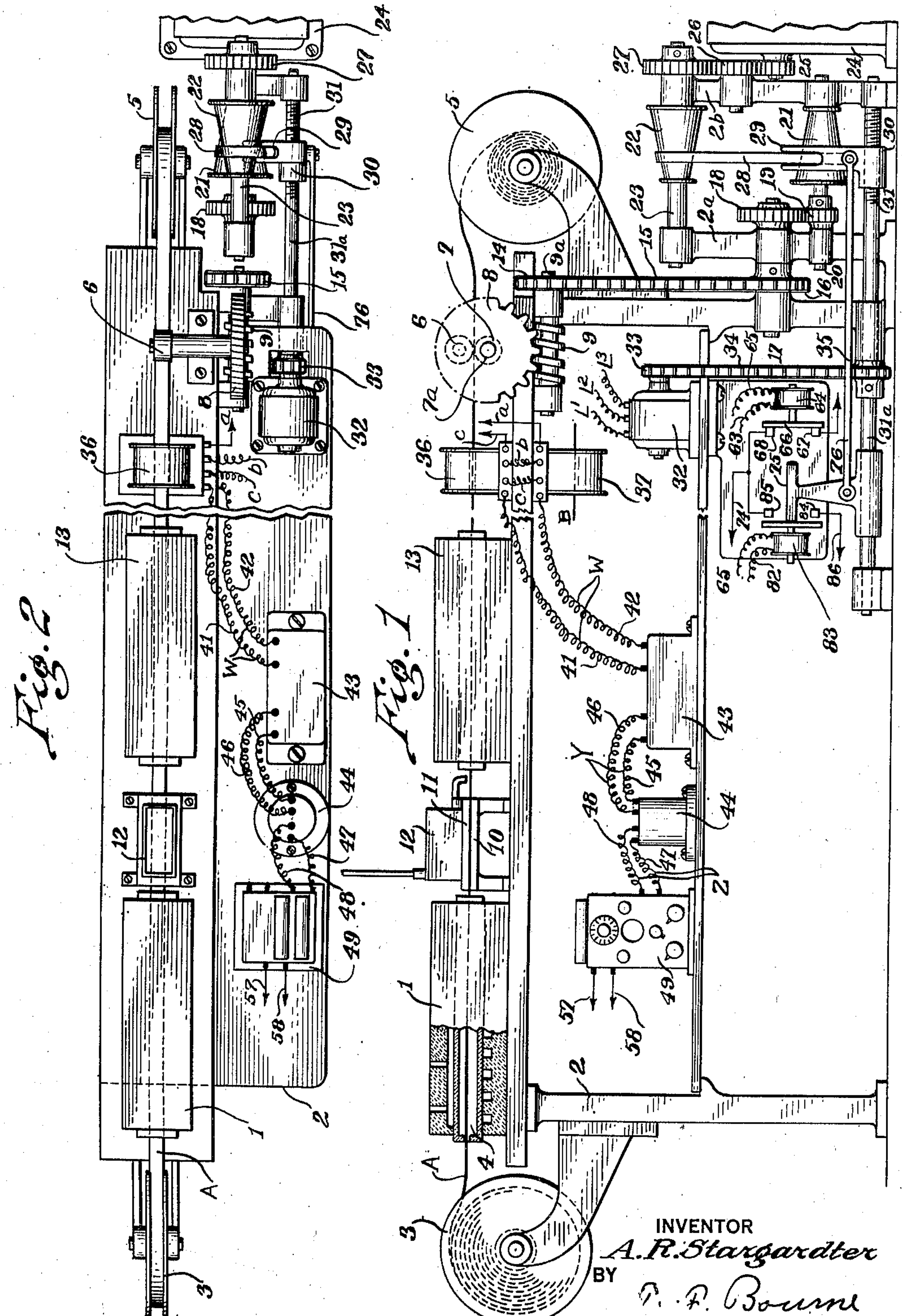
Oct. 27, 1936. A. R. STARGARDTER 2,059,054

METHOD OF AND MEANS FOR TREATING METAL

Filed May 13, 1932 4 Sheets-Sheet 1



INVENTOR
A. R. Stargardter
BY
R. F. Bourne
ATTORNEY

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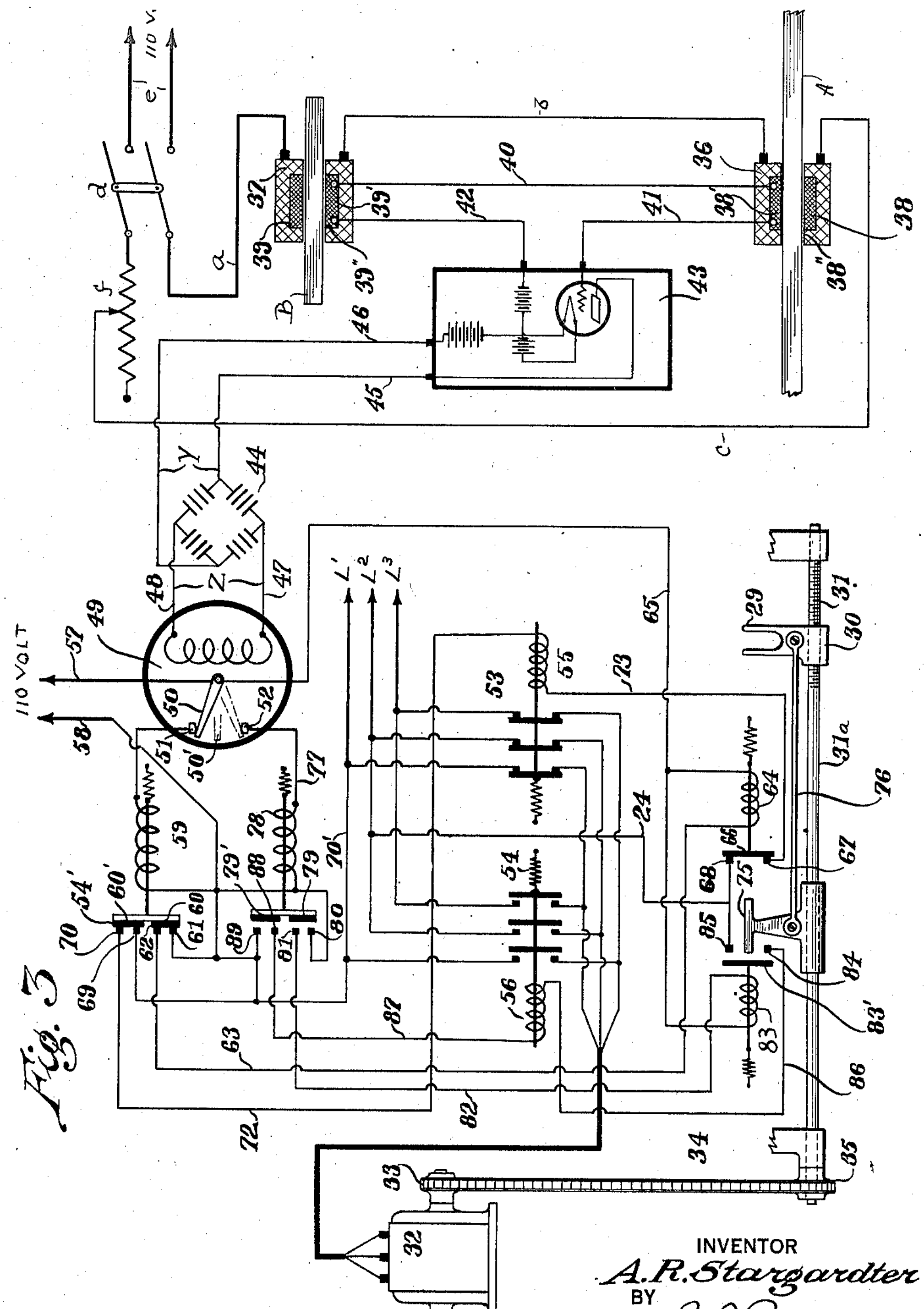

Fig. 3

INVENTOR
A. R. Stargardter
BY
P. P. Bourne
ATTORNEY

Oct. 27, 1936. A. R. STARGARDTER 2,059,054

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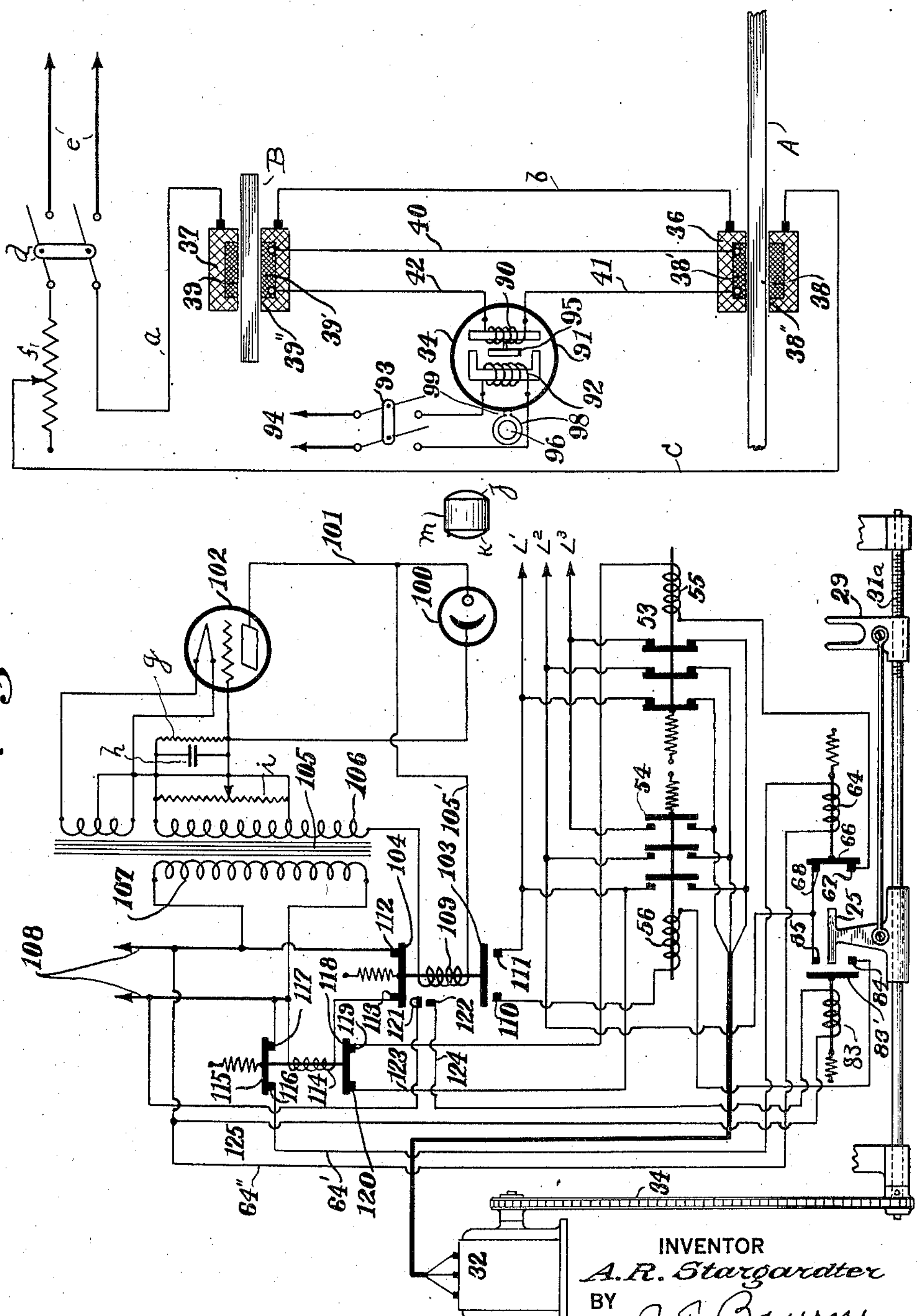

Fig. 4

INVENTOR
A. R. Stargardter
BY
F. F. Bourne
ATTORNEY

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Fig. 5

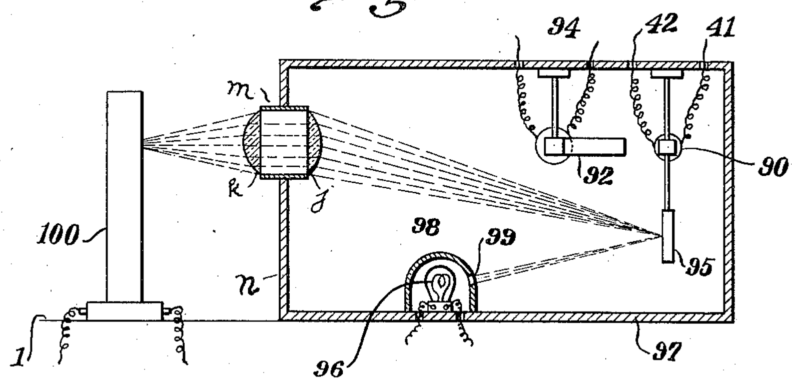


Fig. 6

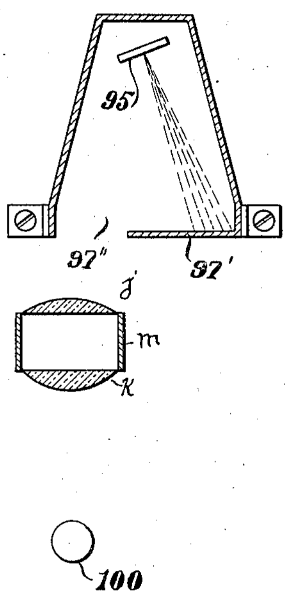


Fig. 7

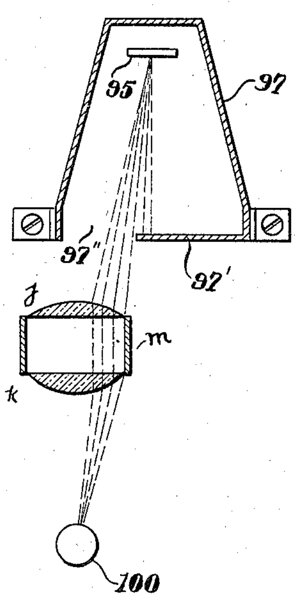
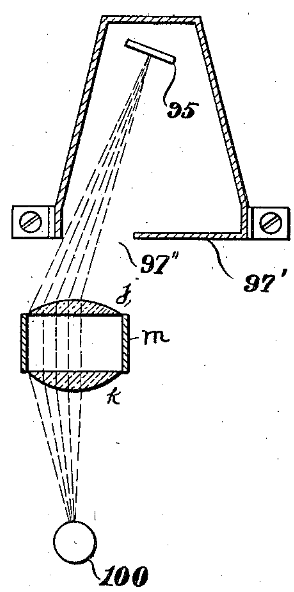


Fig. 8



INVENTOR
A. R. Stargardter
BY
A. F. Bourne
ATTORNEY

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UNITED STATES PATENT OFFICE

2,059,054

METHOD OF AND MEANS FOR TREATING METAL

Albert R. Stargardter, Brookline, Mass., assignor to Gillette Safety Razor Company, Boston, Mass., a corporation of Delaware

Application May 13, 1932, Serial No. 611,099

46 Claims. (Cl. 148—21.5)

An object of my invention is to control the heat treatment of continuous lengths of magnetizable metal strips, such as for producing substantial uniformity of a desired character throughout the length of the strip, during travel of the latter. My invention contemplates control of the heat applied to a traveling magnetizable metal strip by utilizing definite characteristics in portions of the strip, or variations or changes therefrom in the metallurgical characteristics within other portions of the strip itself, to retain a correct or desired amount of heat applied to the strip while in the heating zone or zones, the latter being maintained at a predetermined temperature most suitable in intensity for application to the strip, the amount of heat input applied to the magnetizable metal strip being varied, as required, as the strip is conducted through the heat treating system by automatically varying the speed of travel of the strip through said system, thereby securing control of hardening and/or tempering and/or annealing the strip.

Any change in the microstructure of steel or any other ferrous-alloy is accompanied by a change in the electrical permeability of the metal. For example, a steel which has been quenched from 1600° F. will possess less permeability than if it had been quenched from 1500° F. The same steel quenched from 1500° F. will possess less permeability than if it had been quenched from 1400° F. at the same cooling rate. These phenomena are due to the fact that in a given steel or steels identical in composition, microstructure, and prenatal history, the higher the quenching temperature, the greater the amount of carbides held in solid solution; it also follows that the longer the steel is held at a given stationary quenching temperature the greater the amount of carbides held in solid solution.

The electrical permeability is inversely proportional to the amount of carbides in solid solution. This principle is also true for annealed steels. A steel annealed from 1500° F. at a certain cooling rate will possess greater permeability than the same steel or steels identical in composition and prenatal history annealed from 1400° F. since the steel annealed from 1500° F. will have less carbide in solid solution than that annealed from 1400° F. It is also true that a steel annealed from 1500° F. will possess greater permeability if subjected to the high heat for a period of five minutes than would the same steel subjected to the same heat for three minutes since it will have less carbide in solid solution when subjected to the longer heat immersion.

It also follows from the above that in the case of either hardened or annealed steels (or ferrous-alloys) the electrical permeability is inversely proportional to the cooling rate. For the following reasons identical steels cooled at the rate of one degree per second will have greater permeability than those cooled at the rate of 40° per second, etc. Thus, water-quenched steels have less permeability than similar steels oil quenched. This is because the faster quenching rate leaves a greater amount of carbide in solution. Oil as a cooling agent yields a slower quenching rate than water.

It is also true that in the case of steels identical in composition and prenatal history the electrical permeability varies inversely with the net carbon content.

In accordance with my invention, I utilize the electrical permeability of a "standard" piece of magnetizable metal which has been predetermined as to the desired characteristics, to cause a desired metal strip to be heat-treated, namely, to be hardened and/or tempered, or annealed, in substantial correspondence as to desired characteristics in the treated strip of those in the standard strip.

In carrying out my invention I cause the strip to be treated to travel through one or more heating furnaces or baths, of any desired construction, in which the heat input at an optimum temperature, predetermined and maintained substantially constant, is applied to the strip, with means to propel the strip through the furnace or bath at variable speeds, as required, and through electrical devices, whereby to secure control of the length of time during which the heat input is applied to the strip. Said devices are adapted to react to electrical permeability changes or variations in such strip as compared to a "standard" piece of similar material in said devices to control automatically any changes or variations from the standard piece to cause the heating means to apply more or less heat to the traveling strip by automatically causing longer or shorter immersion of the strip at the predetermined temperature, by varying the speed of travel of the strip through the heating means or zone, to cause the strip to be heat treated whereby its desired characteristics will, throughout its length, substantially correspond to those of the standard piece.

In the example illustrated in the accompanying drawings I provide a heating zone for the strip, such as a furnace or bath, maintained at a substantially constant temperature, means to propel the strip through said heating zone, which means includes a variable speed transmission having devices to cause variable speed of travel of the strip through the heating means, and electrical devices adapted to receive the traveling metal strip and also a "standard" piece of similar metal, and means controlled by said electrical devices due to similar or different characteristics between the traveling heat-treated strip and the standard piece, to control the transmission for varying the speed of travel of the strip, as may be required, to cause the strip to travel through the heating zone at a greater or lesser speed for application to the traveling strip of more or less heat to cause the characteristics of the strip to substantially correspond to those of the standard piece.

My invention also comprises novel details of improvement that will be more fully hereinafter set forth and then pointed out in the claims.

Reference is to be had to the accompanying drawings wherein:—Fig. 1 is a side elevation of an apparatus embodying my invention; Fig. 2 is a plan view corresponding to Fig. 1; Fig. 3 is a diagrammatic view of devices for controlling the speed of travel of strip through the heating zone; Fig. 4 is a diagrammatic view of modified means to control the speed of travel of the strip through the heating zone; Fig. 5 is a detail view illustrating the galvanometer and photo-electric cell of Fig. 4; and Figs. 6, 7 and 8 are diagrammatic views illustrating various positions of the galvanometer mirror with respect to the photo-electric cell of Figs. 4 and 5.

Similar numerals and letters of reference indicate corresponding parts on the several views.

A suitable heating furnace or bath **1** is shown mounted upon a suitable frame **2**, which furnace or bath may be of any desired design and construction having means to maintain an optimum temperature therein, pre-determined and substantially constant, in a well known way. The metal strip A to be heat-treated may be supported upon a reel **3** in position to pass through the furnace or bath **1**, as through a heating chamber or muffle **4** thereof, and at **5** is a take-up reel for the treated strip. To propel the strip A I have illustrated a pair of opposed rolls **6** and **7** suitably journaled for gripping and feeding the strip. The shafts of the rolls **6** and **7** may be journaled in suitable bearings on frame **2**, the shaft **7**a being shown provided with a gear wheel **8** in mesh with a worm **9** journaled on frame **2**. Strip A, after passing from the heating zone or bath **1**, may be quenched or cooled in any desired way, such as by passing between chilling or cooling plates **10** and **11**. A cooling water tank is indicated at **12** on the plate **11**. The strip A may be hardened and quenched (or annealed) by the means described as the strip travels. If it is desired to temper a hardened steel strip the heated and quenched strip may be tempered as it travels from the furnace by means of a tempering furnace **13** through which the hardened and quenched strip travels. The tempering furnace **13** may be of any desired or well known construction and adapted to have its temperature maintained substantially constant in any well known way. I provide means for varying the speed of travel of the strip A through the heating and quenching means. While any suitable variable driving means for operating the strip feeding or propelling devices, such as the rolls **6** and **7**, may be provided, I have illustrated a variable speed transmission adapted to operate the worm **9** at variable speeds as desired. The shaft **9**a of worm **9** is provided with a sprocket-wheel **14** receiving a chain **15** from a sprocket-wheel **16** on a shaft **17** journaled in suitable bearings connected with the main frame. The shaft **17** is shown provided with a gear **18** in mesh with a gear **19** on a shaft **20** that carries a cone-pulley **21**. Spaced from the pulley **21** is a reversely disposed corresponding cone-pulley **22** on a shaft **23** journaled in suitable bearings. I have shown frame members **2**a and **2**b in which the shafts **20** and **23** are journaled. A suitable electric drive motor, at **24**, is adapted to rotate the shaft **23** and pulley **22** by means of gearing at **25**, **26** and **27**. At **28** is an endless belt operable upon the pulleys **21** and **22** for rotating the former by the latter at a speed corresponding to the position of the belt upon the pulleys, whereby, through the driving devices described, the rolls **6** and **7** will propel the strip A at the required speed. For shifting the belt **28** back and forth along the pulleys **21** and **22**, to cause the required speed of travel of strip A, I provide a governor or fork **29** that receives belt **28**, which fork is provided with a threaded hub **30** operable upon threads **31** on a shaft **31**a journaled in suitable bearings on the frame. At **32** is a reversing motor for driving the shaft **31**a in opposite directions, as required. I have shown the drive shaft of motor **32** provided with a sprocket **33** receiving a chain **34** that operates on a sprocket **35** on shaft **31**a. When motor **32** operates in one direction the shaft **31** will be rotated in a direction to cause movement of governor or fork **29** in a direction to shift the belt **28** along pulleys **21** and **22**, such as to the right-hand side in Fig. 1, to increase the speed of travel of the strip A by rotating rolls **6** and **7** at an appropriate speed. When motor **32** operates in a reverse direction the shaft **31**a will be correspondingly rotated in a reverse direction to that described to cause the governor **29** to shift belt **28**, as to the left in Fig. 1, to reduce the speed of rotation of the rolls **6** and **7** for reducing the speed of travel of the strip through the heating zone. When the motor **32** is stopped the speed of rotation of the rolls **6** and **7** will be continued constant in relation to the then position of belt **28** upon the pulleys **21** and **22** for causing an appropriate speed of travel of strip A through the heating zone until operation of motor **32** in one or another direction is caused according to required speed of travel of strip A.

In accordance with my invention I provide means to control the speed of travel of strip A through the heating zone such as the furnace **1**, and the tempering furnace **13** when the latter is used, in accordance with a standard piece B of similar material having characteristics desired to be produced in the strip A, whereby, if the characteristics of a treated portion of strip A substantially correspond to desired characteristics of the standard piece B, the speed of travel of strip A through the heating zone will be appropriately maintained, by causing the motor **32** to stop operating, whereby the belt **28** will remain in a fixed position to cause the pulleys **21** and **22** to continue to operate the rolls **6** and **7** at the required speed. If the characteristics of the treated strip should vary from the desired characteristics of the standard piece B, as strip A travels, the motor **32** will be caused to operate in one or another direction to cause the governor **29** to shift the belt **28** along the pulleys in a direction either to increase the speed of travel of strip A, by rotating the rolls 6 and 7 faster, or to cause the belt 28 to be shifted in an opposite direction to cause the pulleys 21 and 22 to rotate the rolls 6 and 7 at a slower speed for propelling the strip A at a reduced speed. Thus more or less heat will be applied to strip A according to its speed of travel through the heating zone, as may be required, to cause the characteristics of the strip to substantially correspond to the desired characteristics of the standard piece B. Therefore, by causing immersion of the strip A as it travels in the heating zone for a required period the characteristics desired in the strip A may be produced in substantial correspondence with the characteristics of the standard piece B, such as hardness.

At 36 and 37 are a pair of step-down transformers having primary windings 38 and 39 in series in a circuit shown including conductors *a*, *b* and *c*. A switch at *d* permits connection of said conductors with the A. C. supply line conductors at *e*. An adjustable resistance *f* is shown for the conductor *c* (Figs. 3 and 4). The secondary windings 38′ and 39′ of said transformers are oppositely wound and are thus electrically opposed, their opposing terminals being shown connected by a conductor 40, the other terminals of said secondaries being respectively connected with conductors 41 and 42. The said secondaries are not provided with permanent cores, but said primaries and secondaries have passageways 38″, 39″, respectively, to receive the traveling strip A and a standard piece of metal B. The conductors 41 and 42 are connected with an amplifier 43, of any well known construction, which in turn is connected with a rectifier 44 by means of conductors 45 and 46, which rectifier is connected by conductors 47 and 48 with a contact making D. C. galvanometer of either potentiometer or millivoltmeter type 49, with either direct or indirect contacts for measuring the output from secondaries of the balanced transformers 36 and 37, (Fig. 3). A standard piece of metal of desired metallurgical characteristics is placed in the transformer 37, and the strip A emanating from the thermo-processing or heat-treating at the heating zone is constantly propelled by the rolls 6 and 7 through the transformer 36, being thereby under constant electrical comparison with standard piece B. The D. C. galvanometer 49 is so adjusted that if the portion of the strip A in the transformer 36 corresponds in desired characteristics to the standard piece B the contactor 50 will be in a neutral position 50′, and circuits hereinafter described will be open to cause the motor 32 to stop operating. If the properties of the strip passing through the transformer 36 are such that a shorter heat immersion in the heating zone is required to produce desired characteristics in the strip, the D. C. galvanometer contactor 50 will move to rest on contact 51 for causing operation of motor 32 to cause acceleration of rotation of the rolls 6 and 7 of the variable transmission for increasing the speed of travel of strip A, and should the characteristics of strip A have required a greater heat immersion in the heating zone to render the strip metallurgically similar in characteristics to the standard strip B in transformer 37, the D. C. galvanometer contactor 50 would have moved to rest against the contact 52 to cause operation of motor 32 in a reverse direction to effect deceleration of the rolls 6 and 7 to decrease the speed of travel of strip A. The operation of the contactor 50 from neutral position to contact 51 or 52, or from either of said contacts to the other, is caused by a variation of balance occurring in the circuit through 40, 41 and 42 and the secondaries 38′ and 39′ and the amplifier 43, by reason of difference in characteristics between the portion of strip A in transformer 36 as compared to the characteristics of the standard piece B in transformer 37. If the portion of strip A passing through the transformer 36 should have increased permeability over the portion that had immediately preceded it in the transformer, which caused balance in the circuit through 40, 41 and 42, whereby the contactor 50 was at neutral, said increased permeability being due to inherent differences in the pre-heat treated strip, the balance of said circuit would be disturbed and a relatively greater potential will flow through the galvanometer 49 to cause contactor 50 to move to contact 52. On the other hand the inherent metallurgical characteristics of the pre-heated strip A being such as to have caused said strip to have acquired decreased permeability due to the amount of heat immersion it had received, a relatively low potential would have been caused to flow through the galvanometer 49, so that the pointer 50 will move from neutral at 50′ to contact 51. In either of these possible conditions of permeability counteractive heat treatment will have been accorded strip A tending to make the finished product substantially uniform as follows: With contactor 50 at contact 52 the decelerating circuit of motor 32 is closed giving the strip greater heat immersion to counteract its condition of excess permeability, and with contactor 50 at contact 51 the reverse effect is attained giving the strip decreased heat immersion to counteract for the metallurgical effect of its decreased permeability.

Current for the motor 32 may be supplied through power lines L^1, L^2 and L^3, as controlled by contacts of the switch 53 or 54 to be controlled by the respective spring-acting solenoid at 55 and 56.

If the galvanometer contactor 50 is in a neutral position all contacts of the switches 53 and 54 will be open so that motor 32 will be at rest, because at such time the characteristics between the treated portion of strip A passing through transformer 36 and the standard piece B in transformer 37 will correspond. If the properties of the portion of strip A passing through transformer 36 are such that a shorter heat immersion in the heating zone is required, the speed of travel of strip A will be increased since the motor M will be caused to operate in the required direction to cause shifting of the governor or fork 29 to shift belt 28 to increase the speed of rotation of rolls 6 and 7, as follows: The circuit through the transformer secondaries 38′ and 39′ will be unbalanced in such a way as to cause the galvanometer contactor 50 to rest on the contact 51, whereupon circuit from line conductors at 57 and 58 (as for 110 volts) will be from 57 through 50, 51, spring-acting solenoid 59 to conductor 58, causing the solenoid to actuate contacts at 60. A contact 61 is connected with conductor 58 and through contact 66 circuit is closed at contact 62, the circuit leading thence through conductor 63, spring-acting solenoid 64 and conductor 65 to line conductor 57. Solenoid 64 operates to close switch 66 to engage contacts 67 and 68 for circuit through closed contacts at 60′, 69 and 70. Contact 69 is connected by conductor 70′ with line L′ and contact 70 is connected with conductor 72 that leads to solenoid 55, conductor 73 connecting said solenoid with contact 67, the contact 68 being connected by conductor 74 with line conductor L^2. Thereupon solenoid 55 operates to close the reversing switch 53 causing its contacts to close the line circuit for motor 32, whereby the latter will operate the variable speed transmission fork or governor 29 in the accelerating direction. Should the characteristics of strip A remain substantially constant as compared to the standard piece B the circuit of the transformer secondary will be balanced and the galvanometer contactor 50 will move from the contact 51 to a neutral position, the circuits described will be broken, and the motor 32 will come to rest. This condition will pertain until the strip A requires a shorter or longer heat immersion in the heating zone. Should the strip require a shorter heat immersion, the circuit of the secondaries will be unbalanced, contactor 50 will engage contact 51 and the circuits previously described will be closed and motor 32 will be operated in an appropriate direction for actuating transmission fork or governor 29 in the accelerating direction, until the characteristics of strip A and standard piece B balance to cause opening of circuit at 50, 51. Should, however, acceleration continue to an undue extent, I provide means for automatically breaking the aforesaid motor circuit as follows: Interrupter 75 is operated with the fork or governor 29 to engage the contactor 66 to break circuit at 67, 68, de-energize solenoid 55 and open switch 53, said interrupter being shown slidably mounted on shaft 31^a, and connected by rod 76 with fork or governor 29, the latter causing movement of the interrupter toward or from contactor 66 according to the direction of movement of the fork or governor.

If the characteristics of the strip should change before the above described automatic interruption of the variable speed drive acceleration, (and a consequent opening of circuit at 66, 67 and 68, causing the motor to stop operation), and should the characteristics of the strip be such that it requires greater heat immersion in the heating zone to render it metallurgically similar to the standard piece B in the transformer 37, this end is instantly accomplished as follows: The D. C. galvanometer contactor 50 would move from 51 whereby the contacts controlled by solenoid 59 are broken, thereby causing de-energization of solenoid 55, breaking of the circuit of motor 32 at the switch 53 and de-energizing of solenoid 64 to cause breaking of circuit at 66, 67 and 68, and the accelerating movement of the speed drive fork or governor 29 will cease. Simultaneously the contactor 50 will move to contact 52 which is connected by conductor 77 with spring-acting solenoid 78 adapted to operate contact 79 to engage contacts 80 and 81, the solenoid 78 being connected to conductor 58. Contact 80 is connected to conductor 58 and contact 81 is connected by conductor 82 to spring-acting solenoid 83 which is connected to the line conductor 57, as through conductor 65. Solenoid 83 closes a circuit at contacts 84 and 85, the contact 84 being connected through conductor 86 with spring-acting solenoid 56 which is connected by conductor 87 with a contact 88, the contact 88 being adapted to be engaged by a contact 79′ operative by solenoid 78 and adapted to engage a contact 89 shown connected by the conductor 70 with the line L^1. The contact 85 is shown connected by conductor 24 to line L^2. The closing of the circuit at 84, 85 by the solenoid 83 causes closing of circuit at 88, 79′ and 89, whereupon solenoid 56 is energized to cause closing of the line circuit for the motor 32 at switch 54 for rotating the motor in a reverse direction to that previously described, to cause reverse rotation of shaft $31a$ to operate the variable speed drive fork or governor 29 in a decelerating direction, as to the left in Fig. 3. If characteristics between the portion of strip A passing through transformer 36 and the standard piece B in transformer 37 remain similar, the contactor 50 of the galvanometer 49 will pass to neutral and circuit last described will be broken to cause motor 32 to stop operating and the strip A will continue to be propelled under such characteristics until the latter change. If the characteristics between the portion of strip A in transformer 36 and standard piece B in transformer 37 should next vary so as to require deceleration of the traveling strip A the contactor 50 will move to contact 52 causing closing of the circuit previously described and the operation of the motor 32 for propelling strip A at an appropriate decrease of speed, and operating interrupter 75 and variable speed fork or governor 29, as to the left in Fig. 3. If different characteristics between strip A and piece B continue and the interrupter engages the contact 83′ it will break the circuit at 84, 85 and thus de-energize solenoid 56 to break the line circuit for motor 32. If a change in the metallurgical characteristics of strip A passing through transformer 36 occurs it will cause the galvanometer contactor 50 to rest in neutral position when said strip characteristics are in agreement with the standard piece B and all motion of motor 32 will cease, or said contactor might move to contact 51 should the metallurgical characteristic of traveling strip A require it to have less heat input in the heating zone to make it compare with the standard piece B.

Thus, in accordance with my invention, whenever the properties or characteristics of the metal strip A undergoing thermal treatment do not correspond with the desired properties or characteristics of the standard piece B, the strip is allowed greater or lesser heating time by decreasing or increasing the speed of travel of the strip, and when said properties or characteristics are in agreement the strip A is caused to travel at a given speed through the heating zone until such properties or characteristics require variation in speed.

The operation may be described as follows: To obtain an initial adjustment, two pieces of strip metal of similar manufacture to that of the strip A to be treated and bearing the structure desired to be obtained through the treatment of strip A may be placed in the passageways of the transformers 36 and 37. The circuit of the primaries of the transformers will be closed at the switch *d* and the resistance *f* will be adjusted until the contactor 50 is in the neutral position and the motor 32 will be at rest with the transmission governor or belt 28 in a suitable position. The standard piece B is allowed to remain in the transformer 37 and the other piece is removed from transformer 36 and the strip A to be treated extends from the furnace and is inserted into the transformer 36 and passed through the rolls 6 and 7 to the take-up reel 5. Assuming that the standard piece B has been quenched from 1500° F. and it is desired to have the strip A heated to 1500° F. as it travels, the motor 24 will be caused to operate to propel strip A. So long as the portion of strip A passing through transformer 36 corresponds in desired properties of characteristics to those of the standard piece B the motor 24 and the variable speed transmission will continue to propel the strip at a definite speed and the strip will be heated and quenched as it travels, the circuit of the primary winding of the transformers and the bucked circuit of the secondaries of the transformers will remain balanced and the contactor 50 of the galvanometer 49 will remain in neutral. Should the traveling strip A at some portion after quenching, as it passes through the secondary 38′, vary from that of the standard piece, such as to require less heat, a differential will occur in the circuit of the secondary of the transformers, because of different characteristics between the "standard" piece and the said portion of the strip, thereby causing operation of the galvanometer contactor 50 to engage contact 51, causing solenoid 59 to be energized closing circuits at 60 and 60′, thereby energizing solenoid 64, closing contact at 66, 67, 68, and solenoid 55 will become energized causing switch 53 to operate to close the line circuit of motor 32. Said motor will then operate in such a direction as to cause the governor or fork 29 to shift belt 28 to cause increased speed of travel of strip A through the heating zone. As soon as the characteristics of strip A passing through transformer 36 correspond with characteristics of standard piece B the circuit of the secondaries of the transformers will balance and galvanometer contactor 50 will break circuit at 51 and pass to neutral but, should the characteristics of the strip passing through transformer 36 be such that the strip would require still shorter heat immersion, the said movement of belt 28 will continue to gradually increase the speed of the strip, and should such acceleration continue to the limit the interrupter 75 will operate the contactor 66 to break circuit at 67, 68 of solenoid 55, whereupon switch 53 will open and motor 32 will cease operating.

If the characteristics of the strip A should change before the above described automatic mechanical interruption of the variable speed drive acceleration and, on the contrary, be such that the steel strip requires greater heat immersion to render it metallurgically similar to the standard strip in transformer 37, the contactor 50 will move from contact 51 (thereby causing breaking of circuits controlled by said contact), and the operation of motor 32 will cease, causing the belt 28 to remain in set position. The contactor 50 will continue and engage contact 52, thereby causing energization of solenoid 78 to close the circuits at 79, 80 and 81 and at 79′, 88 and 89 to cause energization of solenoid 83 to close circuit at 83′, 84 and 85 to complete the circuit for solenoid 56 to cause closing of switch 54, whereupon motor 32 will operate in a reverse direction to that previously described to cause belt 28 to move in the decelerating direction. Thereupon speed of travel of strip A through the heating zone will be decreased with consequent increased time of immersion of the strip in the heating zone. The decelerating circuit contacts at 83′, 84, 85 will remain closed until broken either by the interrupter 75 operating the contactor 83′, or by change in the metallurgical characteristics of the strip passing through transformer 36 causing the contactor 50 either to move to neutral position or, should the characteristics of strip A then require less heat immersion, the contactor 50 would move to contact 51 to cause the speed of travel of the strip to increase. The operations of galvanometer contactor 50 either to or from the neutral position, or to or from contacts 51 and 52, are according to whether the characteristics in the portion of strip A passing through transformer 36 correspond to standard piece B or vary therefrom to require a variation of heat input to the strip for giving increased or decreased speed of travel to the strip momentarily or for any required period of time. The feature of the mechanical interrupter 75 is such as to assure stopping of motor 32 at the extreme of the accelerating or decelerating travel of the strip caused by the movement of the belt 28 of the variable transmission to avoid injury to the operating parts.

In the form shown in Fig. 4 I have illustrated modified means for controlling operation of the circuit that controls motor 32 for varying the speed of travel of strip A through the heating zone or furnace. The transformers 36 and 37 with their secondaries in a balanced circuit are shown as described with respect to Fig. 3, to respectively receive the traveling treated strip A and the standard piece B. In this form the conductors 41 and 42 of the circuit of the oppositely wound secondaries of the transformers are connected with the movable coil 90 of an alternating current galvanometer 91. The circuit through the coil 92 of the galvanometer field circuit is controlled by switch 93 connected with the A. C. supply line 94 to receive suitable electric current. A mirror or reflector 95 is connected with movable coil 90 so as to be rotated thereby. At 96 is a light source, such as an electric lamp, shown located within a casing 97, to cast a light beam on the mirror. The lamp 96 is shown enclosed within a shield 98, having an aperture 99 for the light beam (Fig. 5). Different angular positions of the mirror, on one side or the other from a predetermined position, such as in Fig. 7, are utilized to indicate and/or control the flow of current. The operation of motor 32, through circuits analagous to those described with respect to Fig. 3, will control the speed of travel of strip A through the heating zone or furnace, in accordance with the similarity or difference in characteristics between the standard piece B in transformer 37 and the portion of strip A passing through transformer 36. Devices for controlling the operations of said circuits by utilization of the light beam from mirror 95, in Fig. 4, are as follows: At 100 is a photo-electric cell which may be supported by frame 1 in position to receive the light beam reflected from the mirror. The circuit 101 of the photo-electric cell, through amplifying tube 102, is utilized for operating the circuits that control motor 32 by the operation of contactors 103 and 104. To obtain the desired power to operate the said contactors, I have illustrated a transformer whose secondary winding 106 is included in the circuit 105′ of the photo-electric cell, and whose primary winding 107 is supplied with suitable A. C. current through the switch controlled line 108. A grid-leak *g*, a fixed condenser *h* and a potentiometer *i* are shown for the photo-electric cell circuits. Alternatively, and in order that the light beam from mirror 95 will not affect the photo-electric cell 100 when the mirror is in certain positions but will affect the cell when the mirror is in other positions, I may provide the casing 97 with a front wall 97′ and with a front opening 97″, as indicated in Figs. 6, 7 and 8. When the mirror is in the position shown in Fig. 6 the light beams or rays from the mirror will be obstructed by wall 97′ so as not to affect the cell 100, and when the mirror has moved a suitable distance so as to be in position shown in Fig. 7 or 8, the light beam may be cast upon the cell

100 through the opening 97'' of the casing 97. To assure the concentration of the light beams or rays on the photo-electric cell in all appropriate positions of mirror 95 I interpose lenses *j* and *k* between the mirror and the cell to intercept the beams or light rays from the latter and direct them so that they will be directed upon the cell in different positions of the mirror from the position of the latter shown in Fig. 6 to its positions shown in Figs. 7 and 8. The lenses are shown connected together by an interposed tube *m* through which rays may pass from the mirror. The tube *m* may be supported by casing 97, as by post or wall at *n*.

In the circuit 105' is included a spring-actuated solenoid 109 for the contactors 103 and 104, the arrangement being such that when the light beam is off the photo-electric cell the solenoid 109 will be de-energized and the contactor 103 by spring action, will be off the contacts 110 and 111 of the line circuits L^1 and L^2 for the solenoid 56 that controls the switch 54 for motor 32, the contactor 83' then being off the contacts 84 and 85. At the same time the contactor 104 will close the circuit at contacts 112 and 113 of the primary 107 of the amplifier 105 through a spring-acting solenoid 114 in the circuit of said amplifier. At such time the contactor 115, by operation of solenoid 114, will close the circuit at 116, 117 of the supply line 108 for the spring-acting solenoid 64, through conductors 64' 64'', which will cause the contactor 66 to close the circuit at 67 and 68 for the circuit through the power lines L^1 and L^2 for the solenoid 55 through closing contactor 118, for the circuit at contacts 119 and 120. When solenoid 55 is energized it will cause operation of the switch 53 for closing the line circuit for motor 32 for operating the variable speed transmission governor or fork 29 in the accelerating direction, giving increased speed to the forward travel of strip A through the heating zone. If the operation of motor 32 is continued for a suitable number of rotations of shaft 31*a* the interrupter 75 will engage the contactor 66 to open circuit at 67, 68 for breaking the circuit of solenoid 55 for de-energizing the latter to break the motor circuit at switch 53, to cause motor 32 to cease operating. At such time the travel of strip A through the heating zone or furnace is at its maximum rate of speed and this condition will persist until altered by change in the metallurgical constitution of the portion of the strip passing through transformer 36. If it be required that the travel of strip A should be at a slower rate of speed, because of change in the composition of the steel strip A passing through transformer 36, slower speed of the travel of the strip is required and by reason of change in the circuit of the secondaries 38' and 39' the galvanometer coil 90 will operate to cause the mirror to turn from the position of Fig. 6, (with a light beam off the photo-electric cell), to cause the light beam to rest on said cell, (Fig. 7). Thereupon current is caused to flow through the secondary 106 and the solenoid 109 will operate contactor 103 for engagement with contacts 110 and 111 and to cause contactor 104 to break contact at 112 and 113. Solenoid 114 will be de-energized causing opening of circuits at 118, 119 and 120, and at 115, 116 and 117, by spring action of 115 and 118, whereupon the motor circuit through switch 53 will be broken. The operation of contactor 104 to break circuit at 112 and 113 will cause the circuit for solenoid 83 to be closed at contacts 121 and 122 to close circuit of solenoid 83 through conductors 123, 124 and 125 with the power line 108, contactor 83' will make contacts at 84 and 85 thus closing the line circuit through solenoid 56 to cause closing of the switch 54 to complete the power line for motor 32 to operate in a reverse direction, such as for decelerating the speed of travel of strip A by causing the variable speed motor governor or fork 29 to operate belt 28 in the decelerating direction, (toward the left in Fig. 4). Should the decelerating action continue until the interrupter 75 engages the contactor 83' the latter will be operated to break circuit at 84 and 85, and solenoid 56 will be de-energized to cause breaking of the circuit of motor 32 at switch 54, to cause stoppage of the motor. Such conditions will continue until reverse conditions are required by reason of the characteristics of the steel strip A passing through the transformer 36 and reverse connections will be automatically made when the light beam moves from the photo-electric cell, as in Fig. 6, as by reason of a faster speed being required to bring the strip A into balance with the standard piece B.

By the means described, whenever the properties or characteristics of the metal strip A undergoing thermo-treatment do not correspond with those of the standard piece B the strip is allowed greater or lesser heating when in the heating zone or furnace, by decreasing or increasing the speed of travel of said strip, the limiting of the maximum acceleration or deceleration of the forward travel of the strip being controlled by the operation of the interrupter 75 of the limit switch to operate the contactor 66 or the contactor 83' to break the corresponding circuit and stop operation of motor 32.

In the accompanying drawings the control transformer 36 is shown located in the direction of travel of strip A beyond the tempering furnace 13. This arrangement is effective if and when the hardening furnace is about six times the length of the tempering furnace, so that the increasing or decreasing increments of heat input, as obtained by the automatic speed variations of the strip previously described, cause metallurgical changes while the strip is in the longer furnace which so far overbalance the corresponding neutralized changes in the shorter tempering furnace as to make the last named effects negligible.

In the event that a hardening and tempering installation is equipped with two furnaces more nearly equal in length a desired location for the transformer 36 would be immediately after the water quenching tank 12.

I have described my improvements as adapted for hardening and tempering a continuous strip of magnetizable steel as it travels, but it will be understood that my invention is adapted also to any appropriate means for heating a strip either for hardening or for tempering it, or for hardening and tempering it, as it travels, or for annealing ferrous-metal strip, or for controlling the quenching rates of hardened steel. The hardening and/or tempering, and quenching, of a ferrous-metal strip may be carried on in a continuous manner, expeditiously and economically to the end that the hardening and/or tempering or annealing of the strip throughout its length will be in accordance with the standards desired to correspond substantially to those of the standard piece selected.

Having now described my invention, what I claim is:—

1. The method of heat-treating a ferrous-metal strip consisting in causing the strip to travel through a heated zone at a temperature above the decalescent point of the metal, and causing speed of travel of the strip through said zone to vary in accordance with variations in the electrical permeability of the strip as compared to the permeability of a selected standard strip.

2. The method of heat-treating a ferrous-metal strip consisting in causing the strip to travel through a heated zone at a temperature above the decalescent point of the metal and causing the electrical permeability of said strip after being heated and as compared to the permeability of a selected standard piece to control the speed of travel of said strip through said zone.

3. The method of heat-treating a ferrous-metal strip consisting in maintaining a heated zone at a substantially predetermined temperature above the decalescent point of the metal, causing the strip to travel through said zone, and varying the time of immersion of said strip in said zone in accordance with variations in the electrical permeability of the strip after being heated and as compared to the permeability of a selected standard strip.

4. The method of heat-treating a ferrous-metal strip consisting in maintaining a heated zone at a substantially predetermined temperature above the decalescent point of the metal, causing the strip to travel through said zone, and varying the time of immersion of said strip in said zone by varying the speed of travel of the strip through said zone in accordance with variations in the electrical permeability of the strip and as compared to the permeability of a selected standard strip.

5. The method of heat-treating a ferrous-metal strip consisting in continuously causing the strip to travel through a heated zone to heat the strip to a temperature above the decalescent point of the metal, passing the heated portion of the strip through a balanced electrical field and causing the electrical permeability of said strip in said field and as compared to the permeability of a selected standard to vary the time of immersion of strip in said zone.

6. The method of heat-treating a ferrous-metal strip consisting in continuously causing the strip to travel through a heated zone to heat the strip to a temperature above the decalescent point of the metal, cooling the strip and then passing the heat-treated portion of the strip through a balanced electrical field and causing the electrical permeability of said heat-treated strip in said field and as compared to the permeability of a selected standard to vary the speed of travel of the strip through said heated zone.

7. The method of heat-treating a ferrous-metal strip consisting in causing the strip to travel through a heated zone to heat the strip to a temperature above the decalescent point of the metal, passing the heat-treated portion of the strip through an electrical field, maintaining a standard metal piece in an electrical field, and causing variations of electrical permeability in the strip after being heat-treated and while passing through said first-mentioned field and as compared to the permeability of the standard piece, to control the time of immersion of the strip in said heated zone.

8. The method of heat-treating a ferrous-metal strip consisting in causing the strip to travel through a heated zone to heat the strip to a temperature above the decalescent point of the metal, passing the heat-treated portion of the strip through an electrical field, maintaining a standard metal piece in an electrical field, and causing variations of electrical permeability in the strip, after being heat-treated and as compared to the permeability of the standard piece to vary the speed of travel through the heated zone.

9. The method of heat-treating a ferrous-metal strip consisting in causing the strip to travel through a heated zone, maintaining a substantially constant temperature above the decalescent point of metal, passing the strip after heating it through electrically operative devices and causing operation of said devices to vary the speed of the strip through the zone according to variations in the electrical permeability of the strip as compared to the permeability of a standard strip.

10. The method of heating and quenching a ferrous-metal strip consisting in causing the strip to travel through a heating zone at a temperature above the decalescent point of the metal and through a quenching zone and varying the speed of travel of the strip through the heating zone in accordance with variations in the electrical permeability of the quenched strip as compared to the permeability of a standard strip.

11. The method of hardening and tempering a ferrous-metal strip consisting in causing the strip to pass successively through a heating zone at a temperature above the decalescent point of the metal, a quenching zone and another heating zone, and varying the time of immersion of the strip in the said zones in accordance with variations in the electrical permeability of the strip as it emerges from said second heating zone as compared to the permeability of a standard strip.

12. The method of hardening and tempering a ferrous-metal strip consisting in causing the strip to pass successively through a heating zone at a temperature above the decalescent point of the metal, a quenching zone and another heating zone, and causing the electrical permeability of said strip after being tempered and as compared to the permeability of a selected standard strip to vary the speed of travel of the strip through the heating and quenching zones.

13. An apparatus for heat-treating a ferrous-metal strip comprising a furnace, means to propel the strip through the furnace at different speeds of travel, and means to vary the time of immersion of the strip in the furnace in accordance with variations in the electrical permeability of portions of the strip after being heated in the furnace and as compared to the permeability of a selected standard piece.

14. An apparatus for heat-treating a ferrous-metal strip comprising a furnace, means to propel the strip through the furnace, and means to cause variation of speed of travel of the strip through the furnace in accordance with variations in the electrical permeability of portions of the strip heated in the furnace and as compared to the permeability of a stationary standard piece of the same metal.

15. An apparatus for heat-treating a ferrous-

metal strip comprising a furnace, means to propel the strip through the furnace including a variable speed transmission, and devices to control the operation of said transmission, said devices including means through which the heated strip passes to cause the transmission to vary the speed of travel of the strip through the furnace in accordance with variations in the electrical permeability of the heat-treated portion of the strip.

16. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip through the furnace including a variable speed transmission having a governor to control the speed of the propelling means, means to operate the transmission continuously, and devices to control the operation of the governor including means through which the heated strip passes to control the operation of said devices for varying the speed of travel of the strip through the furnace.

17. An apparatus, as set forth in claim 16, provided with means to limit the acceleration or deceleration of speed of travel of the strip by the transmission.

18. An apparatus for heat-treating a ferrous-metal strip comprising a furnace, means to propel the strip through the furnace including a variable speed transmission having a governor to control the speed of the propelling means, means to operate the transmission continuously, a motor, means to cause operation of the transmission governor by the motor, and devices to control the flow of current through the motor, said devices including means through which the heated strip passes for causing operation of the motor in one or another direction according to variations in the electrical permeability of the portion of the strip in said devices to vary the speed of travel of the strip through the furnace.

19. An apparatus for heat-treating a ferrous-metal strip comprising a furnace, means to propel the strip through the furnace including a variable speed transmission having a governor to control the speed of the propelling means, means to operate the transmission continuously, a motor, means to cause operation of the transmission governor by the motor, and devices to control the flow of current through the motor, said devices including means through which the heated strip passes, and means to retain a standard piece in said devices, whereby variations in the electrical permeability between the portion of the strip passing through said devices and the standard piece will cause operation of the motor in one direction or another for varying the speed of travel of the strip through the furnace.

20. An apparatus for heat-treating a ferrous-metal strip comprising a furnace, means to propel the strip through the furnace including a variable speed transmission having a governor to control the speed of the propelling means, means to operate the transmission continuously, devices to control the operation of the governor including transformers having their primary windings in series and their secondaries in normally opposed relation in a circuit, one of said transformers having means to permit the passing of the strip, the other transformer having means to receive a standard metal piece, and devices controlled by the circuit of said secondaries for causing operation of said motor in one direction or another through variations in the electrical permeability between the portion of the strip in the corresponding transformer and standard piece for unbalancing the circuit of the secondaries.

21. An aparatus for heat-treating a ferrous-metal strip comprising a furnace, means to propel the strip through the furnace including a variable speed transmission having a governor to control the speed of the propelling means, means to operate the transmission continuously, devices to control the operation of the governor including transformers having their primary windings in series and their secondaries in normally opposed relation in a circuit, one of said transformers having means to permit passing of the strip, the other transformer having means to receive a standard metal piece, and devices controlled by the circuit of said secondaries for stopping operation of the motor when the circuit of the secondaries is balanced, and for causing operating of said motor in one direction or another through variations in the electrical permeability between the portion of the strip in the corresponding transformer and the standard piece for unbalancing the circuit of the secondaries.

22. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip through the furnace at variable speeds of travel including means to cause acceleration and deceleration of speed of travel of the strip, means for maintaining a standard strip adjacent to the exit end of the furnace, and means to control the propelling means in accordance with variations in the electrical permeability in portions of the strip heated in the furnace as compared to the unvarying permeability of the standard strip.

23. An apparatus as set forth in claim 22 including means to limit the acceleration and deceleration of speed of travel of the strip.

24. An apparatus for heat-treating a metal strip comprising a furnace, means for supporting a selected standard strip in a magnetic field located adjacent to the exit end of the furnace, means to propel the strip through the furnace continuously including means to cause the strip to travel at a definite speed and to accelerate and decelerate the speed of travel of the strip in accordance with variations in the electrical permeability in heated portions of the strip and as compared to the unvarying permeability of the standard strip.

25. An apparatus as set forth in claim 24 including means to limit the acceleration and deceleration of travel of the strip through the furnace.

26. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including means to control the speed of travel of the strip, an electro-magnetic holder for a selected standard strip, and means to operate said control means including means operative by variations in the electrical permeability in the heat-treated portion of the strip as compared to the unvarying permeability of the standard strip to regulate the operation of the control means for varying the speed of travel of the strip.

27. An apparatus as set forth in claim 26 including means to limit the operation of said control means to stop acceleration or deceleration of the speed of travel of the strip.

28. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace, means to control the speed of travel of the strip,

and electrically operative devices to actuate said control, including a pair of transformers respectively having means to receive said strip and a standard piece of metal and having their secondaries in opposed relation in a circuit, and means operative through a balanced and an unbalanced condition in said circuit for causing operation of the control means to regulate the speed of travel of the strip through the furnace in accordance with variations in the electrical permeability between the portion of the strip in its associate transformer and said standard piece.

29. An apparatus as set forth in claim 28 including means to limit operation of the control means to stop acceleration and deceleration of the travel of the strip.

30. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace, a motor, means operative by the motor to control the speed of travel of the strip, and electrically operative devices for controlling the motor including a pair of transformers respectively having means to receive said strip and a standard piece of metal, said transformers having their primaries in series, the secondaries of the transformers being connected in opposed relation in a circuit, and an electrical instrument operative by an unbalanced condition in said circuit to control said electrical devices for varying the operations of the motor.

31. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace, a motor, means operative by the motor to control the speed of travel of the strip, and electrically operative devices for controlling the motor including an electrical instrument provided with a movable contactor and contacts to be engaged thereby, reversing switches for the circuits of the motor, coils for operating said switches, circuits for the coils having contacts to control the circuits, coils to control said contacts and connected with the first named contacts, and means to control said electrical instrument operative by variations in the electrical permeability in portions of the strip heated in the furnace.

32. An apparatus as set forth in claim 31 including means operative by said motor to break the circuits of the first named coils to stop the motor to limit acceleration and deceleration of the strip.

33. An apparatus as set forth in claim 31 in which the circuits for the first named coils include interrupter contacts, means operative by the motor to cause breaking of said circuits at said interrupter contacts to cause stoppage of the motor to limit acceleration and deceleration of travel of the strip, and coils, circuits and contacts controlled by the second named coils for operating the interrupter contacts.

34. An apparatus as set forth in claim 31 in which the means to control the electrical instrument includes a pair of transformers respectively having means to receive said strip and a standard piece of metal, said transformers having their primaries in series, the secondaries of the transformers being connected in opposed relation in a circuit, whereby to cause operation of said electrical instrument in accordance with variations in the electrical permeability between the portion of the strip in its associate transformer and said standard piece.

35. An apparatus as set forth in claim 31 in which the means to control the electrical instrument includes a pair of transformers respectively having means to receive said strip and a standard piece of metal, said transformers having their primaries in series, the secondaries of the transformers being connected in opposed relation in a circuit, an amplifier connected with said circuit, a rectifier connected with the amplifier, and means connecting the rectifier with said electrical instrument for causing operation of the contactor thereof in accordance with variations in the electrical permeability between the portion of the strip in its associate transformer and said standard piece.

36. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuits of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, electrically operative devices to control said switches, and means to control said electrical devices by variations in the electrical permeability in heat-treated portions of the strip.

37. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuits of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, electrically operative devices to control said switches, a pair of transformers respectively having means to receive said strip and a standard piece of metal and having their secondaries in opposed relation in a circuit, and means operative through a balanced and an unbalanced condition in said circuit to cause operation of the electrical devices to control said magnetic switches for causing reverse operation of the motor in accordance with variations in the electrical permeability between the portion of the strip in its associate transformer and said standard piece.

38. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace, a motor, means operative by the motor to control the speed of travel of the strip, electrically operative devices for controlling the motor, a photo-electric cell having a circuit to control said devices, and means controlled by variations of electrical permeability in the heated strip to cause a light beam to fall on and be removed from the photo-electric cell for energizing and deenergizing its circuit.

39. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace, a motor, means operative by the motor to control the speed of travel of the strip, electrically operative devices for controlling the motor, a photo-electric cell having a circuit to control said devices, a pair of transformers respectively having means to receive said strip and a standard piece of metal, and transformers having their second-

aries in opposed relation in a circuit, an electrical instrument having a movable coil in said circuit, a photo-electric cell, and means operative by said coil to cast a light beam on and remove it from said cell, said photo-electric cell having a circuit to control said electrically operative devices.

40. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace, a motor, means operative by the motor to control the speed of travel of the strip, electrically operative devices for controlling the motor, a photo-electric cell having a circuit to control said devices, a pair of transformers respectively having means to receive said strip and a standard piece of metal and having their secondaries in opposed relation in a circuit, an electrical instrument having a movable coil in said circuit, a mirror operative by said coil, a light source for the mirror, and a photo-electric cell to receive a light beam from said mirror, said photo-electric cell having a circuit to control said electrically operative devices.

41. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuit of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, electrically operative devices to control said switches, a photo-electric cell having a circuit to control said electrically operative devices, and means operative by variations in the electrical permeability in heated portion of the strip to cast the light beam on and remove it from said photo-electric cell to energize and de-energize its circuit.

42. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuits of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, electrically operative devices to control said switches, a photo-electric cell having a circuit to control said electrically operative devices, means to cast a light beam on and remove it from said photo-electric cell to energize and de-energize its circuit, and a pair of transformers respectively having means to receive said strip and a standard piece of metal, said transformers having their primaries in series, the secondaries of the transformers being connected in opposed relation in a circuit, said circuit including means to cause said light beam to be cast upon and removed from the photo-electric cell.

43. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuits of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, electrically operative devices to control said switches, a photo-electric cell having a circuit to control said electrically operative devices, a mirror to cast a light beam on and remove it from said cell, a light source for the mirror, an electrical instrument for operating said mirror, and a pair of transformers respectively having means to receive said strip and a standard piece of metal, said transformers having their primaries in series, the secondaries of the transformers being connected in opposed relation in a circuit, said electrical instrument having a coil included in said circuit for operating the mirror according to variations in the electrical permeability of heated portions of the strip in its transformer and the standard piece.

44. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuits of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, coils to control said contacts, circuits for said coils including contacts, an amplifier having a coil to control said contacts, other contacts for the circuits of the magnetic switches, said amplifier having a coil to control the last named contacts, a photo-electric cell having a circuit to control said amplifier, means to cast a light beam on and remove it from said cell, and means controlled by variations in the electrical permeability in the heat-treated strip to operate the light beam.

45. An apparatus for heat-treating a metal strip comprising a furnace, means to propel the strip at variable speeds through the furnace including a speed governor, a reversing motor, means operative by the motor to control the governor, magnetically operative reversing switches for the circuits of the motor, contacts in the circuits of the magnetic switches, an interrupter operative with the governor to control said contacts to limit acceleration and deceleration of speed of travel of the strip, coils to control said contacts, circuits for said coils including contacts, an amplifier having a coil to control said contacts, other contacts for the circuits of the magnetic switches, said amplifier having a coil to control last named contacts, a photo-electric cell having a circuit to control said amplifier, means to cast a light beam on and remove it from said cell, and a pair of transformers respectively having means to receive said strip and a standard piece of metal and having their secondaries in opposed relation in a circuit, said circuit including means to control the light beam in accordance with variations in the electrical permeability between the heated portion of the strip in its transformer and said standard piece.

46. Apparatus for heat treating a steel object to produce a predetermined value of a selected magnetization affecting property therein comprising a heating device, an induction device having a primary and a secondary winding, means for advancing successively occurring portions of an object in heat exchanging relation to

the heating device and then through the field of said primary, means for regulating the effective speed of the advancing means, and means operatively connected to said secondary and to said speed regulating means to vary the heat exchange relation between the heating device and portions of the object being heated in response to variations in a function of said selected property occurring in said secondary in respect to portions of the object in the field of said primary.

ALBERT R. STARGARDTER.