

July 31, 1934.

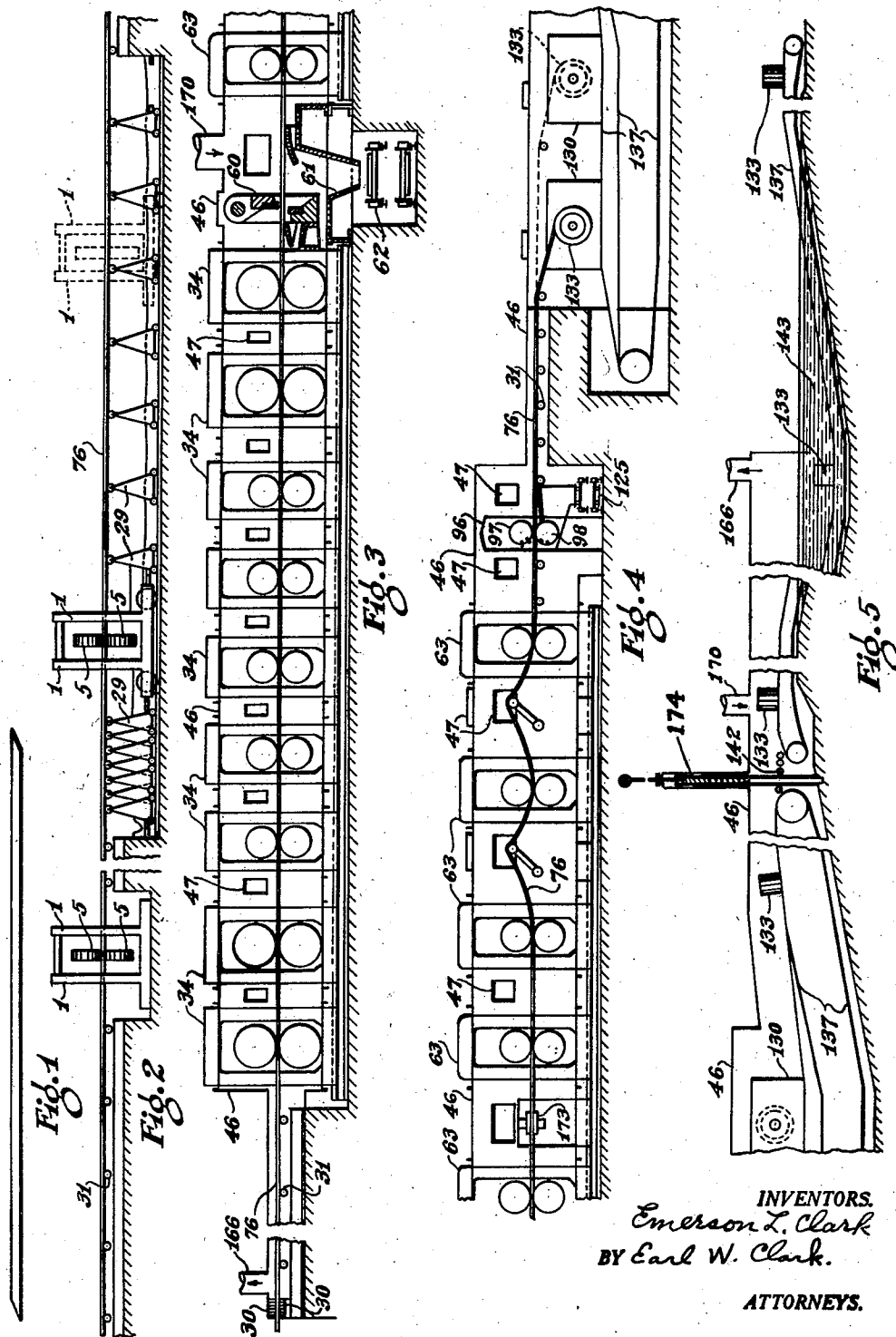
E. L. CLARK ET AL

1,968,442

PROCESS OF HEATING AND ROLLING STEEL IN AN INERT GAS INCLOSURE

Filed Sept. 5, 1931

11 Sheets-Sheet 1



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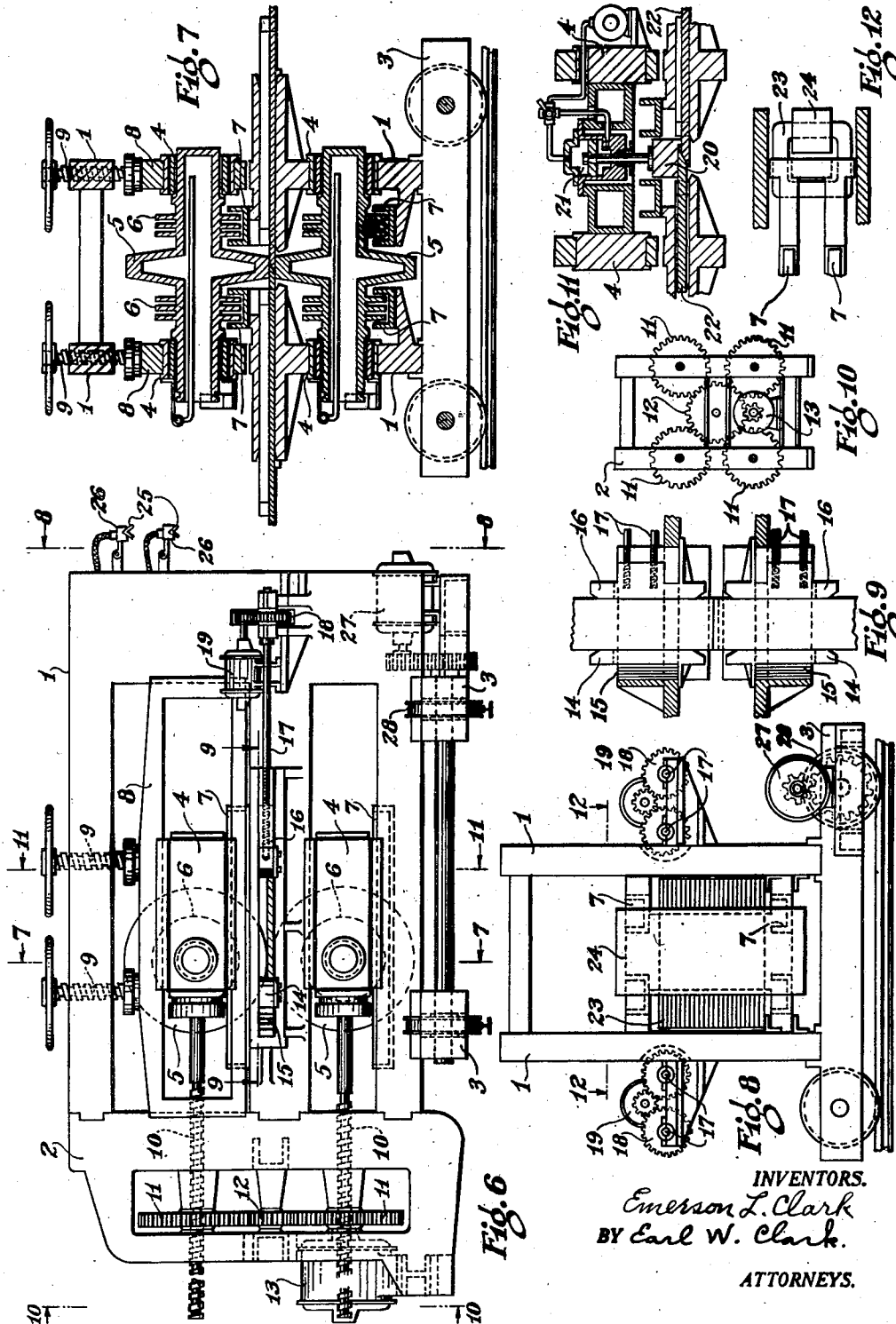
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11 Sheets-Sheet 3

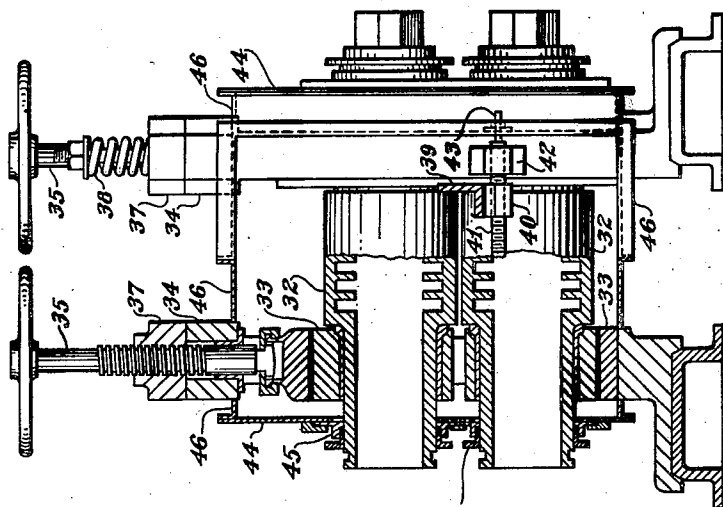
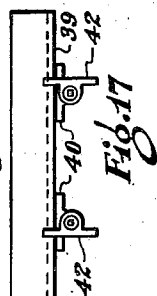
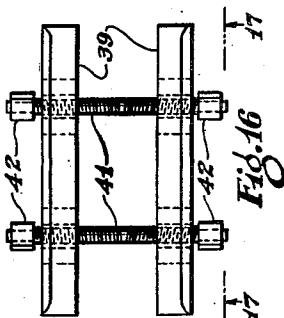
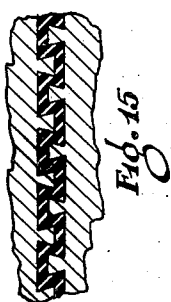


Fig. 14

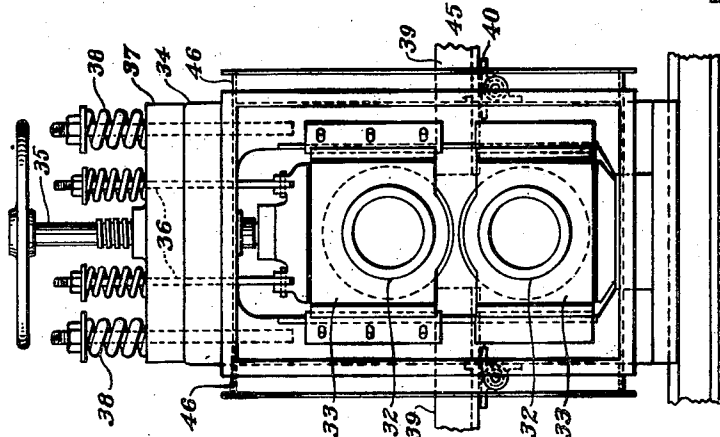


Fig. 13

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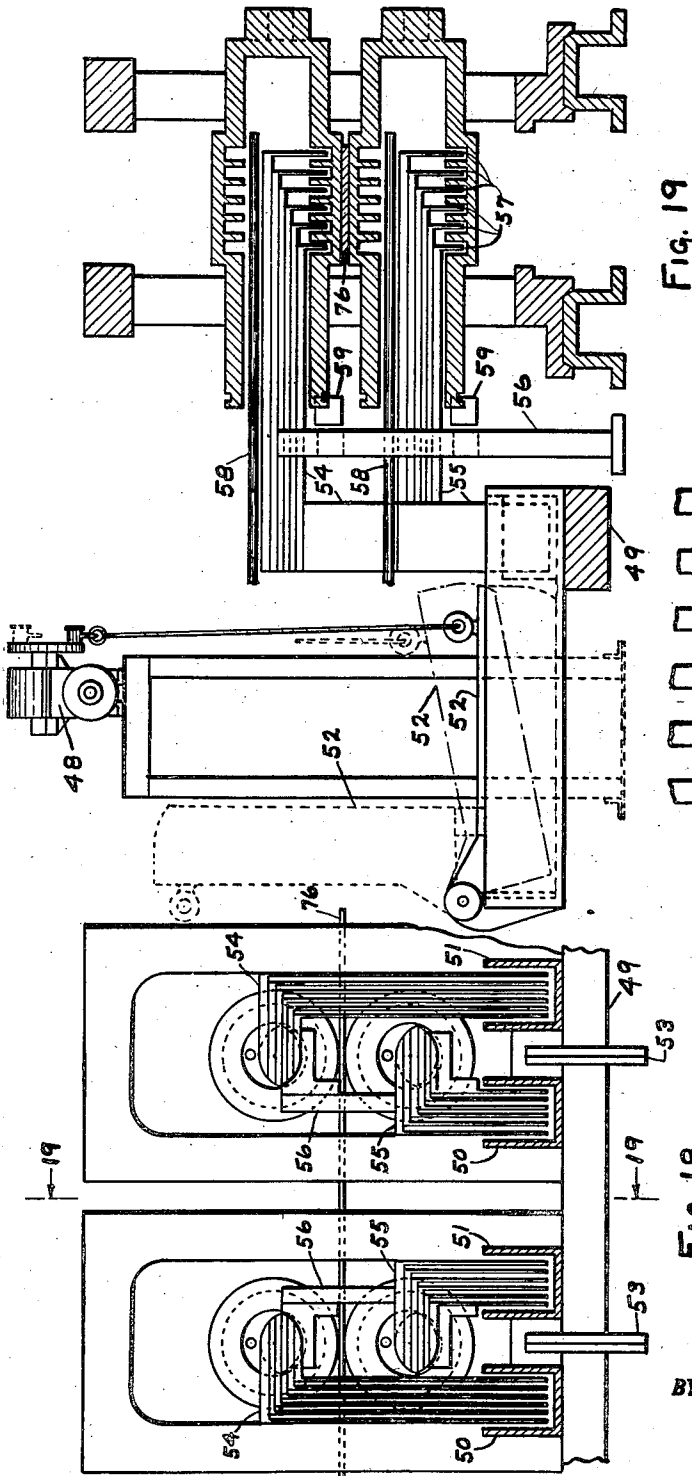


Fig. 19

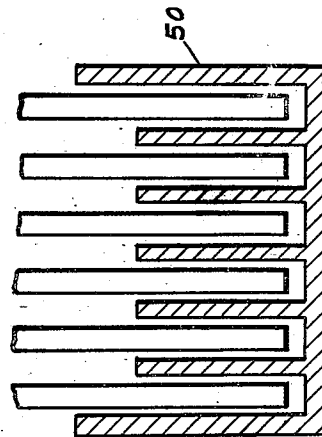


Fig. 20

Fig. 18

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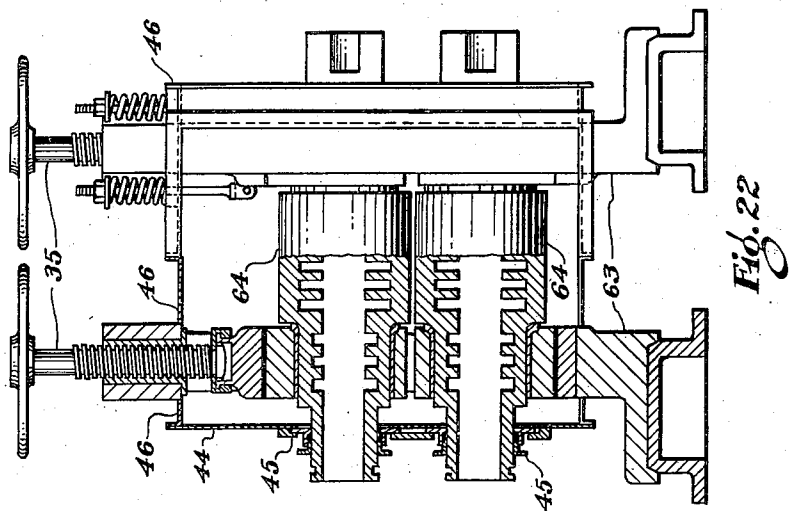


Fig. 22

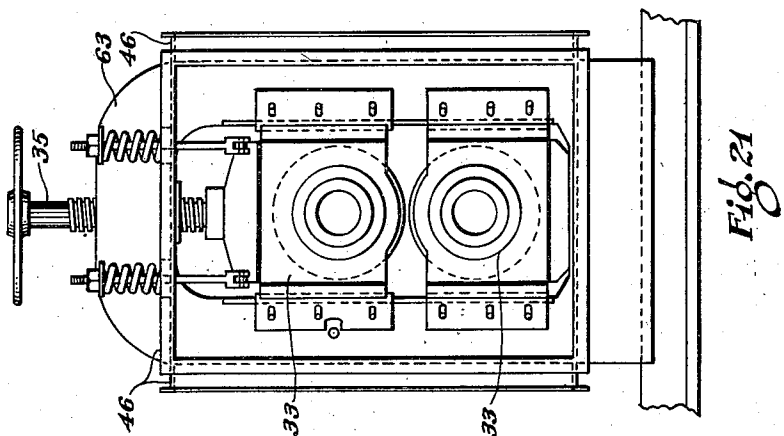


Fig. 21

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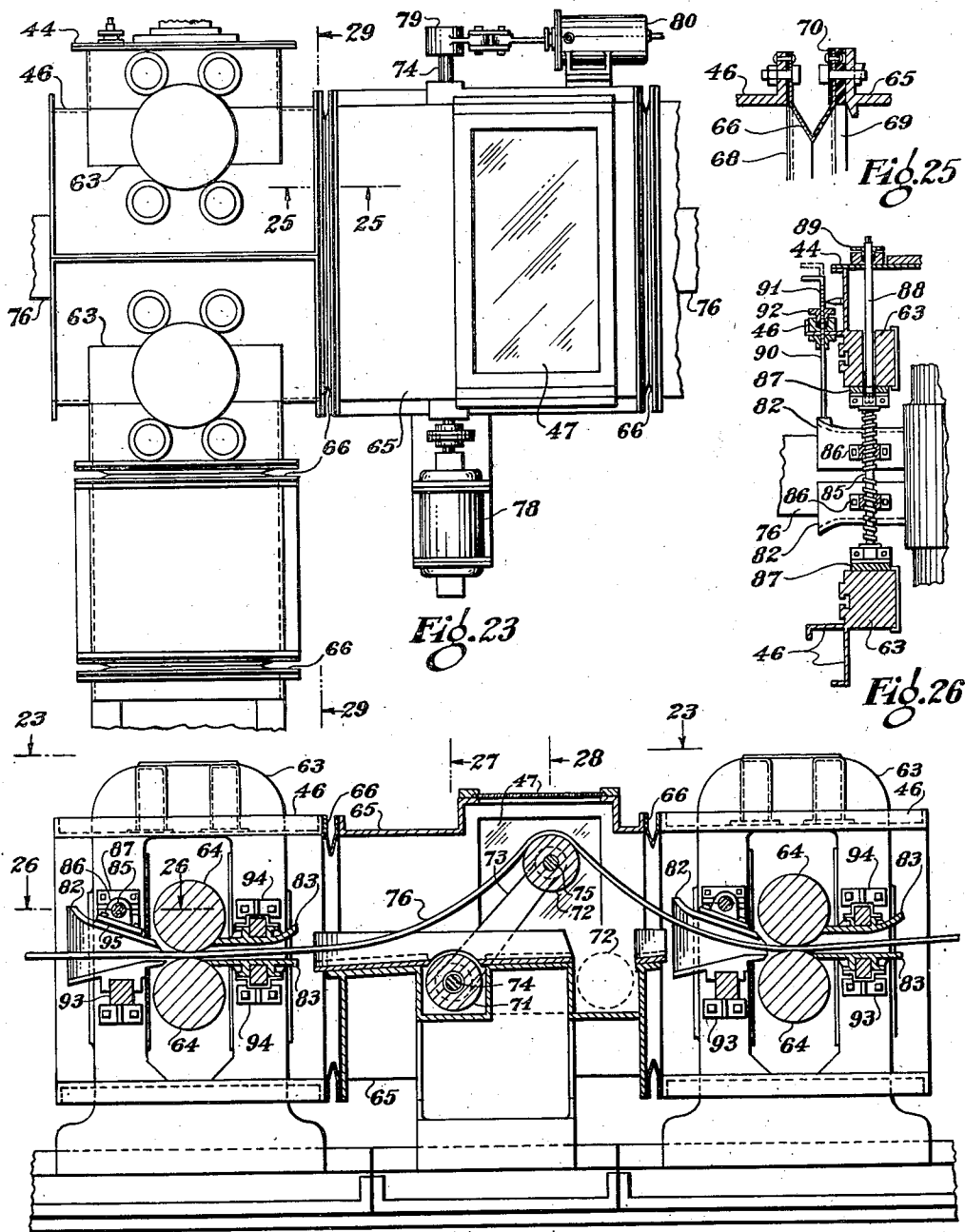


Fig. 24

27 28

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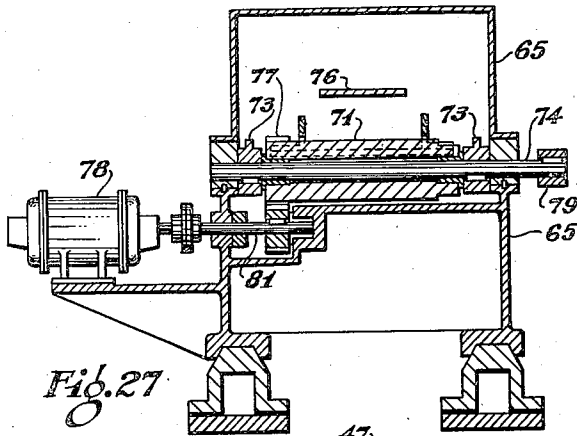


Fig. 27

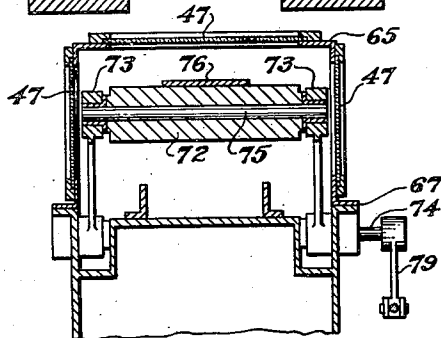


Fig. 28

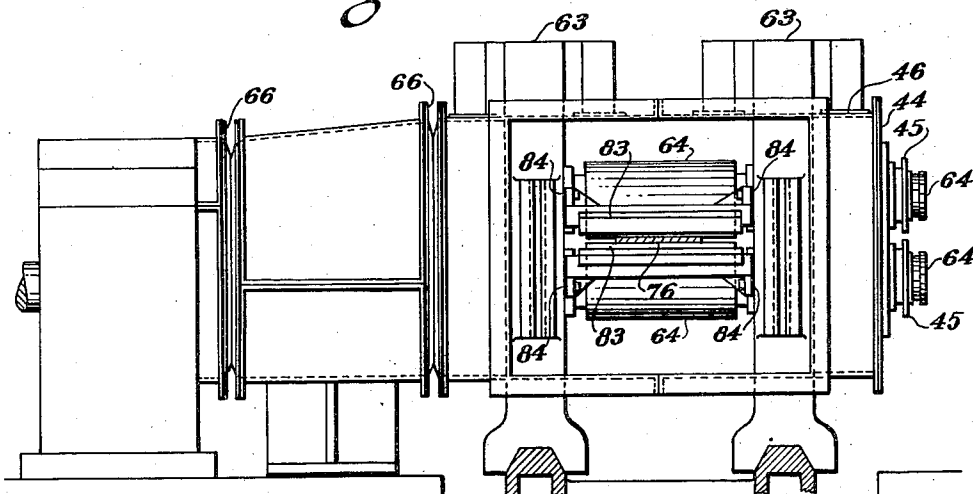


Fig. 29

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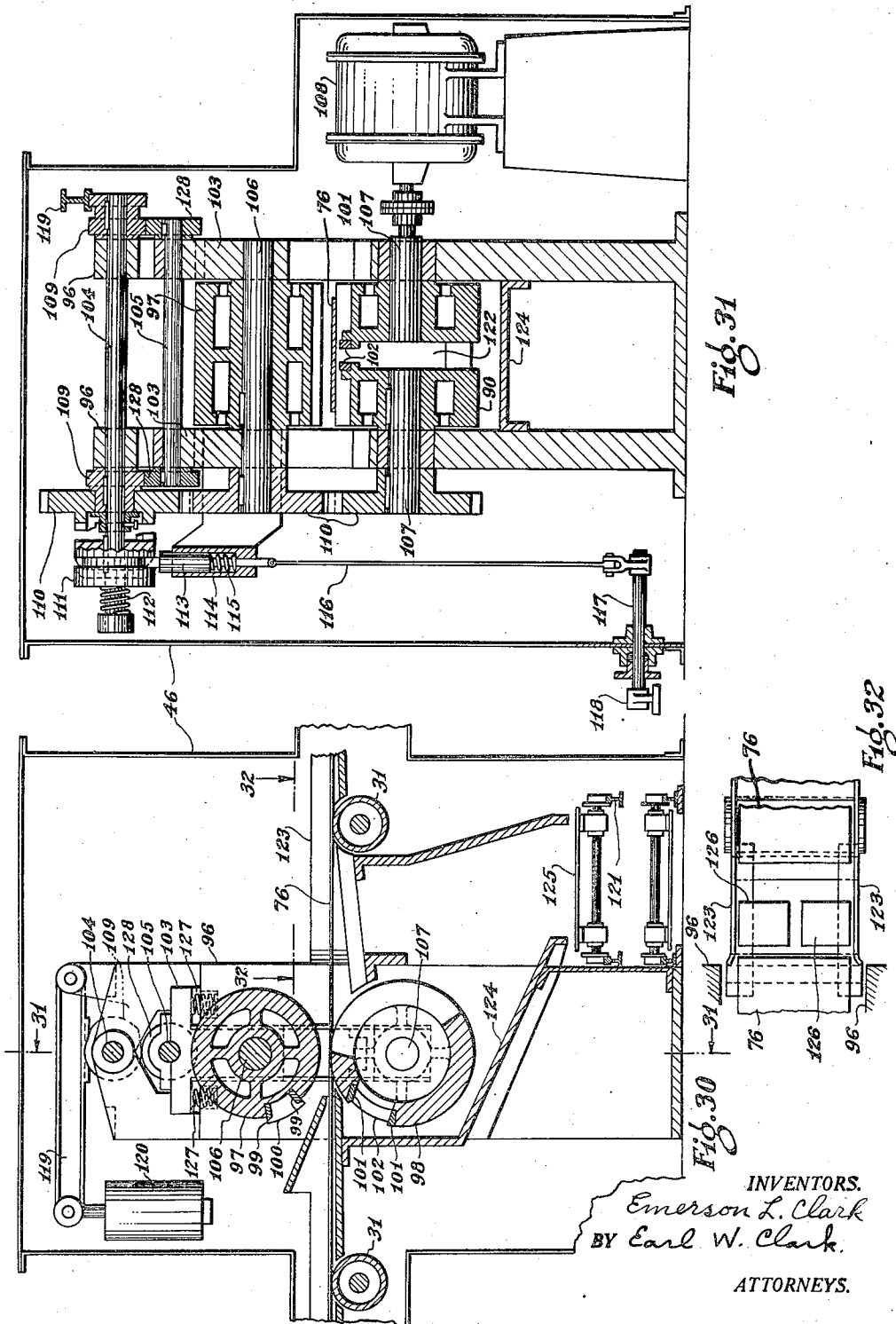
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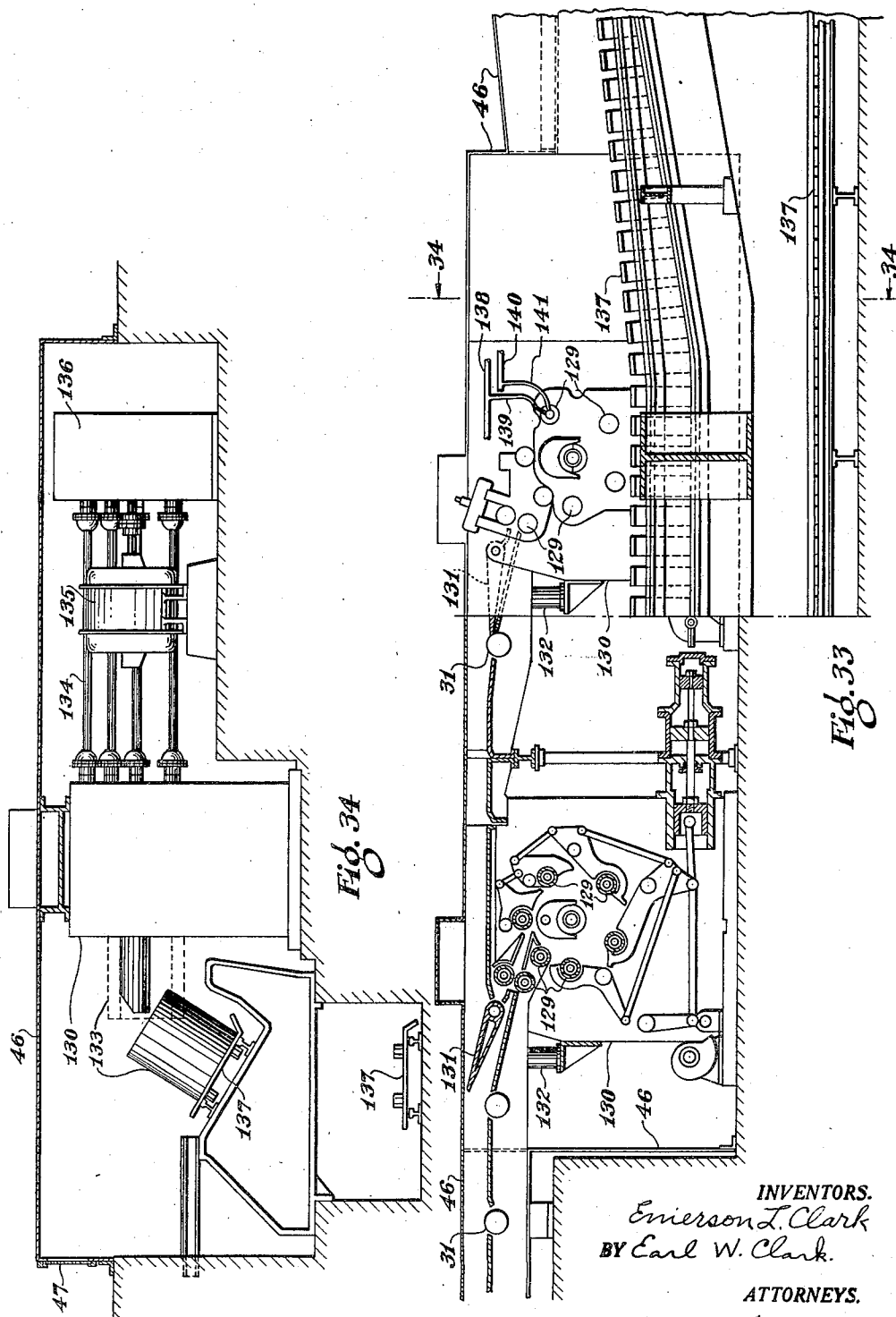
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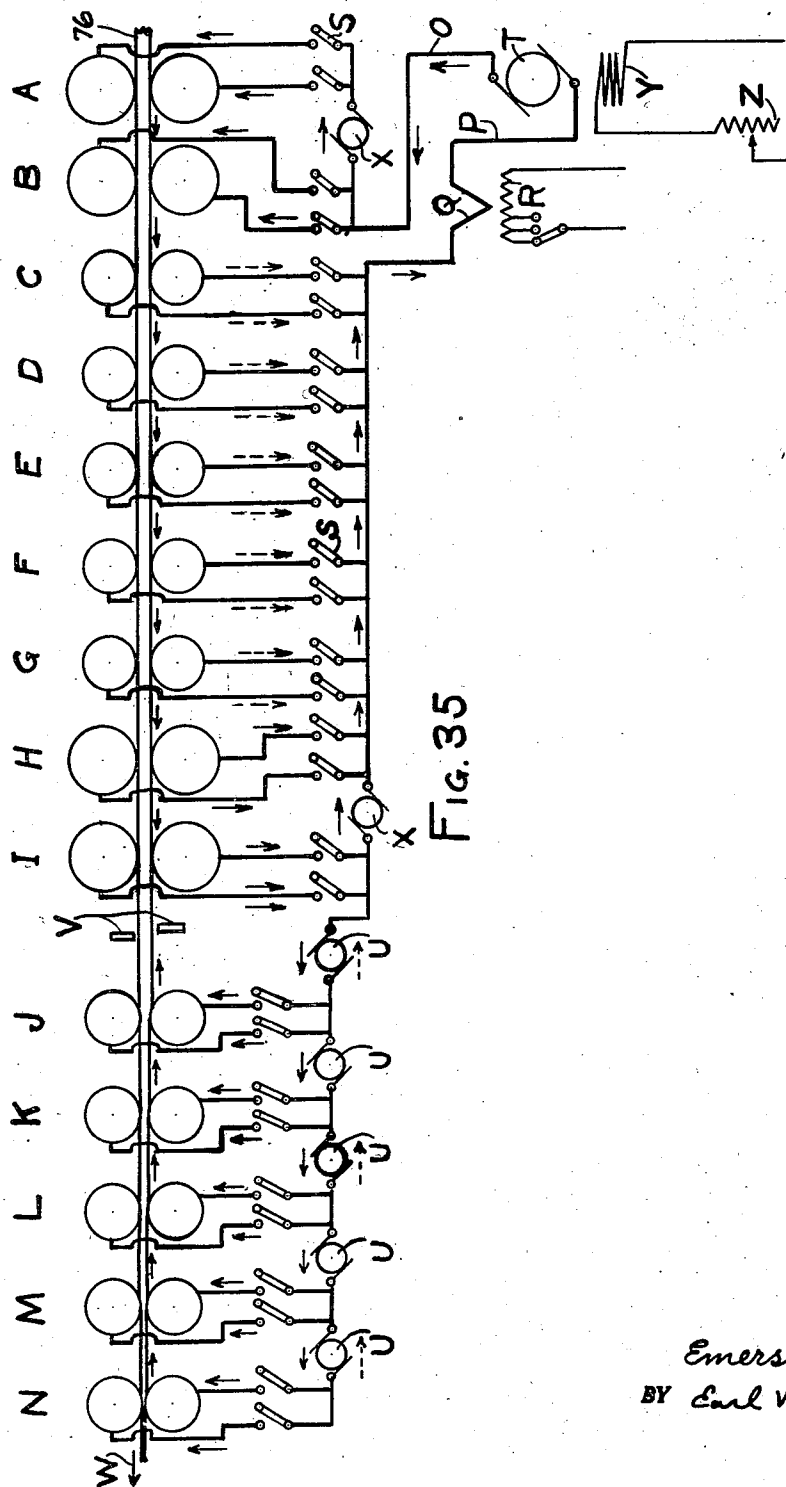


Fig. 35

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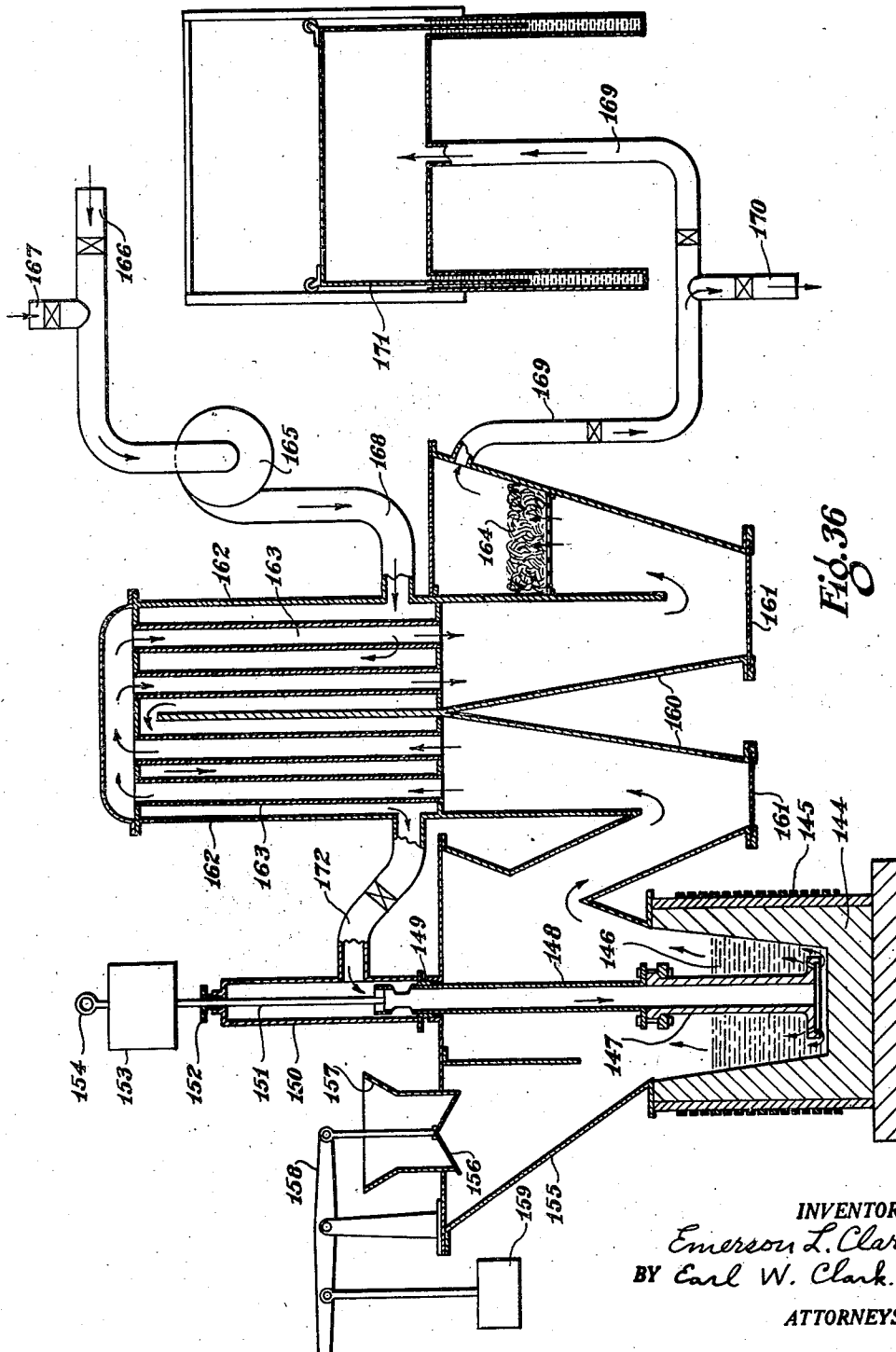
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UNITED STATES PATENT OFFICE

1,968,442

PROCESS OF HEATING AND ROLLING STEEL
IN AN INERT GAS INCLOSUREEmerson L. Clark and Earl W. Clark, Hartford,
Ohio

Application September 5, 1931, Serial No. 561,366

5 Claims. (Cl. 80—60)

Our invention embodies a product and means and method of operation for producing same. The product is steel or other metal heated and hot rolled in an inert atmosphere so that no scale is formed on the surface of the metal during the process. Scale, which always forms on the surface of hot steel in contact with the air, is a most disturbing factor in all present day commercial rolling mill operations on hot steel. Its influence begins at the heating furnace, where it limits the temperature to which the crude slabs to be rolled may be heated, because, when a certain temperature is exceeded, the scale fuses and alloys with the surface of the steel and resists all efforts to dislodge same during the rolling process. This action of the scale on the slabs is known as "rashing". When present, it produces a serious defect in the surface of the finished product. The large amount of scale formed in present practice becomes distributed over the mill and causes rapid wear of the rolls and all other wearing parts of the mill with which it comes in contact. Further, the thin film of scale, which always forms on hot steel in contact with the air, results in rapid die wear, when the metal is worked in presses and interferes with tinning and galvanizing. Much of the metal produced by hot rolling must be pickled to remove this scale when a clean, bright surface is desired. This pickling is an expensive, troublesome, and disagreeable process. Our mill is designed not only to heat and work the metal in an inert atmosphere, but is also designed to produce very large coils of the finished product, which are cooled in an inert atmosphere. The large size of the coils effects a substantial annealing of the finished product, due to the slow cooling.

Aside from the inert gas inclosure, our mill and process have many advantages over that now in use.

The product of our mill embraces all widths and thicknesses of metal rolled on present strip mills, starting with the blooms and slabs produced in present blooming and slabbing mills. Much of the equipment shown can be readily adapted to produce other shapes. Our mill is continuous in a much broader sense than the so-called continuous mills of present practice in that it is designed to operate for long periods of time continuously, upon an uninterrupted slab of metal which is built up as rapidly as the demands of the mill require. The slab is heated electrically to rolling temperature before it enters the mill, and its temperature is maintained elec-

trically as it progresses through the working stands of the mill. The broad idea of direct electric heating of the material to be rolled is old in the patent art and is the subject of a number of expired patents. All of these patents, however, have possessed serious defects and have left so many important problems unsolved that they have never been put to practical use. Electrical engineering shows no precedent for the control and distribution of the enormous electric currents required for this work in the exact manner which the peculiarities of this problem demand. We show in detail a novel construction suitable for this purpose. We greatly reduce the density of heating current required by operating on much longer pieces of metal than are now employed in present day mills of similar size of output. This enables us to include a much longer length of slab in the heating zone, thus increasing the length of time which any given section is acted upon by the heating current at any given speed of operation. This procedure not only reduces the amount of current carried by the contact rollers, but also promotes uniformity of heating of the slab.

A novel means of introducing the current to the interior of the roll is used, which permits control of the current distribution across the roll, and also, eliminates brushes and their associated troubles. A series of intermediate current stands spaced between the group of current introducing rolls nearest the first working roll stand and the group of current introducing rolls, located at the entering end of the heating zone, are provided for the purpose of producing a tapered or graduated heat at the forward end of the continuous slab when the metal is first started through the mill. The temperature distribution in the slab throughout the heating zone is thus substantially the same at the beginning of the rolling operation as is developed subsequently under continued operation. This result is necessary to avoid troublesome hot and cold spots at the start of the rolling operation, which are present in all arrangements which have hitherto been proposed. The action of this portion of our mill is discussed more in detail later in this specification.

Our mill starts with long slabs about two inches thick and of any width desired to suit the product being rolled. These slabs are first pickled to remove all scale, and chipped to remove surface defects. The ends are then scarfed in a milling machine of standard construction to adapt them for welding into a continuous slab on the welding machines described in detail in this speci-

fication. We further show means for producing at low cost the inert gas required by our mill.

Our mill comprises all of the necessary means to weld the individual slabs into one continuous slab, heating and maintaining same at rolling temperature, rolling same to the desired finished product, removing the finished product from the mill, to sample, gauge, test, and inspect the product being rolled as often as desired to check the setting of the mill and the product, without interrupting the continuous operation.

With the foregoing and other objects in view, which will appear in the following description, our invention resides in the novel combination and arrangement of parts and in the details of construction and methods of operation herein-after described and claimed.

In the drawings:

Fig. 1 is an edge view of an individual slab showing the ends scarfed, preparatory to welding into a continuous slab.

Fig. 2 is a diagrammatic sectional elevation of the front end of the complete mill arrangement, showing the position of the welders and the necessary conveying tables used in preparing the continuous slab from the individual units.

Fig. 3, which is a continuation of Fig. 2, represents the heating zone with its inclosure, current introducing rolls, and cropping shear and first working roll stand.

Fig. 4, which is a continuation of Fig. 3, represents the working roll stands, cut off and sampling shear, and the coilers for coiling the finished product.

Fig. 5, which is a continuation of Fig. 4, represents the cooling chamber and conveyor and means for removing the cooled coils through an oil seal.

Fig. 6 is a side elevation of the welder taken in a plane perpendicular to the length of the slab being welded.

Fig. 7 is a sectional elevation taken through the axes of the welding rolls on line 7—7 of Fig. 6, and shows the position of the slab with respect to the welding rolls during the welding operation.

Fig. 8 is an end elevation of the welder on line 8—8 of Fig. 6.

Fig. 9 is a partial sectional plan taken on line 9—9 of Fig. 6, showing the slab edge clamps.

Fig. 10 is a partial end elevation taken on line 10—10 of Fig. 6, showing the motor and gears which operate the screws, which move the welding rolls across the slab.

Fig. 11 is a partial sectional elevation taken on line 11—11 of Fig. 6, which shows the stop which regulates the lapping of the scarfed ends of the slabs preparatory to welding.

Fig. 12 is a partial sectional plan taken on line 12—12 of Fig. 8, showing the transformer and current leads to the mercury troughs.

Fig. 13 is a side elevation of the current introducing roll stand used to heat the slab preparatory to rolling.

Fig. 14 is an end elevation of the current introducing roll stand in half section, the section being taken through the axes of the rolls.

Fig. 15 is a section showing the moulded insulation used in insulating the bearing chocks from the housing.

Fig. 16 is a detached plan view of the slab guides which span the gap between the current introducing roll stands.

Fig. 17 is a side elevation of same taken on line 17—17 of Fig. 16.

Fig. 18 is a sectional side elevation showing the

circuit breaker and electrical leads for feeding the heavy heating current to the current introducing rolls.

Fig. 19 is a mixed section taken on line 19—19 of Fig. 18, with the roll stand shown in section taken through the axes of the rolls.

Fig. 20 is an enlarged section of one of the mercury pockets of Fig. 18, which is used to make electrical connection between the supply conductor and the current introducing rolls.

Fig. 21 is a side elevation of a working roll stand showing provision for inert gas inclosure.

Fig. 22 is an end elevation of the same in half section, said half section being taken through the axes of the rolls.

Fig. 23 is a plan view showing the inert gas inclosure between working roll stands taken on line 23—23 of Fig. 24.

Fig. 24 is a sectional elevation of two working roll stands showing the inert gas inclosure, the adjustable guides, the looper, and the table roller.

Fig. 25 is a sectional view taken on line 25—25 of Fig. 23 showing a detail of the flexible closure joint between roll stands.

Fig. 26 is a partial sectional plan taken on line 26—26 of Fig. 24, showing a detail of guide construction.

Fig. 27 is a sectional elevation taken on line 27—27 of Fig. 24, showing a table roller drive and looper pivot.

Fig. 28 is a section taken on line 28—28 of Fig. 24, showing the looper and looper roll.

Fig. 29 is a section taken on line 29—29 of Fig. 23, showing the delivery guides and closure around the drive spindles and roll neck extension.

Fig. 30 is a sectional elevation of the cut off and sampling shear.

Fig. 31 is a sectional elevation of the cut off and sampling shear taken on line 31—31 of Fig. 30.

Fig. 32 is a partial sectional plan taken on line 32—32 of Fig. 30, showing the opening in the table through which the sample drops onto the conveyor.

Fig. 33 is a mixed sectional elevation taken through the first coiler and through the inclosure on the discharge side of the second coiler.

Fig. 34 is a sectional elevation taken on line 34—34 of Fig. 33, showing the coiler in elevation and the conveyor in section.

Fig. 35 is the wiring diagram of the electrical heating system.

Fig. 36 is a diagrammatic sectional elevation of the inert gas preparation plant.

Referring now to the drawings more in detail wherein like numerals have been used to designate similar parts throughout the various figures. 1, Fig. 6 represents the housing of the slab welding machine; 2 is the housing end cap; 3 is the truck base member upon which the housing rests; 4 is the roll bearing slide and is insulated from the remainder of the machine through molded insulation, constructed as shown in Fig. 15 for the roll bearing chocks; 5 is the hollow welding roll, which is made integral with the contacting discs 6, which dip into the mercury troughs 7, to maintain a low resistance electrical connection between the welding rolls and the secondary of the transformer in all positions of the welding rolls as they traverse the slab.

The upper welding roll slide 4 is carried in a frame 8, which is vertically adjustable in the housing 1, by means of screws 9, to adapt the setting of the welding rolls to different thicknesses of slab to be welded. The connection between the upper slide 4 and the upper screw 10 is made to

allow sufficient relative vertical displacement to permit this vertical adjustment. The traverse movement of rolls 5 and slides 4 is effected through screws 10, working in nuts in the hubs of gears 11, which are all driven simultaneously by gear 12, which in turn is driven by reversible motor 13.

Stop clamp 20, Fig. 11, the face of which has a step which clamps down on the right hand slab end 22 after it is centered in position with respect to the welding rolls, serves to control the lap of the two scarfed ends when the left slab end 22 is forced into the position shown. After thus positioning the slabs, they are tightly clamped edgewise by clamps 14, which are backed up by adjusting liners 15 (Fig. 9) and clamps 16 operated by screws 17, by gears 18 and reversible motor 19, there being a motor and a pair of screws for each slab end. After the edge clamps are tightly set against the slab ends, the stop clamp 20 is lifted by air cylinder 21, carried by upper slides 4. The scarfed slab joint is now ready to be welded. Welding current is supplied to the rolls 5 by welding transformer 23, Figs. 8 and 12, through the mercury troughs 7, the upper pair of which is connected to one end of the transformer secondary, while the lower pair of troughs 7 is connected to the other end of the transformer secondary. The transformer primary 24 is supplied with high voltage current from the conductor bars 25, Fig. 6, through the sliding shoes 26. The welding machine is moved along the track by motor 27, which is geared to track wheel 28. The moving welding machine is mounted on tracks running parallel with the slab being rolled. It is clamped to the rear end of the slab being rolled and allowed to move with the slab while the piece to be welded on is brought into position and the weld made, after which it is unclamped and returned to the position shown in Fig. 2. A series of traveling support rollers 29, Fig. 2, movably mounted alternately on two separate tracks, so as to telescope partially into each other for compactness, are connected together with chains to limit their spacing, and are connected to both sides of the traveling welder, as indicated in Fig. 2. They serve to support the slabs on both sides of the moving welder.

A fixed welder of similar construction, indicated in Fig. 2, is provided in advance of the traveling welder, to weld a number of the shorter slabs together to form a slab of from 100 to 200 ft. in length and reduce the number of traveling welds to be made.

30, Fig. 3, is a closure of closely matted wire brushes, which fill in the space between the entrance to the mill closure and the entering slab. These brushes are readily changeable to suit different sizes of slab. These brushes serve to retard the leakage of the inert gas from the inclosure at this point. 31, Figs. 2, 3, and 4 are table rollers of standard construction.

Figs. 13 and 14 represent the current introducing roll stands used to heat up the slab. They depart from standard roll stand construction in several particulars. The rolls 32 are mounted in chocks 33, which are insulated from the housings 34, screwdown screws 35, and hanger rods 36, by moulded interlocked insulation as shown in Fig. 15. The rolls are of hollow construction with annular disc ribs and chambers alternating axially throughout the length of the body of the roll. These annular chambers are adapted to hold mercury for making contact with the special current introducing leads, which will be described

later. They also serve to provide large cooling area for the internal cooling of the rolls, since it is one of our objects to keep water and water vapor from coming in contact with the heated steel.

The screwdown screw 35, instead of working in a nut secured to the housing, is threaded into a beam member 37, which is movable vertically with respect to the housing, but is held firmly against same by springs 38. Some of these stands must operate on relatively cold portions of the slab, and this means is taken to prevent excessive strains being set up in any part of the stand. Guides 39, Figs. 16 and 17, are provided between the current introducing roll stands 34. These guides 39 are supported by threaded brackets 40, which are insulated from the guides by suitable insulation. The brackets 40 are in turn carried by screws 41, which are provided with right and left hand threads. The screws 41 are journaled in bearing brackets 42, which are bolted to the housings 34. The ends of the screws 41 are provided with square pockets, and these screws may be rotated and the guides adjusted from without the inclosure by means of shafts 43, which have squared ends that fit into the square pockets in screws 41 and extend through the inclosure. Suitable stuffing boxes are provided around shafts 43, where said shafts pass through the inclosure.

44 in Fig. 14 is the closure plate provided at the sides of the housings. Where the roll necks extend through the closure plates 44, we have provided movable stuffing boxes 45 around the roll necks to permit adjustment of the rolls and to prevent leakage of inert gas.

In Fig. 13, the closure plate 44 is removed in order to show the bearing chocks more clearly. Closure extensions 46, which are attached to the housings and are equipped with flanges, provide means by which we are enabled to obtain a tight closure around and between the housings and between the roll stands. The closure between stands 34 is provided with glass windows 47, Fig. 3, to permit observation of the heated slab.

Figs. 18, 19, and 20 show in detail, the electrical construction used to supply heating current to the current introducing rolls and the metal being rolled. Fig. 18 is a sectional elevation taken through the mercury pockets of the main conductor, showing the means for connecting the rolls of two adjacent roll stands to the main conductor. The construction shown is typical of that employed throughout the mill for introducing current to the rolls. The mercury pockets 50 and 51 are integral with the main supply conductor 49, and are provided with ribs to interleave with the sections of the removable roll conductors 54 and 55, the ribs being shown in the enlarged section of the mercury pockets, Fig. 20. Mercury is used to fill the space between and around the pocket ribs and the end of the removable roll conductor. A trough extension without ribs is formed integral with the mercury pockets and filled normally by the hinged block 52, Fig. 19, which displaces the mercury into the space immediately surrounding the pocket ribs and roll conductor, thus maintaining a low resistance contact.

Hinged block 52, when raised by hoisting mechanism 48, allows the contact mercury to run into the trough extension, thus breaking the electrical connection between the pocket and the roll conductor 54 or 55. This switch is used to successively disconnect the five intermediate current

stands from the circuit in the heating zone when first starting a slab through the mill, as described more in detail later.

When filler block 52 is swung 90° to the upright position shown dotted, Fig. 19, the removable conductors 54 and 55 may be withdrawn from the rolls to facilitate repairs or replacements. A very important part of this arrangement is the removable conductor by which the current is carried from the main conductor to the current introducing rolls. 54 and 55 represent the conductors carrying the current to the top and bottom rolls, respectively. Each of these removable conductors is made up of a plurality of heavy copper bars insulated from each other with an insulation which is effective with the low voltages or potential difference between adjacent bars. This potential difference is very small, the oxide surface film usually being sufficient. Each of the bars, comprising the multiple conductor, leads to a particular and corresponding mercury chamber in the current introducing roll. The resistance of all of the individual bars comprising a conductor is made equal, except the two bars leading to the two outside pockets in the roll, which are made of lower resistance to increase the current density at the outer edges of the slab. In this manner, the heating effect across the width of the slab is controlled as desired. These conductors are supported on stand 56, and are insulated therefrom, and the ends of the various individual bars within the roll dip into the mercury contained in the various annular chambers 57. The other ends dip into the mercury pockets, Fig. 20, and the pocket ribs extend between the various bars. Cooling water is introduced into the rolls through pipes 58, and flows out of the roll and into trough 59.

Fig. 3 shows a series of nine current introducing stands, which comprise the heating zone. These are connected up electrically to the main conductor as just described. The first two and the last two of this series of nine stands, which are shown larger than the intermediate five stands, carry all of the heating up current when the mill is in continuous operation. The intermediate five stands are used as current carriers only, when starting a slab through the mill, and the lower rolls act merely as table rollers after the slab is introduced into the mill. The advantage of using two spaced groups of current carrying rollers of opposite polarity, lies in the fact that higher over-all voltage may be used with a corresponding lower current density, which, in any case, is very high. Also, the longer length of slab, included between the current input and take-off points, tends in itself to spread the heating current more uniformly throughout the section to produce more uniform heating, even in the presence of some non-uniformity of the contact across the slab. The multiple number of rollers carrying current in each group further reduces the non-uniformity of contact across the slab to a minimum. The group of current carrying rollers at the hot end of the heating zone is set to bite into the slab and produce a slight reduction by rolling action to insure a good contact across the whole width of the slab. All of the heating roll stands are designed to permit the application of heavy roll pressure to the slab being heated.

The roll diameters recommended for the five intermediate stands are about three feet, and for the end groups, about four feet.

When a slab end is first started through the heating zone, its forward end is held while span-

ning the first two current roll stands and is given a slow forward and backward motion to distribute the point of contact along an arc of the roll to prevent a damaging hot spot from developing in the roll. The end is thus given sufficient preheat before being fed through the remainder of the stands, to insure a section near the front end being superheated substantially above the normal rolling temperature by the time it has passed through the last stand of the heating zone. As soon as the front end of the slab has entered the second intermediate stand D, Fig. 35, the first intermediate stand C, Fig. 35, is disconnected electrically, by raising blocks 52 corresponding to this stand. When the forward end of the slab enters stand E, Fig. 35, stand D is similarly disconnected. Then successively, stands E, F, and G are disconnected immediately after the slab has entered the next stand beyond, thus eliminating all of the five intermediate stands from the electric circuit after the slab has spanned the space between the two end groups of the heating zone. From now on, until a new slab is started through the mill, the five intermediate stands act merely as table rollers and supports. When the front end of the slab has passed through the last stand of the heating zone, its cool end is cropped off in step, not to exceed in length the size of crop which the chutes and conveyor are designed to handle, until a cut is made at a section of high superheat, after which the slab is fed to the rolling stands and the rolling operation started. The design of the mill is such that some loss of temperature of the entering tip will take place, and the superheat of the tip will prevent the temperature of the tip from falling to a point where the mill will be damaged. The type of cropping shear used 60, Fig. 3, has both the top and bottom shear blades driven simultaneously from the same eccentric shaft, with the blades guided in a common housing, which is free to swing about the eccentric shaft. This shear will crop a slow-moving slab while in motion. This shear construction is not new and is not claimed, but its use in this manner is, we believe, new. The cut off crops drop through chute 61, Fig. 3, onto the conveyor 62 and are carried thereon out of the inert gas inclosure through an oil seal, similar to that shown in Fig. 5. The main heating current between the two end groups of stands of the heating zone is supplied by D. C. generator T, Fig. 35, D. C. generators X, Fig. 35, being used to equalize the current between the stands A and B, and also, H and I of the end groups. Low voltage transformer secondary Q, Fig. 35, may be inserted in series with the generator T, for the purpose of superposing an alternating current component upon the main D. C. heating current for the purpose of supplying an increased heating effect at the edges of the slab, to compensate for the extra cooling at this portion. The higher the frequency of the superposed alternating current, the sharper will be the concentration of its heating effect at the slab edges.

The working roll stands, Figs. 21 and 22, have the same special features of design as that described for the heating current roll stands, Figs. 13 and 14, except that the screwdown screw 35 works in a nut in the housing as in standard construction for rolling mill roll stands. The rolls have a smaller hole for the introduction of the electric conductor, since greater strength is required in the roll and less current is needed to supply heat losses.

The roll necks are also provided with cooling ribs and chamber to reduce bearing temperatures. This hollow roll construction permits us to introduce the heating current evenly across the roll and to cool the roll without bringing water or its vapors in contact with the hot metal being rolled. 63 represents the housing; 64 the working rolls. All other numbers apply to parts similar to those already described under Figs. 13 and 14.

Figs. 23 to 29, inclusive, show the installation of two stands with a looper and table roller between them; also, the adjustable entry and delivery guides, and the details of the inert gas inclosure between stands. 64 is the rolls; 63 the housing; 46 is the inclosure extension around the roll stand; 65 represents the inclosure between roll stands having glass windows 47. The top section of the inclosure 65 is removable at the joint 67, shown in Fig. 28, for access to the looper table roller and guides. The closure 65 is joined to the housing closure 46 by the bellows-like section 66, through an insulating joint shown in section in Fig. 25, in which 69 is a thick insulating gasket, riveted to one flange of 66; insulating strip 70 serves to insulate the attaching bolts. The other flange of 66 is faced with gasket 68, which need not be insulating. 71 is a table roller running on shaft 74 and driven by motor 78 through shaft 81 and gear 77; 72 is the looper roll rotating on shaft 75, carried by arms 73, which are rigidly attached to shaft 74, which can be rocked by lever 79 and air cylinder 80 to support the loop in strip 76; looper roll 72, when down in the position shown dotted, acts as a table roller.

The entering guides 82 are made in two parts, laterally slideable on bar 93, which is attached to the housings and insulated therefrom by insulation 84, Fig. 29. The two halves of this guide are adjustable by right and left hand threaded screw 85, which is operated by stub shaft 88, which extends through the closure and is sealed by stuffing box 89. The nut 86, which works on screw 85, is attached to guides 82, but is insulated therefrom by insulation 95; gauge rod 90 carrying graduated scale 91, sealed by stuffing box 92 is operable from without the inclosure and serves to indicate the setting of the guides. Stripper delivery guides 83 are carried on bars 94, which are supported by the housings, but insulated therefrom by insulation 84.

Figs. 30 to 32, inclusive, show the cut off and sampling shear with its inclosure. 97 and 98 are the rotary shear drums, which are rotated with a circumferential velocity about equal to the speed of the rolled strip. The drums are normally held apart by the springs 127 acting on top drum bearing carrier 103, forcing rollers 128 against cams 109, so that knives 99 and 100 of the upper drum do not meet the mating knives 101 and 102 on the lower drum, but clear the strip passing between the drums. The drums 97 and 98 and cam shaft 104 are geared together by gears 110 with gears having long teeth of wringer roll type, which permit considerable displacement of the gear centers without unmeshing. Cam shaft 104 is fitted with a one revolution clutch 111, which cooperates with clutch teeth on top gear 110. Clutch 111 is operated by trip pin 113 and foot pedal 118. The rotation of cam shaft 104 forces the two shear drums together by the action of cams 109 on rolls 128.

The shear knives cut out a narrow piece extending entirely across the rolled strip, thus sev-

ering the rolled strip and simultaneously cut the narrow piece in two in the center by punching out a narrow slug, the width of the piece which drops down through the opening 122 in the lower shear drum. The two parts of the cut out piece are represented by 126 of Fig. 32. These drop down between the support guides 123 onto conveyor 125, which conveys them out of the inclosure through an oil seal similar to that shown in Fig. 5. This shear is used both for severing the strip at the completion of a coil and to furnish samples to check the setting of the mill and for any other test desired. This shear is located behind the last rolling stand and in front of the coilers, as shown in Fig. 4. Closure 46 entirely surrounds the sampling shear.

Figures 33 and 34 represent two coilers of standard construction except that large internally water cooled rolls 129, of similar internal construction to that described for our roll stands, are used. 138 and 140 represent the cooling water supply pipes. 139 and 140 are flexible connections to the interior of the roll. The stuffing box and supply pipes, used to seal the water connections, are shown in detail in our patent application No. 541,353, Fig. 2. The gates 131, operated by air cylinders 132, serve to direct the strip to the desired coiler. Finished coils 133 are ejected onto conveyor 137. The entire coiler and conveyor are inclosed in closure 46.

After leaving the coiler, the conveyor 137 conveys the coils 133 into the cooling chamber, which is a continuation of the inclosure 46 and is made of sufficient length to take the entire output of the mill while the coils are cooling and annealing and to allow the coils to cool down sufficiently by the time the oil seal at the end is reached to permit the coils to dip into the oil seal without damage. The oil seal is indicated by 143, Fig. 5. The coils removed from the oil seal constitute the finished product of the mill. These coils are of annealed steel of fine finish, substantially free from scale. The production of our mill constitutes a new product not now available.

Fig. 36 is a diagrammatic section showing our inert gas producing and storing apparatus. The general principle upon which this work consists in forcing air through a bath of steel in such a way that the air comes in intimate contact with the molten steel to form iron oxide with the oxygen and water present in the air, and then removing the oxide and storing the residual gas in an oil sealed holder, or causing same to flow into the inert gas mill inclosure. 144 is a coreless induction furnace, adapted to melt and hold the metal 146; 145 is the electric coil; 147 is a refractory nozzle, with the end construction shown to distribute the air over a considerable body of the metal near the bottom of the furnace; 148 is a tube to which the refractory nozzle is attached, and passes through the closure 155, which seals the top of the furnace. Chamber 150 forms a closure cylinder over the stuffing box 149, which seals the opening in 155, through which tube 148 extends, and permits the withdrawal of the refractory nozzle from the molten bath, which should be done if for any reason the metal is allowed to solidify. Tube 148 is raised by rod 151, working through stuffing box 152 by means of a hoist not shown, attached to eye 154. Weight 153 serves to force tube 148 downward against the friction of the stuffing boxes when it is desired to lower the nozzle into the bath. Air pressure is supplied to nozzle 147 by blower 165

through heat recuperator 162 and 163, connecting piping 168 and 172, chamber 150 and tube 148. Pipe 166, Fig. 36, is connected to the outlets of the mill inclosure 166, Figs. 3 and 5, at each end of the inclosure.

The gases, after bubbling through the molten metal, pass into closure 155, thence to the first settling hopper 160, upward into the recuperator tubes 163, then down the recuperator tubes into the second settling hopper 160, thence up through the mineral wool filter bed 164, then into pipe 169, thence either into pipe 170, which connects to the mill inclosure at the point indicated by 170, Fig. 3, or into the gas holder 171, Fig. 36. Inlet 167, which is open to the atmosphere, is provided so that an excess of air may be treated and stored in gas holder 171 when the gas in the mill inclosure has reached a satisfactory state and needs no further treatment until it is contaminated. The valves shown in the diagram are so adjusted as to maintain at all times a slight pressure above atmosphere within the mill inclosure.

Hopper 157, bell 156, operated by lever 158 and closed by weight 159, is used for charging fresh metal into the furnace. Iron oxide is withdrawn from the hoppers 160 by manipulating closure slides 161.

Fig. 35 is the wiring diagram of the heating system. The series of circles, lettered A to I, inclusive, indicate the current introducing rolls of the heating zone. Letters J to N, inclusive, indicate the working rolls of five stands, but more working stands would ordinarily be used and the same principles and methods of construction would apply to a larger number. T represents the D. C. generator for the main current supply of the heating zone. A very large unipolar generator should serve well for this purpose, although the more commonly used type can be used. O and P represent the heavy current conductors from the generator T. X represents D. C. generators of about one-half the current capacity of generator T, but of lower voltage to equalize or adjust the distribution of current between the stands A and B, and also, between stands H and I of the two end groups. Q represents an alternating current transformer, the purpose of which has already been described. U represents D. C. generators for supplying heating current to the working roll stands to compensate for cooling losses in the mill. The connection of these generators in the circuit will be obvious from the diagram. S represents the mercury switches for disconnecting or connecting the various rolls to the circuit. In normal operation, these switches are all closed, except the switches for the heating zone stands C to G, inclusive, which are disconnected after the slab has been threaded through the mill, as previously described. The arrow W indicates the direction of travel of the slab through the mill; all other arrows indicate the relative direction of the current flow in adjacent portions of the electric circuit. It will be noted that current flow in the heating up zone is oppositely directed to the flow in the rolling zone. This reduces the potential difference between the two ends of the mill, and with it, the leakage through ground. The dashed arrows on leads from stands C to G, inclusive, indicate the relative direction of current flow for the five intermediate stands when they are in circuit while starting a slab through the mill. V represents the blades of the cropping shear, between the heating zone and the first working roll stand; the slabs having first

been pickled and cleaned before entering the heating zone. The inert gas in the inclosure prevents the formation of scale within the mill, so that the current rolls make contact on clean metal, free from scale. Were scale present, the high contact currents would fuse and alloy the scale with the surface of the steel with consequent defect in its finish, and also, similarly damage the surface of the current rolls. It is thus seen that the slab pickling and inert gas inclosure cooperate to marked advantage with our electrical heating system.

With the polarities of the generators U, as indicated in the diagram, the contact current in the rolls is a minimum, which is the best arrangement for steady operation. When it is desired to stop the mill momentarily, alternate generators U may be reversed with advantage, as indicated by dotted arrows, by reversing the separately excited fields of the generators in question. This arrangement of polarities makes the contact current at the rolls a maximum, and retards the chilling of the metal strip in contact with the cold roll. If, for any reason, it is desired to stop the mill for a considerable time, the mill is slowed down to produce a superheated section, then the slab is cut by the cropping shear at this superheated section and allowed to pass on through the working rolls, the successive working roll stands being disconnected from the electric circuit just before the rear slab end passes the stand, to avoid arcing at the rolls. The portion of the slab in the heating zone is backed out of the mill, the electric current having been previously switched off the mill.

An edging pass 173 is shown between the first and second working stands, Fig. 4; more edging stands can be used if desired. These edging stands are not shown equipped with electric current introducing means, but such means can be applied in a similar manner to that already described, if desired. Two edging passes would be sufficient, and current introduced between them would be through a separate transformer not interconnected with the system already described. The problem of introducing current to the edging rolls, on account of its very narrow contact, is very simple in the light of our foregoing disclosure and would be met by a hollow vertical roll with a closed bottom, forming a pocket for the contact mercury in which the current electrode would dip, the cooling water being introduced over the top of the mercury and permitted to enter the interior of the edging roll.

To give some idea as to the power requirements for heating, the following figures are given: To roll a slab 48 inches wide and 2 inches thick, at the rate of 24 feet per minute, about 45,000 k. w. will be used to heat up the slabs to a rolling temperature of 2,000° F. About 10% additional current will be required to supply the cooling losses in the mill, which are less than in present day mills, on account of our internally cooled rolls, our freedom from scale with its high emissivity, and due to the elevated temperature of the inclosing atmosphere. To supply this amount of power with the two end groups of current introducing rolls spaced about 80 feet apart in the heating zone, will require a voltage of about 100 volts, with a total amperage of 450,000 amperes in the slab and with a contact current per roll of about 112,000 amperes. The cost of heating current at 3 mills per k. w. h., which has been achieved in large stations, will be 64 cents per ton of steel rolled. The above figures are only roughly ap-

proximate, but are sufficient to give an idea of the values dealt with.

The above figures give a calculated output for continuous operation of 235 tons per hour. If the mill is operated slower, the power requirements will be correspondingly reduced, but the heating current per ton will be slightly increased, due to the constant nature of the cooling losses.

All of the roll stands will be driven by individual, adjustable speed motors, gearing, and insulated couplings not shown, but of standard and well known construction.

174, Fig. 5, is a shut-off valve, which permits closing the annealing and cooling chamber whenever it is necessary to open up the remainder of the mill for the purpose of making repairs or doing other work on same.

While one embodiment of our invention has been shown and described in comparative detail, for the purposes of adequate disclosure, the broader idea of our invention is not limited in any of the details disclosed herein, but instead, includes such embodiments thereof as are within the scope of the subjoined claims.

What we claim is:

1. The rolling process consisting of welding together a plurality of relatively short slabs into a continuous length of slab, heating same by the passage of an electric current therethrough in an inert atmosphere, then rolling same to finished size in a plurality of successive roll stands while surrounded at all times during the rolling action by inert gas.

2. The process of rolling steel wherein a plurality of slabs are welded into a continuous slab, passing same into a continuous inclosure containing inert atmosphere wherein the slab is first heated, then rolled, then coiled, annealed, cooled, and removed from the inclosure through an oil seal.

3. The process of rolling steel wherein a plurality of slabs are welded into a continuous slab, passing same into an inclosure containing an inert atmosphere wherein the slab is first heated, then rolled, samples sheared therefrom and removed from the inclosure through an oil seal, coiling the finished product, allowing the coils to anneal and cool within said inclosure and removing said coils from said inclosure through an oil seal.

4. The process of rolling steel wherein a plurality of slabs are welded into a continuous slab, passing same into an inclosure containing an inert atmosphere wherein the slab is first heated, then rolled, the finished product coiled and allowed to anneal and cool in said inclosure.

5. A hot rolling process consisting of passing a scale free slab into an inclosure containing an inert atmosphere wherein the slab is first heated electrically, then rolled, then coiled, and then cooled in said inclosure.

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