Nov. 25, 1930. L. C. MARSHALL 1,783,047

METHOD OF MAKING STEEL PISTON RINGS

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Fig. 1

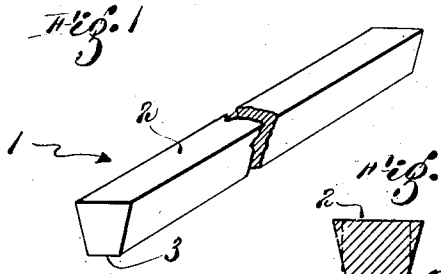


Fig. 2

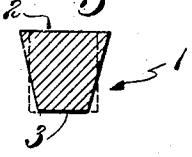


Fig. 3

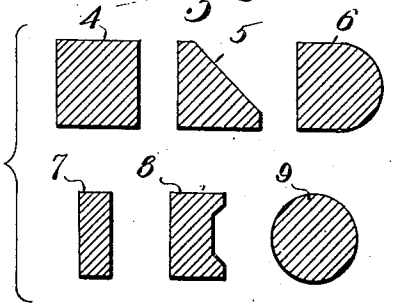


Fig. 4

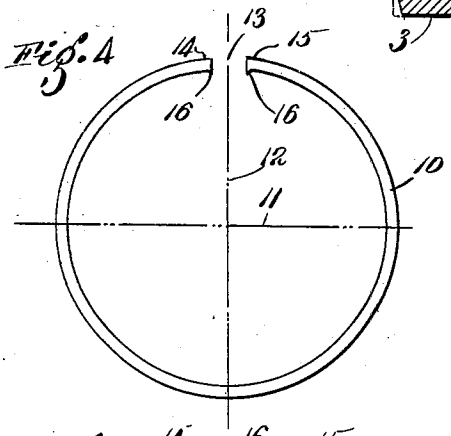


Fig. 5

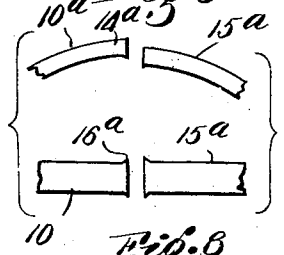


Fig. 7

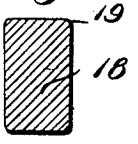


Fig. 6

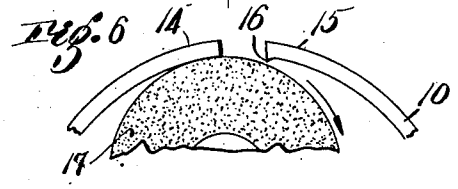


Fig. 8

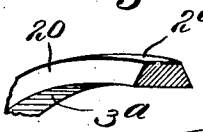


Fig. 10



Fig. 11

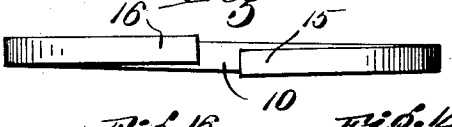


Fig. 9

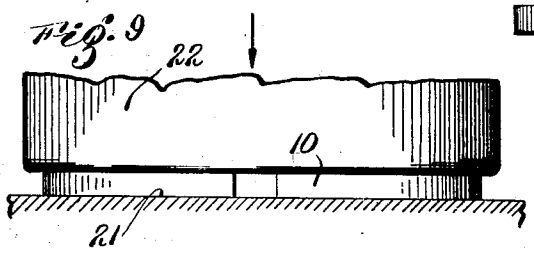


Fig. 16

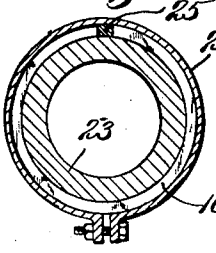


Fig. 14

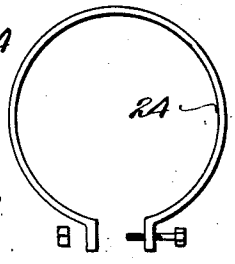


Fig. 12

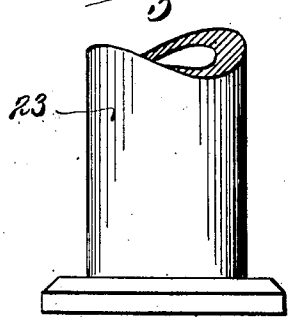


Fig. 15

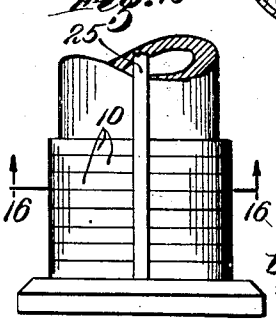
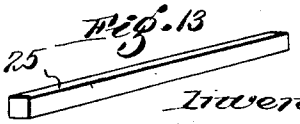


Fig. 13



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METHOD OF MAKING STEEL PISTON RINGS

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Fig. 17

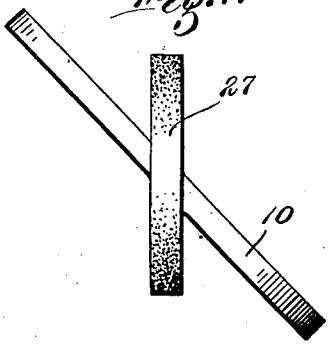


Fig. 18

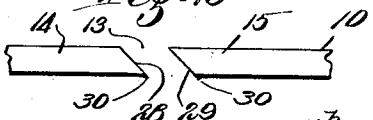


Fig. 20

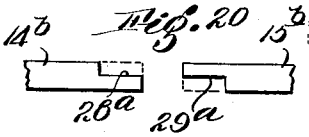


Fig. 19

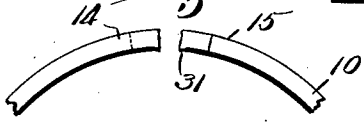


Fig. 21

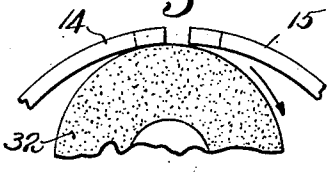


Fig. 22

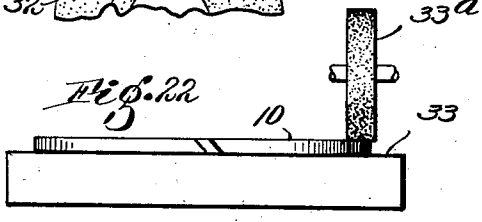


Fig. 25

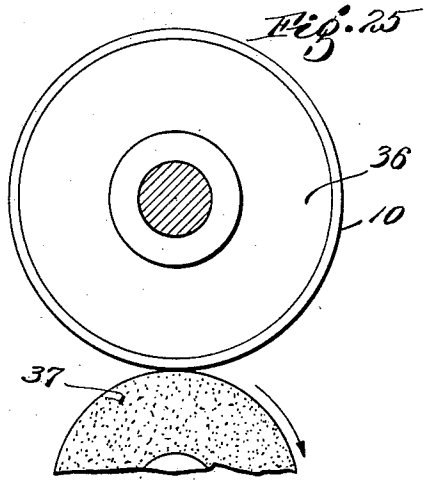


Fig. 23

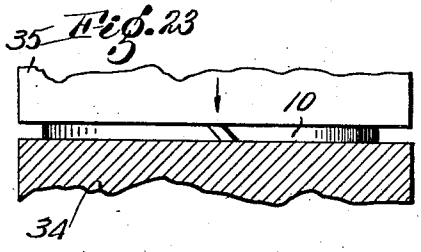
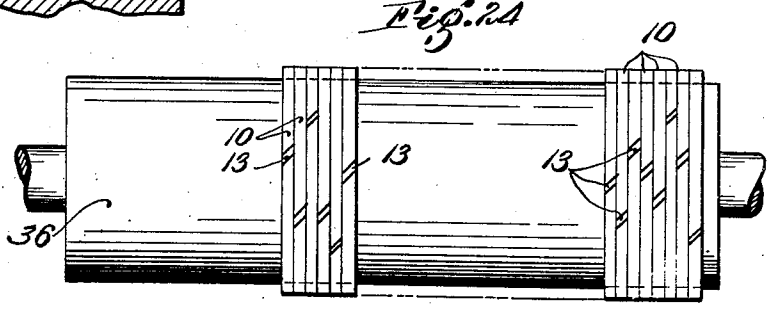


Fig. 24



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UNITED STATES PATENT OFFICE

LEWIS C. MARSHALL, OF WALPOLE, MASSACHUSETTS

METHOD OF MAKING STEEL PISTON RINGS

Application filed June 1, 1927. Serial No. 195,720.

This invention pertains to piston rings for internal combustion engines and the like and more particularly to a method of making such rings from hard steel wire or rod. In my copending application Serial No. 62,825, filed October 10, 1925, I have described my discovery that piston rings of hard steel or steel alloy having physical characteristics similar to that of steel of at least 0.5% carbon (or peferably steel of approximately 0.65% carbon) form a good working surface in contact with the cylinder wall and exhibit no tendency to score the cylinder wall. In said application I have also described one desirable process of producing such rings and apparatus useful in performing such process. In my copending application Serial No. 195,719 filed June 1, 1927, I have disclosed and claimed more specifically certain desirable steps in the production of such rings together with appropriate means for performing those particular steps.

The present invention relates to a modified and improved method embodying certain of the process steps set forth in my above-named applications as well as others not therein specifically disclosed and has been perfected in the endeavor to simplify and cheapen the production of piston rings on a commercial scale. While the specific order of steps hereinafter described is desirable and results in the production of commercially acceptable rings, I do not limit myself to this specific series of steps nor to the inclusion of all of the steps herein described or their equivalents and I contemplate the substitution and addition of other steps as falling within the province of my broad invention.

In the accompanying drawings I have illustrated most of the several steps (herein described as constituting the complete process) by reference to rings or portions of rings showing the results of such steps and in some instances I have illustrated appliances useful in performing one or more of such steps, but as many of the steps may be performed by hand or by the use of instruments or machines of well known type, I have not deemed it necessary, except in particular cases, as above noted, to disclose such instruments or machines in detail in the accompanying drawings.

In the drawings,

Fig. 1 is a fragmentary enlarged perspective view illustrating a piece of wire or rod of a preferred shape useful in making piston rings;

Fig. 2 is a transverse section, to larger scale, showing the wire or rod of Fig. 1 and indicating the shape which this wire assumes after bending;

Fig. 3 is a view illustrating in transverse section various shapes of wire which might conceivably be employed in making piston rings in accordance with this method;

Fig. 4 is a plan view showing a section of the wire bent to form a single annular turn having a gap therein;

Fig. 5 is a view illustrating results sometimes produced by the bending process and in forming the gap in the ring;

Fig. 6 is a fragmentary elevation illustrating the step of removing the burr from the ends of the ring;

Figs. 7 and 8 are a transverse section and a fragmentary perspective view, respectively, illustrating shapes which sometimes result from the bending operation;

Fig. 9 is a fragmentary side elevation, partly in section, illustrating a method of flattening the radial faces of the ring and conforming it to the axial thickness desired;

Fig. 10 is a transverse section illustrating the results of the operation of Fig. 9;

Fig. 11 is a side elevation showing a ring after the operation of Fig. 9 and indicating a characteristic of the ring which is frequently present but which is not always desirable;

Figs. 12, 13 and 14 are views illustrating a device useful in heat treating the ring to reduce it to flat or plane form;

Fig. 15 is a fragmentary elevation showing a series of rings mounted upon the device of Figs. 12, 13 and 14;

Fig. 16 is a horizontal section substantially on the line 16—16 of Fig. 15, showing rings mounted in position for heat treatment;

Fig. 17 is an elevation illustrating one

means for trimming the ends of the ring and producing the desired width and shape of gap;

Fig. 18 is a fragmentary side elevation of the ring showing the gap formed by the operation of Fig. 17;

Fig. 19 is a fragmentary plan view of the ring shown in Fig. 18;

Fig. 20 is a view similar to Fig. 18 but showing a modified construction for the end of the ring;

Fig. 21 is a side elevation illustrating the operation of removing burrs formed in cutting the gap;

Fig. 22 is a side elevation illustrating the operation of flattening the radial faces of the ring by grinding;

Fig. 23 is a similar view illustrating the process of flattening of the radial faces by impact or compression;

Fig. 24 is a side elevation of a mandrel with a series of rings mounted thereon in position for grinding their peripheral faces; and

Fig. 25 is a view at right angles to Fig. 24 illustrating the grinding operation.

In accordance with this process I provide myself with wire or rod of suitable cross section, preferably obtaining this wire in the form of coils which are more easily handled than individual lengths of rod, and which may be produced by usual drawing or rolling operations familiar to those skilled in the metallurgical arts. I select a wire of a composition which by test has been proven to form a good working surface in contact with the wall of an engine cylinder, that is to say, the material chosen should be such that it does not score the cylinder wall when moved rapidly in contact therewith at the high temperature met with in internal combustion engine practice and which is capable of expanding resiliently against the cylinder walls to produce the desired gas-tight fit. This material must also be of a character such that it is capable of undergoing the various steps of the process as hereinafter described, one essential characteristic being that it shall be ductile or capable of bending without danger of breaking,—in other words this material must be tough and not brittle.

As pointed out in my aforesaid pending application Serial No. 62,825, attempts have been made in the past to make piston rings from ductile material, such for example as mild steel or copper, by a process involving bending or similar operations, but heretofore so far as is known to me such efforts have been confined to the employment of the mild or low carbon steels or other soft metals, and I am unaware that any one prior to my discovery has ever recognized the fact that hard steel, that is to say, steel of at least 0.5% carbon, makes a substantially perfect wearing fit against a cylinder wall without scoring or biting into the cylinder wall.

I have experimented with various grades of steel of a carbon content of 0.5% carbon or more and as a result of my experiments I am led to believe that any steel of a carbon content above that noted exhibits these desirable characteristics, although I find that steel of approximately 0.65% carbon is particularly satisfactory since, while it produces a very good wearing surface, it is not so extremely hard as to render its working unduly difficult. I have also experimented with certain alloy steels and in consequence of these experiments believe that any steel having the general physical characteristics (particularly the hardness) of steel of 0.5% carbon or of a carbon content greater than that will give satisfactory results.

Having selected a material exhibiting the physical characteristics above noted, I have this material formed into rod or wire, and if the piston ring to be produced is to have a substantially rectangular cross section, I prefer to employ wire 1 such as is shown in Fig. 2, that is, wire of substantially trapezoidal section having the wide face 2 and the relatively narrow face 3. In the drawings the difference in width of these faces is very greatly exaggerated for illustrative purposes, but in actual practice this difference may be of the order of 0.005 inches. When wire of this section is bent with its narrow face 3 at the inside of the arc, I find that during bending the metal flows to such an extent that the wire assumes a substantially rectangular cross section as indicated in dotted lines in Fig. 2.

While this particular shape of wire is desirable for the reasons noted, I contemplate that for very special purposes wire of other section may be employed, and in Fig. 3 I have indicated at 4, 5, 6, 7, 8 and 9 certain shapes of wire which might be found useful, under some circumstances, it being noted that the shapes here shown are not to be taken as comprehensive of all possible shapes, but that wire of any desired shape might be employed in performing the present process. Having thus selected the material and the shape of wire to be employed I bend this wire in any desired manner by the use, if desired, of any suitable instruments or mechanism, such for example as is disclosed in my copending application Serial No. 195,719, filed June 1, 1927, to form a single annular turn 10 as indicated in Fig. 4. While this annular turn may be substantially circular as formed, I prefer to make it of slightly elliptical shape with the long axis indicated at 11 and the short axis at 12, and at one end of the shorter axis 12 I provide a gap 13. This gap may be formed concomitantly with the bending process and if desired in severing the turn (formed by

bending) from the original length of wire. Thus as disclosed in my copending application just referred to, one desirable mode of bending the wire to form the rough or unfinished ring comprises advancing a length of wire or rod while confining it between appropriate bending devices or implements which constrain the advancing wire to assume an arcuate curvature. Preferably the advance of the wire is intermittent, and during each advance to form a single annular turn the bending devices or implements are relatively moved so as to vary the radius of curvature of the bending wire, thereby producing a ring of flattened or elliptical shape adapted to expand uniformly when the ring is placed in an engine cylinder. As the wire is advanced, it is guided in a helical path, the pitch of which is so moderate that the limit of elasticity of the wire is not exceeded. When one turn has been completed, the advance of the wire is preferably stopped and the turn is cut off by a radial or diagonal cut, as may be preferred, and at such a point that the severed turn is slightly less than a complete circle and a gap is formed substantially at one end of the minor axis of the elliptical turn. As each turn is severed and leaves the bending device, the resiliency of the wire causes it to assume the form of a substantially plain, flat ring (devoid of helical set) which is now ready for the subsequent finishing operations. Obviously, if desired, the relative movement of the bending devices during the advance of the wire may be dispensed with so that the rough or embryo ring will be of circular rather than of elliptical curvature. The single annular turn 10 thus formed comprises the end portions 14 and 15 and as a result of the severing operation I usually find that there is a burr 16 upon one or both of the ends 14 or 15.

While the ideal result of bending and severing would provide a turn 10 whose ends 14 and 15 would be directly opposite to each other, I find in practice that, as shown at the upper part of Fig. 5, the ends 14^a and 15^a of the ring 10^a are not always directly opposite, one end being at a greater radial distance from the center of the ring than the other. Also as illustrated at the lower part of Fig. 5 I sometimes find that burrs 16^a are produced in the cutting operation at the radial faces of the ring.

According to the present process the next desirable step is to remove the burrs 16 or 16^a from the ends of the ring and this may be accomplished as shown in Fig. 6 by applying the ends of the ring to a grinding wheel 17. This operation may be performed by hand or, if desired, the rings may be fed automatically to a machine for removing the burrs either by grinding, milling or otherwise.

Further possible results of the bending operation are indicated in Figs. 7 and 8. As indicated in Fig. 7 the corners 19 of the ring after bending are sometimes rounded and, as shown in greatly exaggerated form in Fig. 8, the bending of the material, particularly if material originally of rectangular cross section is employed, may result in the production of a ring 20 whose outer surface 2^a is less in width than its inner surface 3^a. Other slight irregularities may also be produced in bending or may result from slight initial irregularities in thickness of the wire produced in the drawng or rolling operation. Furthermore, as indicated in Fig. 11, if the bending of the wire be accomplished by a coiling operation, the annular turn, after severing from the original length of wire, may have a slightly helical form so that the ends 15 and 16 do not lie exactly opposite to each other.

For curing such defects as indicated in Figs. 7 and 8 or others of generally like character, I prefer next to subject the ring to pressure applied to its radial faces. As indicated in Fig. 9, the ring 10 is supported upon the upper surface 21 of the lower platen of a press while the upper platen 22 of the press rests upon the upper radial face of the ring. The platens of the press will for this purpose be accurately smooth and parallel and the press should be capable of exerting a heavy pressure, for example of the order of twenty-five tons, so as substantially to flatten the radial faces of the ring and reduce the ring to substantially rectangular cross section, as indicated in Fig. 10.

While the radial faces of the ring, as a consequence of this flattening operation may be substantially parallel to each other and nearly flat, the ring may still retain its helical form, as shown in Fig. 11, and in accordance with the present process, my next step has for its object the removal of this helical formation and the reduction of the ring to true plane form.

I now subject the ring to a heat treatment in which I preferably use instrumentalities such as shown in Figs. 12, 13 and 14. These instrumentalities include a mandrel 23 which may be of cast iron or similar heat resistant material and of a cross section substantially like the desired internal contour of the ring. If a circular ring is desired, this mandrel will be circular, but ordinarily in order to produce a ring which will bear with substantially equal pressure at all points against a cylinder wall, I prefer as above described to make the ring slightly elliptical and consequently the mandrel 23 will usually be slightly elliptical. I also provide a clamping shell 24 which is preferably of resilient metal and provided with means for drawing it snugly about the rings mounted upon the mandrel 23. I further provide a narrow bar 25 which in one dimension is substantially equal to the radial thickness of the ring and in the other dimension is substantially equal to the width

of the gap 13 in the ring. I next mount a series of rings 10 upon the mandrel 23 and arrange them so that their gaps 13 are in alignment. I then place the bar 25 in the series of gaps 13 and while subjecting the series of rings 10 to endwise pressure sufficient to reduce them to substantially plane form, I clamp the member 24 about the series of rings with sufficient firmness to draw them closely about the mandrel and to prevent them from moving endwise. I then introduce the mandrel with its series of rings into a suitable furnace where they are subjected to a temperature of the order of 900° F. which I find sufficient to remove all strains introduced by the bending operation and to give the rings a permanent set such that when cooled they accurately retain the shape of the mandrel and have substantially no tendency to return to the helical form.

Having heat treated the rings I next proceed to trim the ends 14 and 15 of the ring so as to produce a gap of the desired width and shape. Thus if the ring is to have a diagonal gap I may, as indicated in Fig. 17, present the ring to a grinding wheel 27 or a milling cutter arranged at the proper angle and of the proper width so that a single passage of the grinding wheel or cutter through the gap 13 in the ring will produce the desired width and complemental finished faces 28 and 29 (Fig. 18) adapted, when the ends of the ring are brought into contact, to form an overlapping and substantially gas-tight joint.

While these finished end surfaces may be formed by grinding, I contemplate that they also may be produced by a milling operation, and of course they might be produced by filing, although this latter method would hardly be a commercial method of performing this step.

Instead of making a diagonal gap as indicated in Figs. 17, 18 and 19, I may provide a step-end formation as shown in Fig. 20 where the ends 14^b and 15^b of the ring are provided with overlapping surfaces 28^a and 29^a of stepped formation. Such surfaces may be formed by a milling operation or possibly by a suitable grinding operation.

In trimming the ends of the ring as just above described I find that burrs, as indicated at 30 and 31 in Figs. 18 and 19, are sometimes produced, although I contemplate that methods of trimming the ring may be devised which will not result in the production of such burrs. If such burrs be produced I propose as the next step in the present process to remove these burrs and this may be accomplished as indicated in Fig. 21 by subjecting the ring to the action of a grinding wheel 32. Of course, these burrs might be removed by a milling operation or by filing if such methods were found practical. If the trimming operation does not result in the formation of burrs, this last-described step of removing the burrs may obviously be omitted.

Having removed the burrs, if necessary, I next prefer to subject the ring to an operation which accurately flattens its radial faces and reduces the ring to its final axial thickness. I may accomplish this purpose as indicated in Fig. 22 by placing the ring 10 upon a support 33, for example a magnetic chuck, and subjecting the opposite radial face of the ring to the action of a grinding wheel 33^a accurately spaced from the supporting surface of the member 33. In accordance with this process I prefer to grind one radial face of the ring and then to turn the ring over and grind the opposite face, the last grinding resulting in the reduction of the ring to the final desired thickness.

Instead of grinding the radial faces of the ring as just described, I may produce similar results by impact or by the application of pressures, as indicated in Fig. 23, where I have shown the ring 10 as undergoing pressure between the platens 34 and 35 of a powerful press. When I refer to the application of pressure at this stage of the procedure, as well as at the earlier stage which I have described with reference to Fig. 10, I intend to include both gradual pressure and also suddenly applied pressure, that is to say, pressure in the form of a blow, and in most instances I prefer to supply the pressure suddenly in the form of a blow since I found that pressure thus applied is far more efficacious than is more slowly and gradually applied pressure.

Having thus reduced the ring to its final axial thickness and provided accurately smooth and parallel radial faces, I next if necessary finish the outer peripheral surface of the ring by grinding or otherwise to produce the surface which is to contact with the cylinder wall. While I may finish the peripheral surface of each ring individually, I prefer, as indicated in Figs. 24 and 25, to mount a large number of rings upon a mandrel 36 preferably staggering the gaps 13 of the several rings. I then preferably mount the mandrel 36 upon centers, so that it may be rotated at desired speed, and while rotating the mandrel 36 I bring a grinding wheel 37 into engagemnt with the peripheral surfaces of the rings, causing the grinding wheel or mandrel or both to move axially so as to grind the entire series of rings and reduce them to the proper outside diameter.

After this final grinding operation I may, if desired, subject the rings to inspection and measurement, rejecting all rings which do not conform to the desired qualifications.

As previously stated, the several steps above described result in the production of a ring which is commercially acceptable and which is far superior to cast iron rings in strength

and durability, and in ease, simplicity and low cost of production, while at the same time the ring possesses none of the disadvantages which have previously prevented steel rings from coming into commercial use.

While I have specifically described certain steps as desirable in the present process, I contemplate, as above suggested, that some of these steps may be omitted and that other or possibly equivalent steps may be substituted for those here described and that under some circumstances additional steps may be necessary to produce rings having peculiar and unusual characteristics, but I wish it to be understood that I do not limit myself to the specific order of steps here illustrated nor to a process comprising all of such steps or which is restricted to the employment of the exact steps here described.

I claim:

1. That method of making split packing rings from hard steel wire or rod which comprises as steps bending a length of wire or rod, whose surface at least is sufficiently hard to form a good bearing against a cylinder wall, to form a single annular turn, severing said turn from the material before completing a subsequent turn, at such a point as to form a ring having a gap therein, and removing any burr produced in severing the material.

2. That method of making split packing rings which comprises as steps bending a length of steel rod or wire of from 0.6% to 0.8% carbon to form a single annular turn, severing said turn from the length to form a ring having a gap at one point, flattening the radial faces of the ring, and removing burr produced in preceding steps.

3. That method of making split packing rings which comprises as steps bending the end portion of a length of steel wire or rod of at least 0.5% carbon to form a helical turn, severing said turn from the length of wire at such a point as to provide a ring having a gap therein, compressing the ring axially to reduce it to the form of a plane ring, and heating the ring while so axially compressed to impart a permanent set thereto.

4. That method of making split packing rings which comprises as steps bending the end portion of a length of steel wire or rod of at least 0.5% carbon to form a helical turn, severing said turn from the length of wire at such a point as to provide a ring having a gap therein, confining said ring both axially and circumferentially within predetermined bounds, and heating the ring so confined to a temperature such as to impart a permanent set thereto.

5. That method of making split packing rings which comprises as steps bending a length of wire having substantially the physical characteristics of steel of approximately 0.6% carbon to form a single annular turn, severing said turn from the length to provide a ring having a gap at one point, clamping said ring about a forming mandrel of predetermined contour, and heating the ring while clamped to the mandrel to a temperature of approximately 900° F.

6. That method of making split packing rings which comprises as steps bending the end portion of a length of steel wire or rod of at least 0.5% carbon to form a helical turn, severing said turn from the length of wire at such a point as to provide a ring having a gap therein, placing said ring together with like rings upon a mandrel, compressing the several rings axially, confining the rings circumferentially to make then conform to the mandrel, and heating the mandrel and rings to substantially 900° F.

7. That method of making split packing rings which comprises as steps bending a length of steel wire or rod of at least 0.5% carbon to form a single annular turn of substantially elliptical contour, severing said turn from the length of material at such a point as to form a gap adjacent to one end of a minor axis of the ring, placing said severed turn upon a mandrel of elliptical contour, clamping the entire length of the turn against the mandrel, and heating the turn to a temperature such as to impart a permanent set thereto.

8. That method of making split packing rings which comprises as steps bending a length of metallic rod or wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, confining the ring circumferentially within predetermined bounds, and heating the ring while so confined substantially to 900° F.

9. That method of making split packing rings which comprises as steps bending a length of metallic rod or wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, confining the ring both axially and circumferentially within predetermined bounds, and heating the ring to a temperature such as to cause it to acquire a permanent set.

10. That method of making split packing rings which comprises as steps bending a length of hard steel rod or wire in such a way as to form a single annular turn substantially devoid of permanent helical set, cutting off said turn from the length at such a point as to produce a ring having a gap therein, and finishing the ends of the ring at opposite sides of the gap to provide accurately complemental surfaces.

11. That method of making split packing rings which comprises as steps bending a length of hard steel rod or wire in such a way

as to form an elliptical turn substantially devoid of permanent helical set, cutting off said turn from the length at such a point as to produce a ring having a gap adjacent to one end of the minor axis of the ring therein, and simultaneously subjecting the ends of the ring at opposite sides of the gap to means for producing finished complemental end faces adapted to contact with each other to form a tight joint.

12. That method of making split packing rings which comprises as steps bending a length of hard steel rod or wire in such a way as to form a single annular turn substantially devoid of permanent helical set, cutting off said turn from the length at such a point as to produce a ring having a gap therein, subjecting said ring, while confined within predetermined bounds, to a temperature such as to impart a permanent set thereto, and shaping the end portions of the ring at opposite sides of the gap to form accurately complemental surfaces.

13. That method of making split packing rings which comprises as steps bending a length of hard steel rod or wire so as to form an elliptical turn substantially devoid of permanent helical set, cutting off said turn from the length at such a point as to produce a ring having a gap therein adjacent to one end of its minor axis, heating the ring to a temperature such as substantially to remove internal strains set up in the prior steps, removing material at the ends of the ring at opposite sides of the gap to produce complemental end surfaces, and removing burrs produced in the last-named step.

14. That method of making piston rings which comprises as steps bending a length of steel wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, heat treating the ring while confining it axially and circumferentially within predetermined bounds, and flattening its radial faces.

15. That method of making piston rings which comprises as steps bending a length of steel wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, confining the ring axially and circumferentially within predetermined bounds and subjecting it to a temperature of the order of 900° F., and again flattening the radial faces of the ring.

16. That method of making piston rings which comprises as steps bending a length of steel wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, removing burrs produced in prior steps, confining the ring circumferentially and subjecting it to heat sufficient to impart a permanent set to it, trimming the ends of the ring at opposite sides of the gap, removing burr produced in the trimming operation, and again and accurately flattening the radial faces of the ring.

17. That method of making piston rings which comprises as steps bending a length of steel wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, removing burrs produced in prior steps, confining the ring circumferentially and subjecting it to heat sufficient to impart a permanent set to it, trimming the ends of the ring at opposite sides of the gap, and grinding the radial faces of the ring.

18. That process of making split packing rings which comprises as steps bending a length of metallic rod or wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, confining and heat treating the ring upon a forming mandrel to impart the desired contour to the ring, trimming the ends of the ring at the gap to provide complemental surfaces, and grinding the peripheral surface of the ring.

19. That process of making split packing rings which comprises as steps bending a length of metallic rod or wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, grinding the radial faces of the ring, and grinding the peripheral surface of the ring.

20. That method of making piston rings which comprises as steps bending a length of steel wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, removing burrs produced in prior steps, confining the ring circumferentially and subjecting it to heat sufficient to impart a permanent set to it, trimming the ends of the ring at opposite sides of the gap, removing burr formed in the trimming operation, grinding the radial faces of the ring, and grinding the peripheral surfaces of the ring.

21. That method of making piston rings from steel wire or rod which comprises as steps bending the wire to form a turn of substantially elliptical contour, cutting off said turn from the wire at such a point as to provide a substantially elliptical ring having a gap adjacent to one end of its shorter axis, placing the ring upon a mandrel of substantially elliptical contour, compressing and heating the ring to conform it to the mandrel, and finishing the radial and peripheral surfaces of the ring.

22. That method of making piston rings from steel wire or rod which comprises as steps bending the wire to form a turn of sub-

stantially elliptical contour, cutting off said turn from the wire at such a point as to provide a substantially elliptical ring having a gap adjacent to one end of its shorter axis, placing the ring upon a mandrel of substantially elliptical contour, compressing and heating the ring to conform it to the mandrel, trimming the end portions of the ring to provide complemental surfaces at opposite sides of the gap, grinding the radial faces of the ring, and grinding the peripheral surfaces of the ring.

23. That method of making piston rings which comprises as steps bending a length of steel wire to form an annular turn, cutting off said turn from the length at such a point as to produce a ring having a gap therein, flattening the radial faces of the ring, removing burrs produced in prior steps, confining the ring circumferentially and subjecting it to heat sufficient to impart a permanent set to it, trimming the ends of the ring at opposite sides of the gap, assembling the ring with others upon a mandrel, and moving the mandrel relatively to a grinding wheel whereby to grind the peripheral surfaces of the several rings.

24. That method of making piston rings which comprises as steps bending a length of steel rod or wire to produce a ring having a gap therein, flattening the radial faces of the ring, confining the ring circumferentially and subjecting it to heat sufficient to impart a permanent set to it, trimming the ends of the ring at opposite sides of the gap, grinding the radial faces of the ring and grinding the peripheral surfaces of the ring.

25. That method of making piston rings which comprises as steps bending a length of steel rod or wire to produce a ring having a gap therein, flattening the radial faces of the ring, confining the ring circumferentially and subjecting it to heat sufficient to impart a permanent set to it, trimming the ends of the ring at opposite sides of the gap, assembling the ring with others upon a mandrel and moving the mandrel relatively to a grinding wheel whereby to grind the peripheral surfaces of the several rings.

26. That method of making piston rings from a length of steel wire or rod which comprises as steps bending the wire to form a ring of substantially elliptical contour having a gap adjacent to one end of its shorter axis, placing the ring upon a mandrel of substantially elliptical contour, compressing and heating the ring to conform it to the mandrel, trimming the end portions of the ring to provide complemental surfaces at opposite sides of the gap, grinding the radial faces of the ring and grinding the peripheral surface of the ring.

27. That method of making piston rings which comprises as steps bending a length of metallic rod or wire to form a single annular turn, severing said turn in such a way as to form a ring having a gap therein, confining the ring circumferentially within predetermined bounds, and heating the ring so confined to a temperature such as to impart a permanent set thereto, and flattening the radial faces of the ring.

28. That method of making piston rings which comprises as steps bending a length of metallic rod or wire to form a single annular turn, severing said turn in such a way as to form a ring having a gap therein, and simultaneously finishing the ends of the ring at opposite sides of the gap to produce finished complemental end faces adapted to contact with each other to form a tight joint.

Signed by me at Boston, Massachusetts, this 24th day of May, 1927.

LEWIS C. MARSHALL.