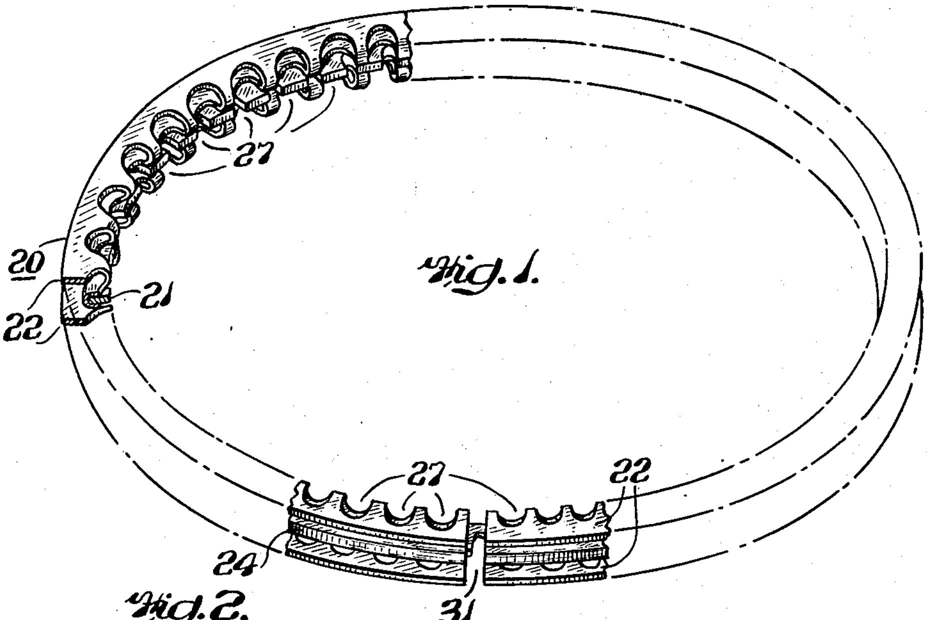
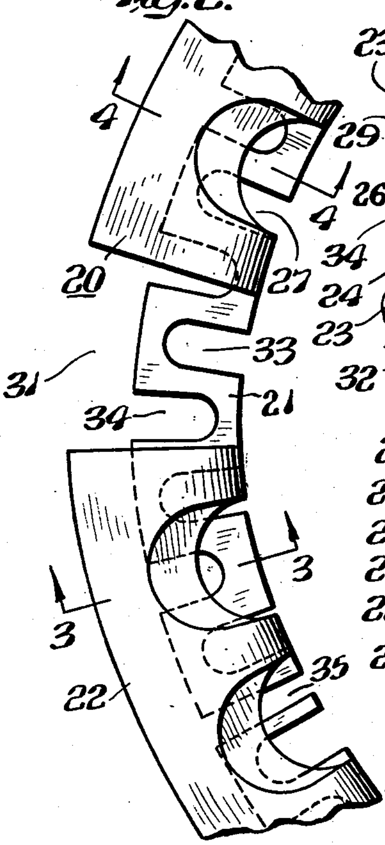
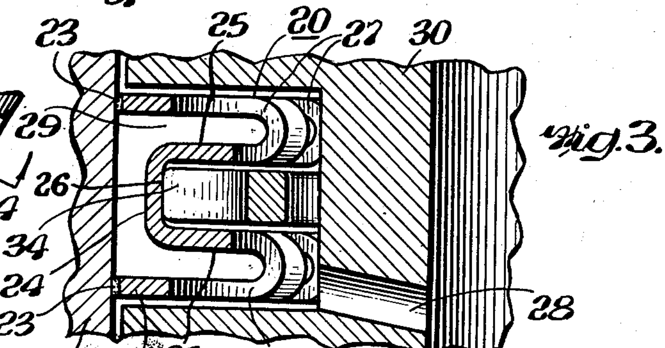
Feb. 2, 1954 HSIA-SI PIEN 2,668,088

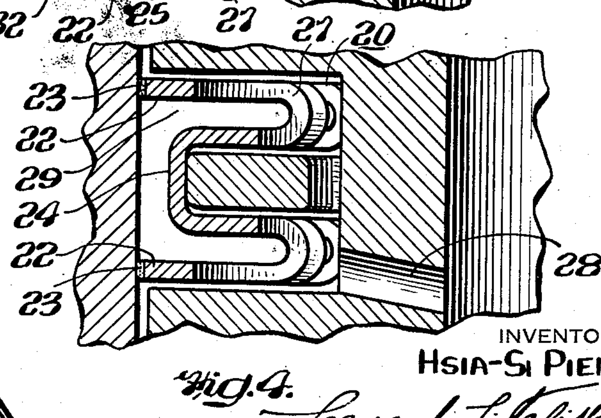
PISTON RING AND EXPANDER THEREFOR

Filed March 20, 1948 3 Sheets-Sheet 1









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Feb. 2, 1954 HSIA-SI PIEN 2,668,088

PISTON RING AND EXPANDER THEREFOR

Filed March 20, 1948 3 Sheets-Sheet 2

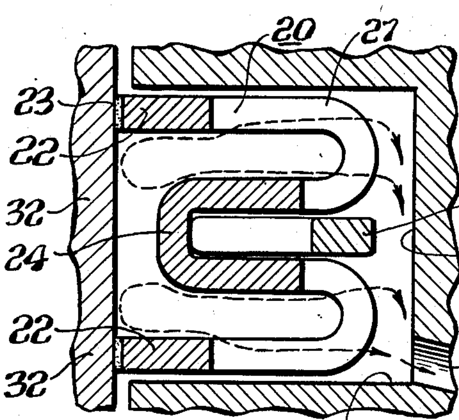


Fig. 5.

Fig. 7.

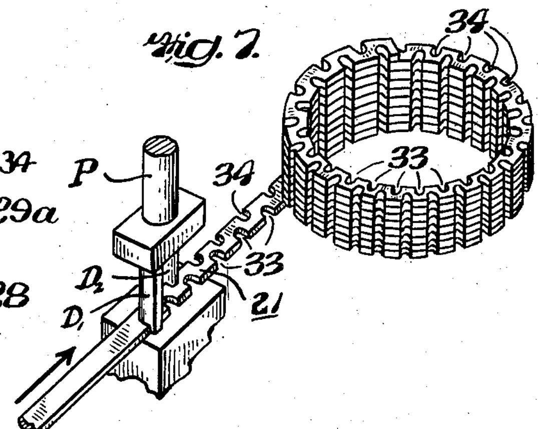


Fig. 6.

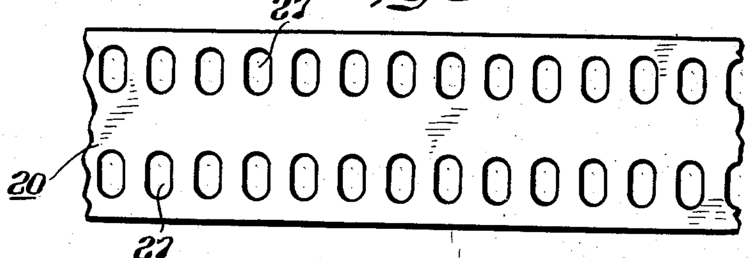


Fig. 9.

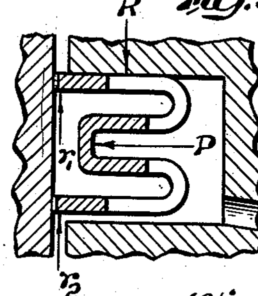


Fig. 8.

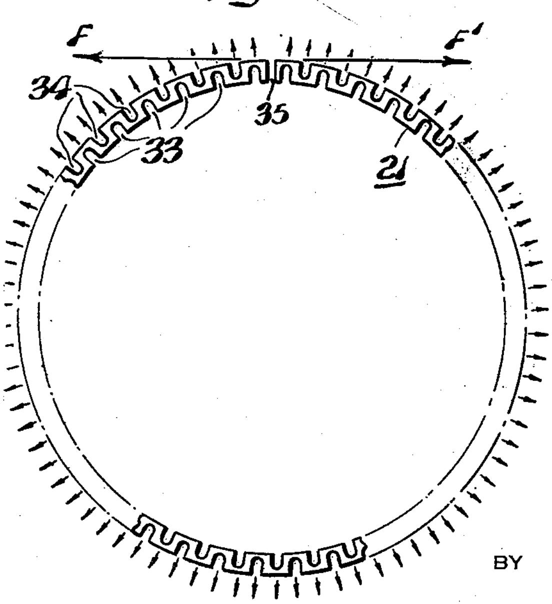
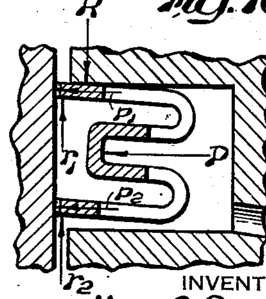


Fig. 10.



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PISTON RING AND EXPANDER THEREFOR

Filed March 20, 1948 3 Sheets-Sheet 3

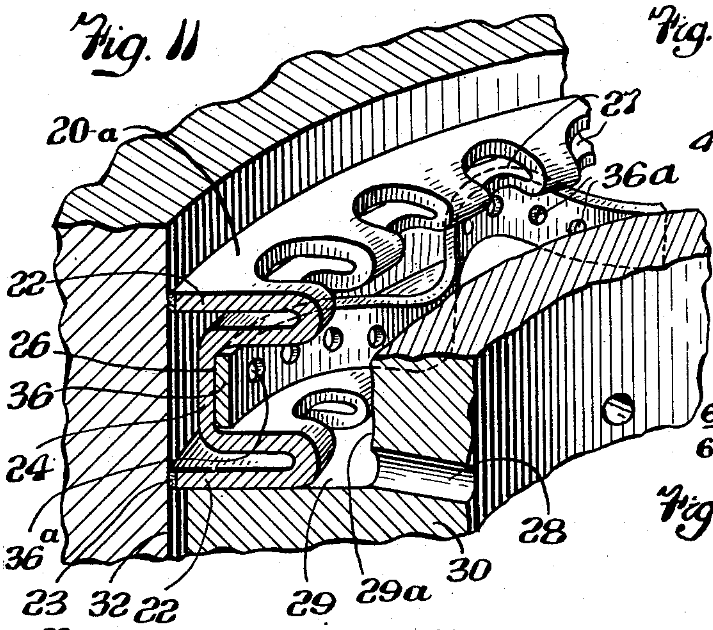

Fig. 11

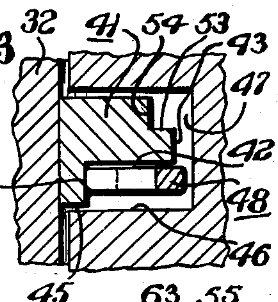

Fig. 13

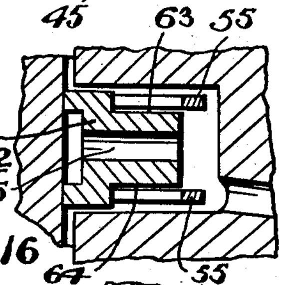

Fig. 16

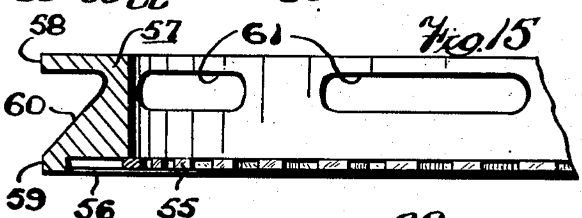

Fig. 15

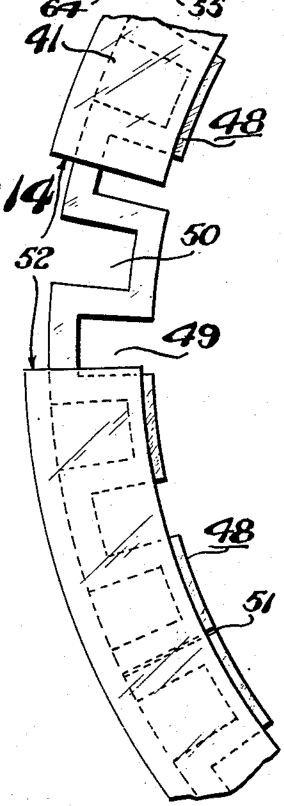

Fig. 14

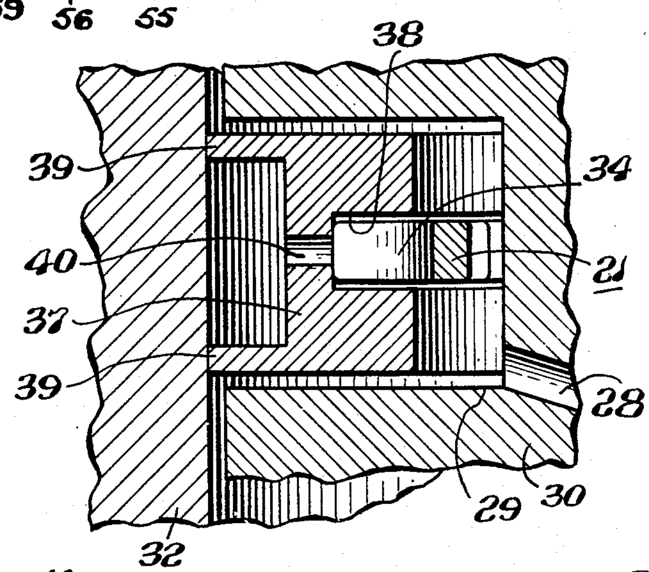

Fig. 12

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Patented Feb. 2, 1954

2,668,088

UNITED STATES PATENT OFFICE

2,668,088

PISTON RING AND EXPANDER THEREFOR

Hsia-Si Pien, Drexel Hill, Pa., assignor to Wilkening Manufacturing Company, Philadelphia, Pa., a corporation of Delaware

Application March 20, 1948, Serial No. 16,054

5 Claims. (Cl. 309—29)

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The present invention relates to piston-rings for internal-combustion engines, diesel engines or the like, and it relates more particularly to piston-rings which are used for oil-control.

An object of the present invention is to provide a new and improved piston-ring and particularly an oil-control piston-ring for internal-combustion engines, diesel engines or the like. Another object of the present invention is to provide an oil-control piston-ring which is relatively simple and inexpensive to manufacture and which has good peripheral pressure distribution and sectional pressure distribution characteristics, and which provides efficient oil-scraping and oil-circulating action not readily impaired by carbon formation, and which is easy to install upon a piston and within a cylinder and which is relatively long-wearing and effective even in relatively worn or out-of-round cylinders.

Other objects and advantages of the present invention will be apparent in the following detailed description, appended claims and accompanying drawings.

As is well-known in the art, modern internal-combustion engines, diesel engines or the like employ one or more oil-control piston-rings in the lowermost groove or grooves of the piston for the purpose of wiping lubricating oil from the cylinder wall and returning it (through openings in the oil-control ring and drainage apertures extending from the piston groove) to the crankcase.

Among the many different types of oil-control piston-rings which have been suggested in the past is that disclosed in Patent 1,911,736 which consists of a trans-split apertured annulus of cast-iron or the like, which has no appreciable transverse flexibility and which has only relatively limited circumferential flexibility and which is maintained in resilient contact with the cylinder wall by an inner annular expander spring which is radially-corrugated so that it contacts the inner periphery of the ring and also "bottoms" against the inner or back-wall of the piston groove. While the oil-control ring shown in Patent 1,911,736 has proved commercially satisfactory for many years and has been used in extremely large numbers, I believe that improved performance can be obtained by the novel oil-control ring of my present invention in that more efficient oil-control is possible and, in addition, the need for accurately dimensioning the back-wall of the piston groove in order to obtain the proper ring pressure is eliminated.

Various types of resilient sheet-metal oil-control piston-rings have also been suggested heretofore but none of these has proven entirely satisfactory, primarily because the performance of these resilient sheet-metal rings has been unpredictable and subject to considerable variations.

The present invention contemplates a new and

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improved construction for oil-control piston-rings which combines the advantages of greater sheet-metal flexibility (with improved oil-wiping and oil-control action) with greater uniformity of pressure and consistency of operation such as heretofore not obtainable in sheet-metal oil-control piston-rings.

Generally speaking, the present invention comprises a composite two-piece oil-control piston-ring which includes an outer unitary ring-portion of flexible but non-resilient sheet-metal, generally W-shaped in axial cross-section (the free arms of the W providing upper and lower axially-spaced cylinder-contacting walls or flanges or lands, and the intervening portion of the W being formed as a rounded loop or groove portion terminating short of the outer periphery of the cylinder-contacting flanges), and a separate inner expander spring consisting of an annular ring of relatively thicker resilient metal disposed generally in a radial plane of the outer ring-portion and dimensioned to fit behind and within the center loop or groove of the W-shaped outer ring-portion so as to urge it outwardly against the cylinder wall when installed upon a piston and within a cylinder (the expander spring being provided with peripheral notches disposed alternately at the outer and inner peripheries, whereby it is more or less continuously S-shaped in radial cross-section and whereby it is provided with the necessary flexibility as well as elasticity to insure uniform peripheral and sectional pressure distribution on the outer ring.

For the purpose of illustrating the invention, there are shown in the accompanying drawing forms thereof which are at present preferred, although it is to be understood that the various instrumentalities of which the invention consists can be variously arranged and organized and that the invention is not limited to the precise arrangements and organizations of the instrumentalities as herein shown and described.

Referring to the accompanying drawings in which like reference characters indicate like parts throughout:

Fig. 1 represents a perspective view of one embodiment of the present invention with the outer ring and the expander shown in the relationship which they would bear when installed upon a piston and within a cylinder.

Fig. 2 represents a fragmentary plan view, on an enlarged scale, of the embodiment of Fig. 1; parts being broken away, better to reveal the construction thereof.

Fig. 3 represents a vertical cross-sectional view taken generally along the line 3—3 of Fig. 2 but showing how the oil-control piston-ring would appear in relation to the piston and cylinder.

Fig. 4 represents a cross-sectional view generally like that of Fig. 3 but taken along line 4—4 of Fig. 2.

Fig. 5 represents a cross-sectional view generally like that of Fig. 3 but showing, schematically, the manner in which oil is wiped from the cylinder wall and is transferred radially inwardly therefrom through the oil-drain openings in the ring.

Fig. 6 represents a fragmentary elevational view showing the sheet-metal blank from which the outer ring-portion is formed by subsequent shaping and other operations.

Fig. 7 represents a schematic perspective view showing an elongated strip of resilient steel going through the slot-punching and coiling operations as preliminary stages in the formation of the expander-spring.

Fig. 8 represents a schematic plan view indicating the uniform peripheral pressure distribution developed by the expander-spring of the present invention.

Fig. 9 represents a more or less schematic cross-sectional view showing the position of the oil-control ring of the present invention as it appears at the start of the downward stroke of the piston.

Fig. 10 represents a cross-sectional view like that of Fig. 9 but showing a tilting of the cylinder-contacting flanges or lands as a result of the various forces acting thereon during the downward movement of the piston.

Fig. 11 represents a fragmentary view, partly in perspective and partly in cross-section, showing the outer-ring of Fig. 1 used with a different type of expander-spring.

Fig. 12 represents a vertical cross-sectional view showing the expander spring of Fig. 1 used with another type of oil-control ring.

Fig. 13 represents a vertical cross-sectional view of another embodiment of the present invention showing the S-shaped expander used with a compression piston-ring.

Fig. 14 represents a fragmentary top plan view of the ring-and-expander of Figure 13.

Fig. 15 represents a view, partly in cross-section and partly in elevation showing the novel expander of the present invention used with another type of cast oil-control piston-ring.

Fig. 16 represents a vertical cross-sectional view generally like that of Figure 12 but showing a modified construction wherein two axially-spaced expanders are used in conjunction with a cast oil-control piston-ring.

In one embodiment of the present invention shown generally in Fig. 1, I may provide a composite two-piece oil-control piston-ring made up of an outer apertured ring **20** of non-resilient flexible sheet-steel or the like which is bent and folded into a general W-shaped cross-sectional configuration, and an expander-spring **21** of tempered spring-steel formed into a resilient trans-split annulus, notched alternately at its outer and inner peripheries to provide uniform outward pressure when installed radially inward and behind the center loop or groove of the W-shaped ring **20**.

The ring **20** is integrally formed and includes substantially identical upper and lower annular flanges or cylinder-contacting lands or shoulders **22** which lie in generally parallel radial planes, and which may be chrome-plated along their outer peripheries as at **23**.

The outer ring **20** also includes a reversely-bent annular portion **24** terminating short of the outer edges of the flanges **22** thereby to provide a more or less W-shaped configuration, when viewed in axial cross-section.

The middle portion **24** is preferably formed with generally right-angle bends so that its upper and lower sides **25** normally lie in radial plane generally parallel to the planes of the flanges **22** and so that its outer side **26** normally extends generally axially at right-angles to the planes of the sides **25**.

Upper and lower rows of circumferentially distributed openings **27** are provided in the ring **20**; the openings **27** being symmetrically and uniformly placed relative to the center-line of the ring and with each pair of upper and lower openings extending from points spaced from the free edges of the flanges **22**, and inward and across the innermost bent edges thereof and outward a short distance along the sides **25** of the middle portion or groove **24**, as shown particularly in Figs. 3 and 4.

As will be described more fully hereinbelow, the openings **27** provide oil-drain passageway whereby lubricant wiped from the cylinder wall by the flanges **22** can pass radially inward through the ring and can be returned to the crank-case through oil-drain passageways **28** extending inwardly from the groove **29** of a piston **30** as indicated particularly in Fig. 5.

The ring **20** is formed as a trans-split annulus having a gap **31** which is closed when the free ends of the ring are brought into abutment during installation of the ring within the piston groove **29** and which thereafter opens slightly when the ring **20** is expanded into contact with the cylinder wall **32** by the expander spring **21** as will be more fully described hereinbelow.

The expander-spring **21**, as mentioned hereinabove, is formed from a length of tempered spring steel having generally rectangular cross-section, as indicated particularly in Fig. 7, along the inner and outer peripheries of which slots **33** and **34** respectively are formed in alternate relationship.

The thickness or axial dimension of the expander spring **21** is slightly less than the distance intervening the upper and lower sides **25** of the middle portion or groove **24** of the ring **20** so that the spring **21** can fit within and behind said middle portion or groove with a slight top and bottom clearance as shown particularly in Figs. 3 and 4.

As also indicated particularly in Figs. 3 and 4, the transverse or radial dimension of the expander spring **21** may be generally the same as the radial distance from the axial side **26** of the middle portion or groove **24** and the inner periphery of the outer ring **20** and the radial dimension of the outer slots **34** is somewhat greater than that of the outer uninterrupted portions of the upper and lower sides **25** so that, as indicated in Figs. 2 and 3, there are continuous axial and radial passageways across the assembled ring-and-expander through the openings **27** and slots **34**.

The expander-spring **21** is also formed as a trans-split annulus having a gap **35** formed by juxtaposed free ends and provides more or less uniform peripheral pressure distribution when assembled with the piston-ring, within a cylinder, so that it is compressed from its free dimension, with its ends in general abutting relationship.

It is desirable, when assembling the composite two-piece piston-ring of the present invention, to position the gap **35** of the expander **21** at a point somewhat circumferentially spaced from the gap **31** of the ring **20**, as indicated, for example, in Fig. 2.

It is possible to construct the expander-spring as a radially-corrugated wire member or the like instead of forming the corrugations by cutting slots on alternate sides of a continuous strip of metal, as described hereinabove, in a manner analogous to that disclosed in Wilkening Patent 2,293,450.

However, we prefer to employ the slotted form of construction shown in Fig. 2, as distinguished from the bent-wire construction, since the former has been found to give better and more dependable results as an expander-spring.

The expander-spring may be formed in the manner shown schematically in Figure 7, by first forming an elongated strip of tempered spring steel, thereafter punching the inner and outer slots **33** and **34** using any suitable punch-press, subsequently winding the punched strip into a helical coil using any suitable winding machine, and finally cutting the coil axially to form a plurality of trans-split annuli. Appropriate heat-treating and grinding operations may also be employed in a manner well known in the art.

While, in Figure 7, the punch-press P is shown schematically as having a pair of oppositely-directed dies D_1 and D_2 so that an inner slot **33** and an outer slot **34** are formed in a single punching operation, it is apparent that this could be varied to use only a single die or to use a larger number of dies.

The installation of the ring upon a piston and within the cylinder is extremely simple. Thus, the expander-spring **21** is placed within the middle portion or groove **24** of the ring **20**, with the gap **35** displaced somewhat from the gap **31**. The spring-and-expander are opened somewhat to fit over the piston and are then placed into the groove of the piston whereupon the ring collapses the expander into the groove after which any conventional type of compressor is used to fit the piston into the cylinder.

The ring-and-expander spring is so dimensioned relative to the cylinder that the expander will exert a radially outward pressure upon the ring maintaining it in firm, more or less uniform, peripheral contact with the cylinder wall, thereby providing a more or less "free-floating" resilient support for the ring, without the need for support from the back or innermost wall of the piston groove.

With the expander compressed by the ring in the cylinder, equal and directly opposite tangential forces F and F′ are produced at the gap **35**, as indicated schematically in Fig. 8; the forces F and F′ in turn developing a uniform pressure around the circumference of the expander (see Prescott's "Applied Elasticity" page 293; Dover Publication 1946 edition), due to the fact that the ring and the expander take the form of the cylinder wall and due to the further fact that the expander provides the entire support for the ring and is completely free from the piston-groove, so that its pressure is exerted completely upon the cylinder wall through the ring **20**.

Since the axial dimensions from the center point of the middle portion or groove **24** to the upper and lower flanges **22** are the same (so that the pressures p_1 and p_2 exerted by the flanges upon the cylinder wall are equal and together make up the total outward pressure P of the expander-spring at that point as indicated schematically in Fig. 10), and due to the fact that the radial dimension from the expander-ring contact-point to the cylinder wall is extremely small, the pressures exerted by both of the flanges or lands against the cylinder wall are uniform, within very close tolerance.

The novel ring of the present invention exerts an extremely effective oil-scraping action upon the cylinder wall. Thus, for example, during the downward or power stroke of the piston, the ring is first transferred to the upper wall of the piston groove as indicated schematically in Fig. 9.

Further downward movement of the piston creates a tilting force tending to rotate the upper flange of the ring to the position shown in Fig. 10.

This tilting force results from the downward pressure R exerted upon the upper flange by the top wall of the piston at a zone spaced somewhat inwardly from the outer peripheral edge. The radial outward pressure P exerted by the expander spring, splits up into two equal forces p_1 and p_2 acting on the cylinder wall through the upper and lower flanges as mentioned above, which in turn generate resistance against downward movement represented by upwardly-directed forces r_1 and r_2, at the extreme peripheries of the flanges.

It is obvious that the net effect of the forces R and r_1 upon the upper flange will result in the tilting of the flange clockwise relative to its outer periphery from the horizontal position of Fig. 9 to the inclined position of Fig. 10.

The extent of this tilting or deformation of the section depends upon the pressure P, the speed of the piston, the coefficient of friction between the cylinder wall and the flange and the flexibility of the section.

In the novel oil-control ring of the present invention much greater flexibility than is possible with conventional rings is attained by reason of the very great linear length of the section (resulting from the reversely-curved W-shaped configuration).

Due to this extremely great flexibility, the lower flange, too, tends to tilt clockwise about its periphery as indicated in Fig. 10 so as to give effective oil-scraping at both flanges.

It is apparent, that in less flexible constructions, there would be no appreciable tilting of the lower flange or land and that, therefore, the oil-scraping action would be less efficient.

As indicated in the schematic view of Fig. 5, the efficiency of oil-circulation is also improved by the novel construction of the present invention.

Thus, it has been found that the transfer of oil through an oil-control ring takes place primarily in the form of a film adhering to the surfaces of the ring.

As can be seen from Fig. 5, the novel oil-control piston ring of the present invention provides four such guiding-surfaces for the transfer of the oil (namely, the upper and lower sides of the middle portion or groove **24** as well as the upper and lower flanges **22**) as distinguished from conventional oil-control piston rings wherein only the upper and lower flanges or lands provide oil-guiding surfaces.

The present oil-control piston ring is also advantageous in that there is no appreciable tendency toward the stiffening action which frequently results in conventional constructions as the result of carbon formation on the expander-spring.

Thus, the continuous proximity of the axial sides of the expander-spring with the axial sides of the ring groove prevents substantial variation in the values of p_1 and p_2 as a result of carbon formation on the axial sides of the expander since, in such case, the expander pressure is simply transmitted through the intervening carbon layers as well as through the middle portion 24 of the ring groove. Moreover, the flexing action of the section, as described above, prevents any substantial accumulation of carbon on the axial sides of the expander-spring.

The flexing action also aids in preventing an accumulation of carbon on the outside diameter of the expander spring, this last-mentioned action being further aided by the fact that any accumulation of carbon on the outside diameter would result in increase of pressure at that point between the outside diameter and the axial-wall 26 of the groove 24 which would tend to break up the carbon particles so that the flow of oil can carry them away.

It should also be noted that the formation of carbon on the inside diameter of the expander-spring does not affect the pressure of the expander because the inside diameter is a "free-floating" surface which is not in contact with any support. This is in contrast to the conventional "bottoming" radially-corrugated expanders which contact the back-wall of the piston groove and, accordingly, are adversely affected by the formation of carbon on their inner peripheries.

The chrome-plating of the peripheries of the cylinder-contact flanges lengthens the life of the ring by reducing wear and friction and also give smoother operation. It is obvious, of course, that these peripheries could be electro-plated with other metals (or alloys) than chromium; as, for example, cadmium, nickel, silver, etc. It is also apparent that this protective metal coating, instead of being deposited by electro-plating, can be applied in other ways, as for example by spraying, dipping, etc.

While the outer ring 20 of the present invention is intended primarily for use with the non-bottoming "free-floating" expander-spring 21, it can also be used with conventional radially-corrugated expander-springs.

Thus, in Fig. 11, I have shown a ring 20–*a* (which is identical with the ring 20 described above except that its groove portion 24 has a relatively larger axial dimension) installed with an axially-corrugated expander-spring 36 which bottoms against the back or inner-wall 29–*a* of the groove 29 of the piston 30; alternate bends of the expander 36 contacting the axial wall 26 of the ring groove portion 24 of the ring 20–*a* so as to exert radially outward pressure upon it, thereby to maintain it in contact with cylinder wall 32.

The expander-spring 36 may be generally of the same type as that disclosed in Patent 1,911,736 except that it has a smaller axial dimension and a deeper radial corrugation to permit it to fit into the ring groove portion 24. The expander-spring 36 may be provided with openings 36–*a* to facilitate the flow of oil thereacross and into the passageways 28 leading from the piston groove 29, although these openings may be omitted, since the oil can pass above and below the spring through the opening 27.

It is apparent that still other types of conventional expander-springs can be used to support the outer ring 20 although, as stated above, we prefer to utilize the novel expander-spring 21 disclosed herein.

Similarly, novel expander-spring 21 of the present invention, while intended primarily for use with the sheet-metal piston-ring 20 or with the piston-ring shown in my co-pending application Ser. No. 16,055 filed simultaneously herewith, now Patent No. 2,531,784, can also be used with other types of piston-rings.

Thus, in Fig. 12, I have shown the expander-spring 21 used with an apertured cast-iron oil-control ring 37 which is generally like that of Patent 1,911,736 except that a groove 38 is formed on its inner periphery into which the outer periphery of the expander spring 21 fits; the groove 38 having a lesser radial dimension than the outer slots 34 of the expander-spring 21 so that oil scraped from the cylinder wall 32 by the flanges 39 of the ring 37 can pass through the oil-drain openings 40 of said ring 37 and into the piston groove 29 and the passageways 28.

It is obvious that the novel expander-spring of the present invention could be used with other types of non-resilient piston-rings, both oil-control and compression rings.

Thus, in Figures 13 and 14, the S-shaped expander 48 of the present invention is shown as used with a compression ring 41 which may be of cast-iron or steel or the like and which may have an annular groove extending along its underside and formed by a radial wall extending from the inner edge 43 of the ring and a cylindrical wall 44 extending axially intermediate the outer edge of the wall 42 and the bottom wall 45 of the ring 41; the groove extending for substantially more than half the radial dimension of the piston-ring. As can be seen particularly in Figure 13, the radial wall 42 is preferably slightly smaller in radial dimension than the expander-spring 21 while the wall 44 is slightly greater in axial dimension than the spring 48.

The inner edge of the ring 41 may also be provided with an upper groove formed by an annular wall 53 extending radially inward for a relatively short distance and a cylindrical wall 54. This upper groove is for the purpose of more or less equalizing the pressure of the ring by balancing the lower expander-contained groove. However, the upper groove may be omitted, if desired.

The expander spring 48 is retained in place within the lower groove by the lower wall 46 of the piston groove 47 (which does not have any oil-drain openings as in the case of the oil control groove 29).

As indicated particularly in Figure 14, the expander spring 48 is generally like the spring 21 described heerinabove except that the inner and outer slots 49 and 50 are formed by angularly related walls instead of being curved at their inner edges.

The gap 51 of the expander spring 48 is preferably somewhat circumferentially displaced from the gap 52 of the ring 43.

In Figure 15 there is shown a radially-corrugated expander 55 generally like those described hereinabove except that it is reduced in transverse or axial dimension and is adapted to be fitted within the relatively narrow back groove 56 of a trans-split cast-iron oil-control piston-ring 57.

The piston ring 57 includes upper and lower cylinder-contacting lands 58 and 59 connected by an upwardly and inwardly inclined annular wall 60; a plurality of elongated circumferentially-spaced oil-drain slots 61 extending radially through the ring at the narrowest portion thereof (adjacent the upper end of the wall 60).

In Figure 16 there is shown a trans-split cast-iron oil-control piston-ring 62 which is generally like the ring 37 of Figure 12 except that relatively narrow upper and lower annular grooves

63 and 64 are provided at the inner edge of the ring (above and below the central oil-drain openings 65) to receive a pair of relatively thin radially-corrugated expanders 55 like that shown in Figure 15.

The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof, and it is therefore desired that the present embodiments be considered in all respects as illustrative and not restrictive, reference being had to the appended claims rather than to the foregoing description to indicate the scope of the invention.

Having thus described my invention, I claim as new and desire to protect by Letters Patent:

1. For use with a flexible but relatively non-resilient one-piece piston-ring having an annular groove formed in its inner periphery, a non-bottoming expander-spring comprising a trans-split annulus of resilient metal or the like which is radially-corrugated and which has its free ends constructed and arranged to be maintained in generally abutting relationship so that, when compressed, the expander-spring will provide generally uniform radially-outward pressure, the corrugations providing substantial circumferential clearances at the inner periphery of said expander-spring thereby to allow appreciable compression of said expander-spring without metal-to-metal contact at said inner periphery, the axial dimension of the expander-spring being somewhat less than that of the piston-ring groove whereby slight axial clearances are provided intermediate the expander-spring and the walls of the groove.

2. For use with a flexible but relatively non-resilient one-piece piston-ring having an annular groove formed in its inner periphery, a non-bottoming expander-spring comprising a trans-split annulus of resilient metal or the like which is radially-corrugated and which has its free ends constructed and arranged to be maintained in generally abutting relationship so that, when compressed, the expander-spring will provide generally uniform radially-outward pressure, said expander-spring having appreciable axial dimension and having still larger radial dimension in cross-section, the corrugations providing substantial circumferential clearances at the inner periphery of said expander-spring thereby to allow appreciable compresison of said expander-spring without metal-to-metal contact at said inner periphery, the axial dimension of the expander-spring being somewhat less than that of the piston-ring groove whereby slight axial clearances are provided intermediate the expander-spring and the walls of the groove.

3. For use with a flexible but relatively non-resilient one-piece piston-ring having an annular groove formed in its inner periphery, a non-bottoming expander-spring comprising a trans-split annulus of resilient metal or the like which is radially-corrugated and which has its free ends constructed and arranged to be maintained in generally abutting relationship so that, when compressed, the expander-spring will provide generally uniform radially-outward pressure, said expander-spring having appreciable axial dimension and having still larger radial dimension in cross-section and being formed from a curved strip of metal having slots formed alternately at its outer and inner edges, said slots having substantial circumferential dimension at said edges thereby to permit appreciable compression of said expander-spring without abutment of the sides of said slots, the axial dimension of the expander-spring being somewhat less than that of the piston-ring groove whereby slight axial clearances are provided intermediate the expander-spring and the walls of the groove.

4. For use with a flexible but relatively non-resilient one-piece piston-ring having an annular groove formed in its inner periphery, a non-bottoming expander-spring comprising a trans-split annulus of resilient metal or the like which is radially-corrugated and which has its free ends constructed and arranged to be maintained in generally abutting relationship so that, when compressed, the expander-spring will provide generally uniform radially-outward pressure, said expander-spring having appreciable axial dimension and having still larger radial dimension in cross-section and being formed from an elongated curved strip of metal having generally rectangular cross-section and having radially-extending slots formed alternately at its inner and outer edges, said slots having substantial circumferential dimension at said edges thereby to permit appreciable compression of said expander-spring without abutment of the sides of said slots, the axial dimension of the expander-spring being somewhat less than that of the piston-ring groove whereby slight axial clearances are provided intermediate the expander-spring and the walls of the groove.

5. For use with a flexible but relatively non-resilient one-piece piston-ring having an annular groove formed in its inner periphery, a non-bottoming expander-spring comprising a trans-split annulus of resilient metal or the like which is radially-corrugated and which has its free ends constructed and arranged to be maintained in generally abutting relationship so that, when compressed, the expander-spring will provide generally uniform radially-outward pressure, said expander-spring having appreciable axial dimension and having still larger radial dimension in cross-section and being formed from an elongated curved strip of radially-corrugated wire or the like, the corrugations providing substantial circumferential clearances at the inner periphery of said expander-spring thereby to allow appreciable compression of said expander-spring without abutment of the sides of said corrugations, the axial dimension of the expander-spring being somewhat less than that of the piston-ring groove whereby slight axial clearances are provided intermediate the expander-spring and the walls of the groove.

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