



(43) International Publication Date  
2 October 2014 (02.10.2014)

- (51) International Patent Classification:  
*B23P 15/06* (2006.01) *F16J 9/02* (2006.01)
- (21) International Application Number:  
PCT/US2014/019714
- (22) International Filing Date:  
1 March 2014 (01.03.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:  
13/827,255 14 March 2013 (14.03.2013) US
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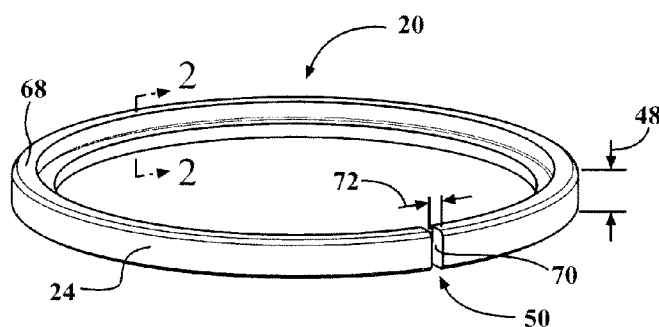
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: DYKES-TYPE PISTON RINGS AND METHOD FOR MANUFACTURING THE SAME



**FIG. 1**

(57) Abstract: The invention provides a dykes-type piston ring (20) having a finished outer diameter and negligible tangential tension. The method includes the steps of machining a stock bar to an initial outer diameter slightly greater than the finished outer diameter of the piston ring (20), finishing the initial outer diameter of the stock bar to a rounded profile having a nominal diameter equal to the finished outer diameter, and machining the stock bar to the preferred cross-section. Dykes-type piston rings can have keystone or semi-keystone shaped cross-sections. The method continues by detaching the piston ring (20) from the stock bar using a parting tool in response to completing all tension inducing operations including the steps recited above. The method continues with the steps of lapping the piston ring to a final longitudinal thickness (48) and cutting the piston ring longitudinally to form a final gap (50).



WO 2014/158734 A1

## **DYKES-TYPE PISTON RINGS AND METHOD FOR MANUFACTURING THE SAME**

### **TECHNICAL FIELD**

**[0001]** The subject invention provides a method for manufacturing a low tension piston ring, specifically a dykes-type piston ring having a finished outer diameter and negligible tangential tension.

### **BACKGROUND**

**[0002]** Piston rings are a critical component of an internal combustion engine. The engine includes at least one cylinder and piston. Piston rings are metallic seals disposed between the cylinder wall and the piston to seal the combustion chamber from the crankcase and facilitate heat transfer from the piston to the cylinder. Other functions of piston rings are to prevent the oil not needed for lubrication from passing from the crankcase to the combustion chamber and to provide a uniform oil film on the cylinder bore surface. To achieve this, the piston rings must remain in contact with the cylinder and the piston. Radial contact is generally achieved by means of the inherent spring force of the piston ring. Piston rings are also employed as metallic seals for rotating shafts and are used both as contracting and expanding seals.

**[0003]** Today, piston rings are typically manufactured in one of two ways. In one method, the piston rings are cast as individual rings in a noncircular shape. Such rings are then typically machined to the required shape by means of double cam turning, a process in which the ring blank, already axially ground, is cam turned simultaneously on the inside and outside diameters. After a segment equivalent to the free gap is cut from the piston ring, it assumes the free shape that will give it the required radial pressure distribution when fitted into the cylinder. Once inside the cylinder, the piston ring exerts the predefined radial pressure against the cylinder wall. Besides using double cam turning, ring blanks may also be shaped

by machining the inside and outside diameters separately. This involves cam turning the outside diameter of the noncircular blank and machining the inside diameter with the piston ring in the compressed state. The free gap is cut out in a step between the outer diameter and inner diameter machining.

**[0004]** According to a different method, steel piston rings are made from a profiled wire. The rings are first coiled into a circular shape and then the gap is cut out. The necessary shape is obtained using a heat treatment process in which the rings are mounted onto an arbor appropriately designed to impart the required radial pressure distribution. Profiling of the outer diameter is carried out, depending on the piston ring design, on automatic outer diameter lathes or profile grinding machines using profile cutting tools.

**[0005]** The problem with manufacturing piston rings according to the methods described above is that the piston rings are produced with residual tangential tension. Production of piston rings with residual tangential tension is problematic because such piston rings have a tendency to twist or warp. Such ring twist or warp may lead to excessive oil consumption and blow-by, a condition where combustion gasses escape from the combustion chamber by passing along the piston between the piston rings and the cylinder wall. Accordingly, piston rings with residual tangential tension may adversely affect the efficiency, the performance, the emissions, and/or the reliability of the engine.

**[0006]** Methods aimed at producing piston rings with reduced tendency to twist or warp have been developed. One such method includes the step of heat treating a stock bar made of cast iron at a high temperature, for example 1100° Fahrenheit (593.33° Celsius), to remove foundry strains and hard spots. After the stock bar is heat treated, piston ring blanks are cut from the stock bar. Once the piston ring blanks are detached from the stock bar, the method continues with the steps of conventional machining and finishing the piston ring blank to final outer and inner diameters. The last step is cutting a final free gap into the piston ring.

Although this method produces rings having less of a tendency to twist or warp, significant tangential tension still remains in the piston rings.

[0007] What is needed is a method of manufacturing piston rings wherein only a negligible amount of residual tangential tension remains in the finished products. Without residual tension, the rings will not have a tendency to twist or warp. Residual tension is especially a concern with piston rings with unconventional cross-sections, such as dyke-type piston rings which have an L-shaped cross-section.

[0008] Dykes type piston rings allow for better sealing at higher engine speeds and combustion pressures. However, the asymmetrical shape of the dykes type piston ring results in a piston ring that is more prone to twist or warp than conventional piston rings. Accordingly, there is a need for piston rings, particularly dykes-type piston rings with negligible tangential tension.

#### SUMMARY OF THE INVENTION

[0009] In accordance with a preferred embodiment of the invention, a piston ring is detached from a stock bar using a parting tool after completing all tension inducing operations including the steps of machining the stock bar to the initial outer diameter, finishing the stock bar to a predetermined profile, and machining the stock bar to a predetermined cross-section. The piston ring is not separated from the stock bar until after all of the machining and finishing steps have been completed. In this manner, the stresses associated with the machining and finishing operations are borne by the thicker stock bar before the piston ring is separated.

[0010] As to dykes-type piston rings in particular, the subject invention can provide a dykes-type piston ring including an annular ring body having a measurable tangential tension ranging from zero to 25 Newtons in a free and uncompressed state. In accordance with this design, the dykes type piston ring defines a final gap having a gap width measurable between

a pair of lateral faces ranging from zero to 0.4 millimeters when the annular ring body is in its free and uncompressed state.

[0011] These and other features and advantages of the present invention will be readily appreciated, as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1 is a perspective view of an exemplary dykes-type piston ring.

[0013] Figure 2 is a cross-sectional view of the exemplary dykes-type piston ring.

[0014] Figure 3 is a perspective view of an exemplary dykes-type piston ring experiencing a condition known as piston ring warp or piston ring twist.

[0015] Figures 4-6 are perspective views illustrating steps of machining a stock bar to form a piston ring.

[0016] Figure 7 is a perspective and elevation view illustrating an exemplary step of machining the stock bar to an L-shaped cross-section;

[0017] Figure 8 is a perspective and elevation view illustrating an exemplary step of detaching the piston ring from the stock bar;

[0018] Figure 9 is a perspective view illustrating an exemplary step of lapping the piston ring to a final longitudinal thickness;

[0019] Figure 10 is a perspective and elevation view illustrating an exemplary step of cutting the piston ring longitudinally to form a final gap; and

[0020] Figure 11 is a perspective view illustrating an exemplary step of installing the piston ring on a mandrel to size the final gap to a predetermined dimension during heat treating.

[0021] Figures 12 and 13 illustrate exemplary pistons with traditional piston rings and with dykes-type piston rings, respectively.

## DETAILED DESCRIPTION OF THE EMBODIMENT

[0022] Figure 12 illustrates a conventional piston **100** with traditional piston rings **18** mounted on it. Figure 13 illustrates a piston **200** with dykes-type piston rings **20** positioned on it.

[0023] In the Figures, like numerals indicate corresponding parts throughout the several views. In Figures 1 and 2, a dykes-type piston ring **20** having a finished outer diameter is presented. It should be appreciated that the piston ring **20** is circular in shape and has a circumference **24**. The finished outer diameter extends along the circumference **24**.

[0024] A preferred method embodiment of the subject invention is shown in Figures 4-6. The method includes the steps of machining a stock bar **26** to an initial outer diameter **28** slightly greater than the finished outer diameter of the piston ring **20**, finishing the initial outer diameter of the stock bar **26** to a predetermined profile **30** having a nominal diameter **32**. The diameter **32** is equal to the finished outer diameter **22**. The stock bar **26** is also machined to form a structure with an L-shaped cross-section. The method continues with the step of detaching the piston ring **20** from the stock bar **26** in response to completing all tension inducing operations including the steps of machining the stock bar **26** to the initial outer diameter **28**, finishing the stock bar **26** to a predetermined profile **30**, and machining the stock bar **26** to an L-shaped cross-section **34**.

[0025] It has been found that machining and finishing operations typically leave residual tensile forces in thin work pieces such as piston rings. This residual tension arises in a tangential direction with respect to the circumference of the piston rings. As a result, the piston rings are prone to twist or warp around the circumference when constrained in the cylinder of an internal combustion engine. This is shown in exaggerated form in Figure 3.

[0026] With the present invention where the piston ring is not separated from the stock bar **26** until after all of the machining and finishing steps have been completed, the stresses

associated with the machining and finishing operations are borne by the thicker and more rigid stock bar **26**. It has been found that the tangential tension induced by the machining and finishing operations can be better controlled and minimized in this manner. As a result, the piston ring **20** has only a negligible amount of tangential tension when it is detached from the stock bar **26** in comparison to the prior art.

[0027] Piston ring twist or warp is particularly harmful in applications that utilize dykes-type piston rings due to the asymmetrical ("L-shaped") cross-sectional shapes of the rings.

[0028] According to one aspect of the subject invention for manufacturing dykes-type piston rings, the method step of machining the stock bar to an L-shaped cross-section may include machining a lip section extending longitudinally and a tail section extending radially inwardly from the lip section. The tail section may be machined to present a keystone shaped cross section defined by one or two inwardly tapering sides.

[0029] The method of finishing the initial outer diameter of a stock bar to a predetermined profile having a nominal diameter equal to the finished outer diameter may include finishing the initial outer diameter of the stock bar to a predetermined profile having a variety of shapes. The predetermined profile may have a rounded shape. With a symmetrical or asymmetrical curve profile. For example, as shown in Figure 6, the exemplary rounded profile asymmetrical curve profile can be defined by a pair of arcs **42** converging at a tangent point **44**. The arcs **42** may have different radii. Alternatively, the predetermined profile may have a flat linear shape arranged along the longitudinal direction or sloped at an angle relative to the longitudinal direction. Regardless of the shape of the predetermined profile, the term "nominal diameter", as it is used herein, designates the maximum outer diameter of the predetermined profile.

[0030] In one preferred embodiment, the step of machining a stock bar **26** to an initial outer diameter **28** slightly greater than the finished outer diameter **22** of the piston ring **20**

may include machining the stock bar **26** such that the initial outer diameter **28** is between 0.4 mm and 3.0 mm larger than the finished outer diameter **22** of the piston ring **20**. In this way, the profiling step may be completed more quickly as less material is removed by profiling when the initial outer diameter **28** of the stock bar **26** is close to the finished outer diameter **22** of the piston ring **20**. Additionally, the profiling step induces less tangential tension on the stock bar **26** when only a small thickness of material has to be removed.

**[0031]** The method may further include the steps of lapping the piston ring **20** to a final longitudinal thickness and cutting the piston ring **20** longitudinally to form a final gap **50**. It should be appreciated that the lapping step may include rubbing the piston ring **20** with an abrasive. The lapping step may include using a dual action lapping machine (not shown) having a rotating lapping pad presenting an abrasive surface. The piston ring and the lapping pad may be rotated in opposite directions and the piston ring **20** may be reciprocated back and forth in a transverse direction across the rotating lapping pad.

**[0032]** As shown in Figures 9 and 10, the cutting step may include using a circular saw blade **56** to make a longitudinal cut through the entire L-shaped cross-section of the piston ring **20** to form the final gap **50**. The final gap **50** need only be sufficient in size so as to prevent end butting of the piston ring **20** at the operational temperatures of the engine. Accordingly, the final gap **50** of the dykes-type piston ring **20** produced by this method may be many times smaller than the final gap of conventional piston rings.

**[0033]** In accordance with the subject invention, the method may further include the step of heat treating the piston ring **20** by placing the piston ring **20** in a non-oxidizing atmosphere between 400-450° Celsius to relieve any residual tension left in the piston ring **20**. The step of heat treating the piston ring **20** in a non-oxidizing atmosphere may be achieved by baking the piston ring **20** in an oven filled with a non-oxidizing gas such as nitrogen. The method



may further include the step of installing the rings on a mandrel **58** to size the final gap **50** to a predetermined dimension during the heat treating step. This is shown in Figure 11.

**[0034]** The method step of machining the stock bar to the initial outer diameter may include turning the stock bar relative to a machining tool. Similarly, the step of finishing the initial outer diameter to a predetermined profile may include turning the stock bar **26** relative to a profiling tool **62** (Figure 5). The step of machining the stock bar **26** to the L-shaped cross section may include turning the stock bar **26** relative to a machining tool **60**, and the step of detaching the piston ring **20** from the stock bar **26** may include turning the stock bar **26** relative to a parting tool **64** (Figure 8). As the term is used herein, turning is a specific machining process wherein the piston ring is rotated relative to the tool using a lathe. It should be appreciated that the machining, finishing, and parting steps provided are not limited to turning and can be accomplished using a variety of other tools and operations.

**[0035]** A variety of materials have been found to be suitable for the manufacture of piston rings **20**. According to an aspect of the subject invention, the stock bar **26** can be made of a fine grained spheroidal cast iron. However, it is envisioned that other materials may be used.

**[0036]** It should be appreciated that the method of the subject invention applies not only to the manufacture of low tension dykes-type piston rings, but to the manufacture of other types of low tension piston rings as well. Accordingly, a method for manufacturing a low tension piston ring having a finished outer diameter is also provided. The method includes the steps of machining a stock bar to an initial outer diameter slightly greater than the finished outer diameter of the piston ring, finishing the initial outer diameter of the stock bar to a predetermined profile having a nominal diameter equal to the finished outer diameter, and machining the stock bar to a predetermined cross-section. The method continues with the step of detaching the piston ring from the stock bar in response to completing all tension-inducing operations. These operations include machining the stock bar to an initial outer diameter,

finishing the stock bar to a predetermined profile, and machining the stock bar to a predetermined cross-section. According to one aspect of this method, the step of machining a stock bar to an initial outer diameter slightly greater than the finished outer diameter of the piston ring may include finishing the initial outer diameter of the stock bar to a predetermined profile having a rounded shape. According to another aspect of this method, the step of machining the stock bar to a predetermined cross-section may include machining the stock bar to a keystone shaped cross-section or a semi-keystone shaped cross-section.

[0037] The method described above produces a novel dykes-type piston ring **20** having unique properties. As shown in Figures 1 and 2, the dykes-type piston ring **20** that is produced includes an annular ring body **68** presenting a generally L-shaped cross-section **34**. The L-shaped cross-section **34** is comprised of and defined by a lip section **36** extending longitudinally relative to the ring body **68** and a tail section **38** having a pair of sides **40** extending radially inwardly from the lip section **36**. The annular ring body **68** also presents a pair of lateral faces **70** defining a final gap **50** therebetween. It should be appreciated that the final gap **50** is created by the method step of cutting the detached piston ring **20** longitudinally or discussed above. The pair of lateral faces **70** is arranged such that they face one another in an opposing spaced relationship. The annular ring body **68** has little or no tangential tension, ranging from zero to 25 Newtons (N), in a free and uncompressed state. This range is considerably less than the tangential tension residing in piston rings **20** produced by prior art methods. This low tangential tension also allows the piston ring **20** to have a miniscule final gap **50** in comparison to conventional piston rings including prior art dykes-type piston rings. In accordance with the subject invention, the final gap **50** has a gap width **72** measurable between the lateral faces **70** ranging from zero to 0.4 millimeters when the annular ring body **68** is in its free and uncompressed state. In accordance with another aspect of the subject invention, the gap width **72** may range from zero to 0.1 millimeters

when the annular ring body **68** is in its free and uncompressed state. These ranges are approximately thirty times smaller than the final gap of conventional piston rings.

**[0038]** The dykes-type piston ring **20** of the subject invention may further include a tail section **38** having various shapes. The side of the tail section **38** may each taper inwardly to define a keystone shaped cross-section. Alternatively, one of the sides of the tail section may taper inwardly to define a semi-keystone shaped cross-section. The dykes-type piston ring **20** of the subject invention may further include an outer circumferential surface having a predetermined profile of arcuate shape. The arcuate, or rounded, shape of the predetermined profile may follow a symmetrical or asymmetrical curve. For example, the predetermined profile may follow an asymmetrical curve as shown in Figures 5 and 6 where the curve is defined by a pair of arcs **42** converging at a tangent point **44**. The arcs **42** can have different radii **46**. Alternatively, the predetermined profile **30** may have a flat linear shape arranged along the longitudinal direction or sloped at an angle relative to the longitudinal direction.

**[0039]** Obviously, many modifications and variations of the present invention are possible in light of the above teachings and may be practiced otherwise than as specifically described while within the scope of the appended claims.

What is claimed is:

1. A method for manufacturing a low tension dykes-type piston ring having a finished outer diameter, comprising the steps of:

machining a stock bar to an initial outer diameter;

finishing the initial outer diameter of the stock bar to a predetermined profile having a nominal diameter that is less than the initial outer diameter;

machining the stock bar to a generally L-shaped cross-section to produce a dykes-type piston ring in accordance with the remaining portions of the stock bar, and

detaching the piston ring from the stock bar, only after completing the steps of machining the stock bar to the initial outer diameter and finishing the stock bar to a predetermined profile and machining the stock bar to an L-shaped cross-section.

2. A method as set forth in claim 1 wherein the predetermined profile has a rounded shape defined by a pair of arcs converging at a tangent point.

3. A method as set forth in claim 1 wherein the L-shaped cross-section includes a lip section extending longitudinally and a tail section extending radially inward from the lip section.

4. A method as set forth in claim 3 wherein the tail section is machined to a keystone shaped cross section.

5. A method as set forth in claim 3 wherein the tail section is machined to a semi-keystone shaped cross section.

6. A method as set forth in claim 1 wherein the initial outer diameter of the stock bar after machining is between 0.4 mm and 3 mm larger than the finished outer diameter of the piston ring.

7. A method as set forth in claim 1 wherein the step of machining the stock bar to the initial outer diameter includes turning the stock bar relative to a machining tool.

8. A method as set forth in claim 1 wherein the step of finishing the initial outer diameter to a predetermined profile includes turning the stock bar relative to a profiling tool.

9. A method as set forth in claim 1 wherein the step of machining the stock bar to the L-shaped cross section includes turning the stock bar relative to a machining tool.

10. A method as set forth in claim 1 wherein the step of detaching the piston ring from the stock bar includes turning the stock bar relative to a parting tool.

11. A method as set forth in claim 1 further comprising the step of lapping the piston ring to a final longitudinal thickness.

12. A method as set forth in claim 1 further comprising the step of cutting the piston ring longitudinally to form a final gap.

13. A method as set forth in claim 12 further comprising the step of heat treating the piston ring by placing the piston ring in a non-oxidizing atmosphere between 400-450 degrees Celsius to relieve any residual tension left in the piston ring.

14. A method as set forth in claim 13 further comprising the step of installing the piston ring on a mandrel to size the final gap to a predetermined dimension during heat treating.

15. A method as set forth in claim 1 wherein the stock bar is made of a fine grained spheroidal cast iron.

16. A method for manufacturing a low tension piston ring having a finished outer diameter comprising the steps of;

machining a stock bar to an initial outer diameter;

finishing the initial outer diameter of the stock bar to a predetermined profile having a nominal diameter that is less than the initial outer diameter;

machining the stock bar to a generally L-shaped cross-section to produce a dykes-type piston ring in accordance with the remaining portions of the stock bar, and

detaching the piston ring from the stock bar, only after completing the steps of machining the stock bar to the initial outer diameter and finishing the stock bar to a predetermined profile and machining the stock bar to an L-shaped cross-section.

17. A method as set forth in claim 16 wherein the predetermined profile has a rounded shape.

18. A method as set forth in claim 16 wherein the predetermined cross-section is keystone shaped.

19. A method as set forth in claim 16 wherein the predetermined cross-section is semi-keystone shaped.

20. A method as set forth in claim 16 wherein the initial outer diameter of the stock bar after machining is between 0.4 mm and 3 mm larger than the finished outer diameter of the piston ring.

21. A dykes-type piston ring comprising;

an annular ring body presenting a generally L-shaped cross-section with a lip section that extends longitudinally relative to said ring body and a tail section with a pair of sides that extends radially inwardly from said lip section,

said annular ring body having a pair of lateral faces defining a final gap therebetween, and

said annular ring body having a measurable tangential tension ranging from zero to 25 Newtons in a free and uncompressed state.

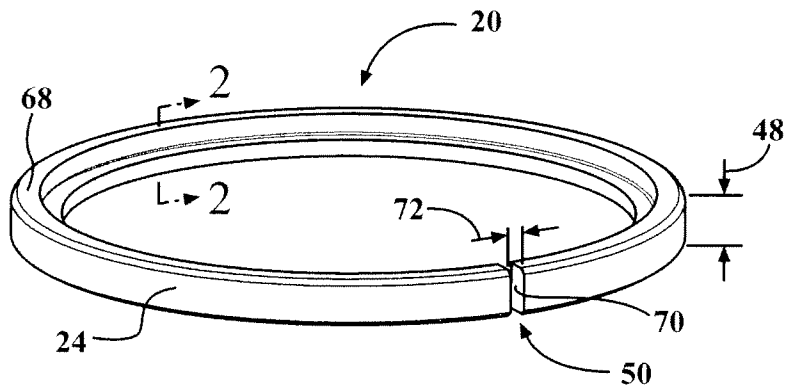
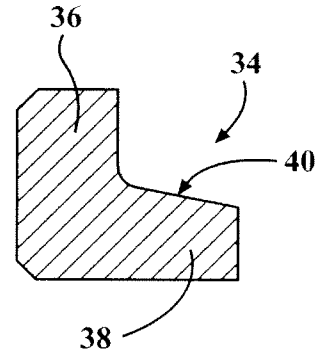
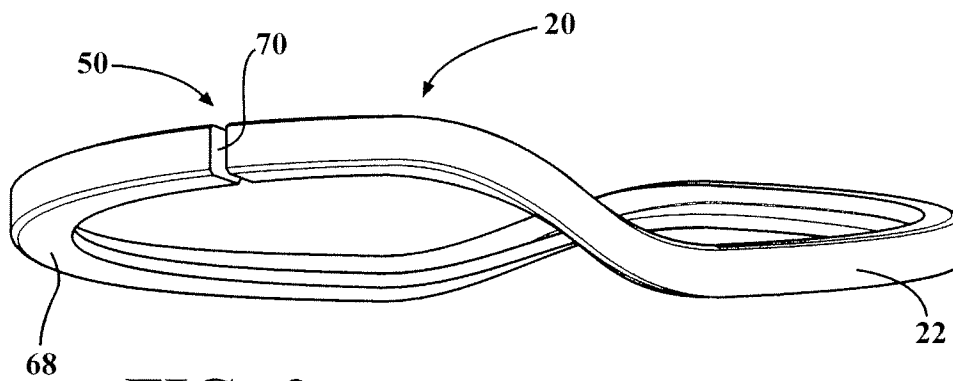
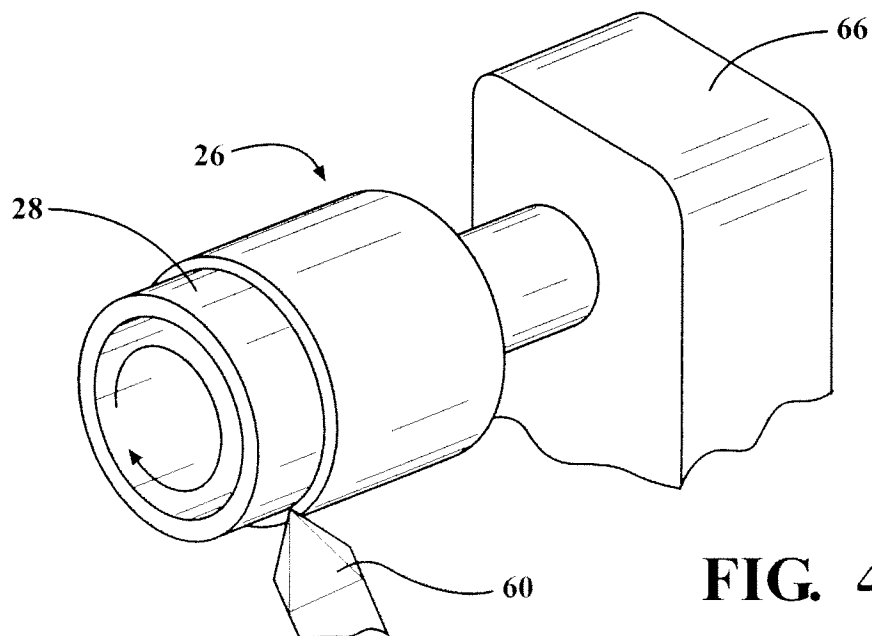
22. A dykes type piston ring as set forth in claim 21 wherein said final gap has a gap width measurable between said lateral faces ranging from zero to 0.4 millimeters when said annular ring body is in said free and uncompressed state.

23. A dykes type piston ring as set forth in claim 22 wherein said gap width ranges from zero to 0.1 millimeters when said annular ring body is in said free and uncompressed state.

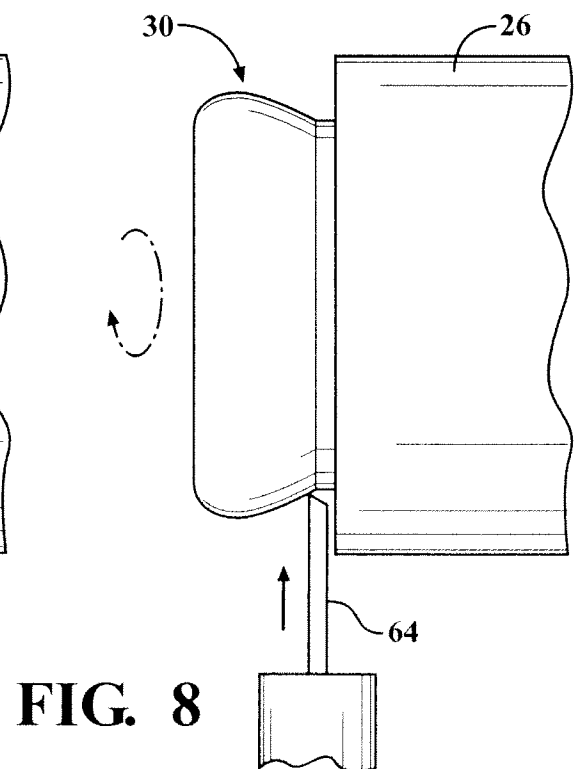
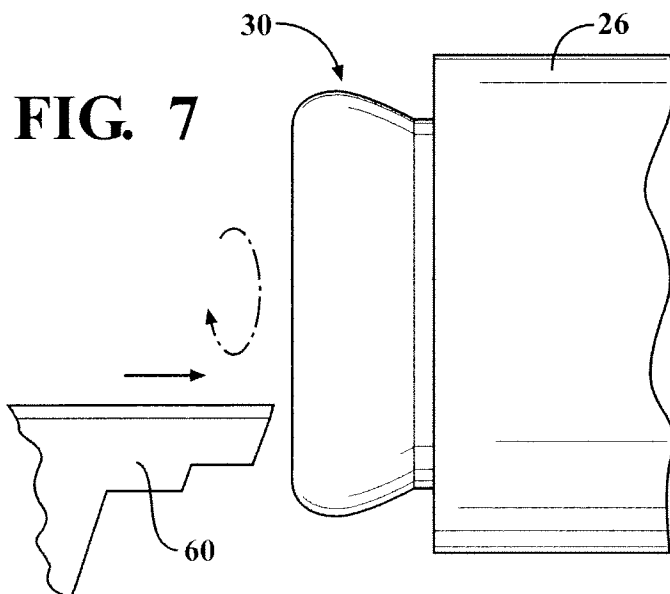
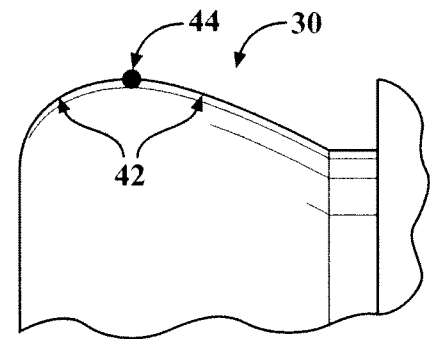
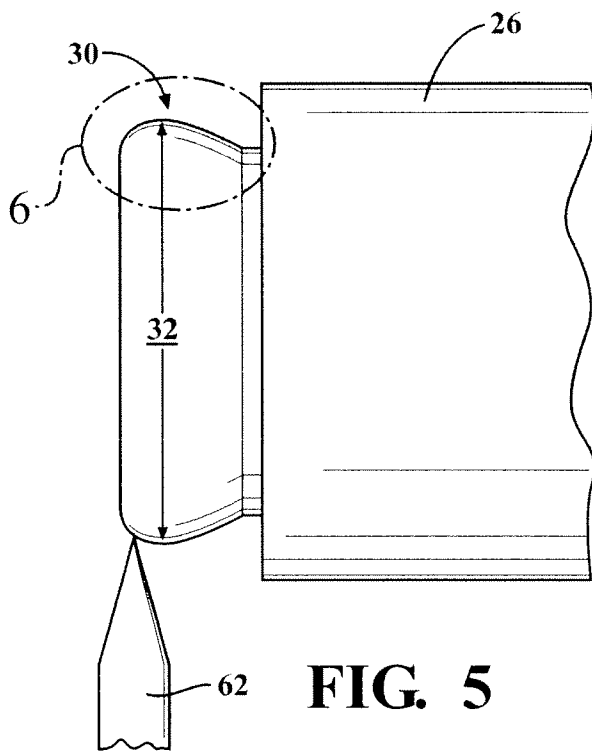
24. A dykes type piston ring as set forth in claim 21 wherein said pair of sides of said tail section each taper inwardly to define a keystone shaped cross-section.

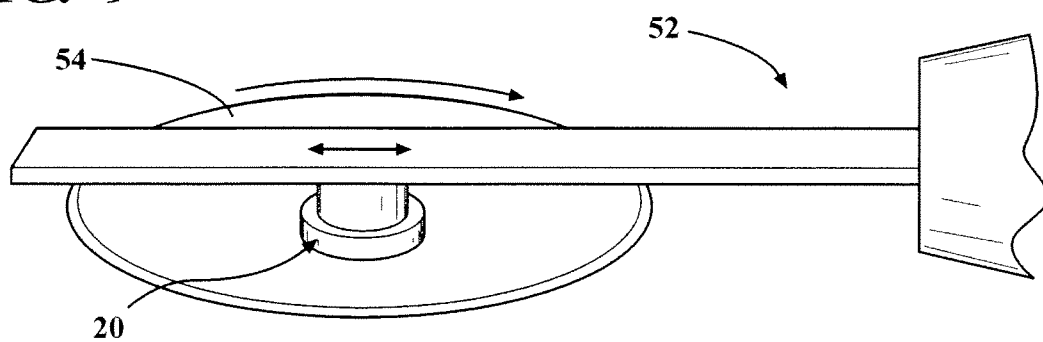
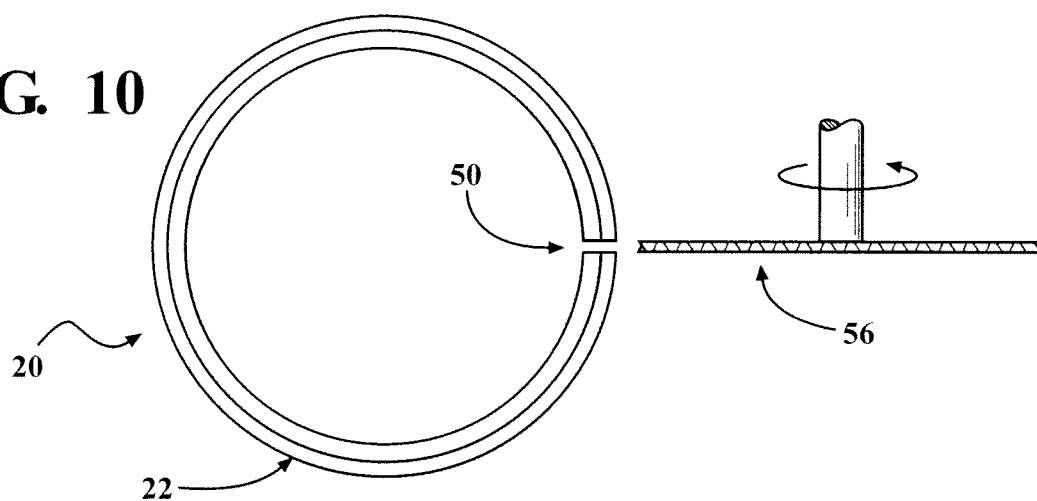
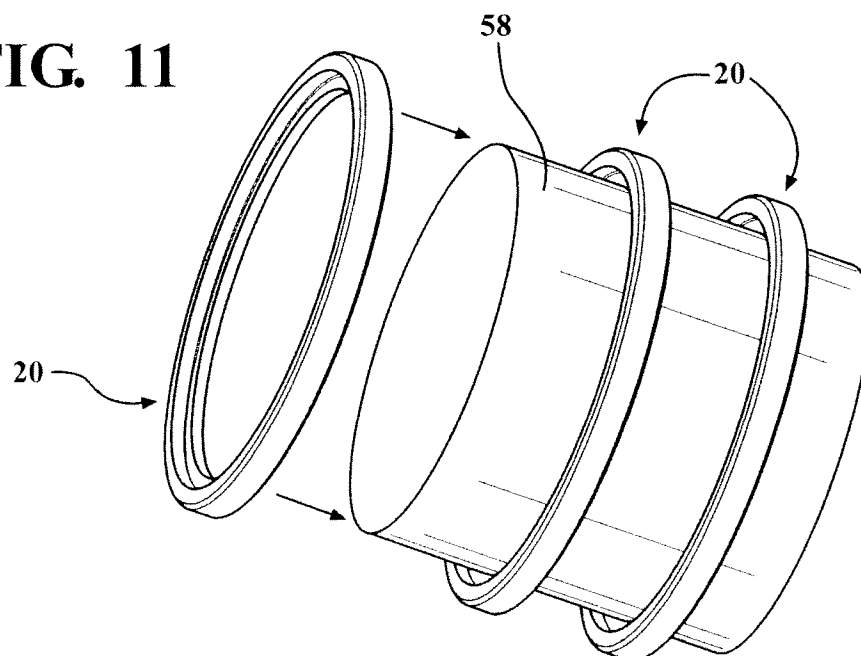
25. A dykes type piston ring as set forth in claim 21 wherein one of said pair of sides of said tail section tapers inwardly to define a semi-keystone shaped cross-section.

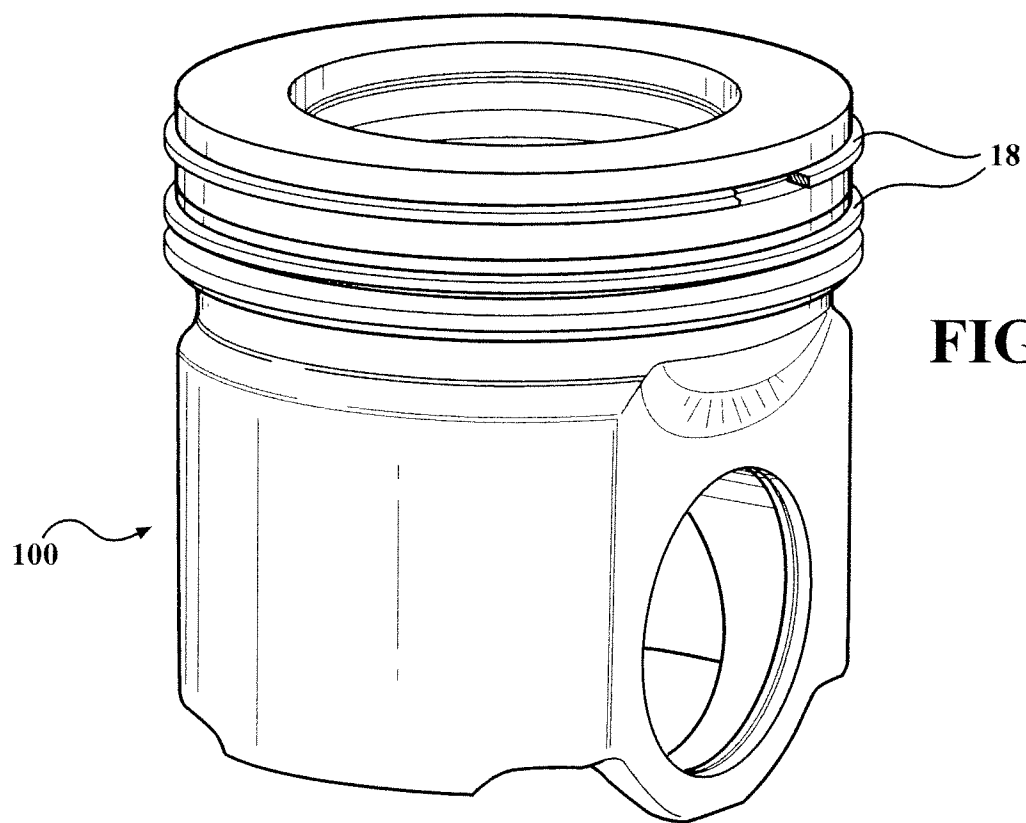
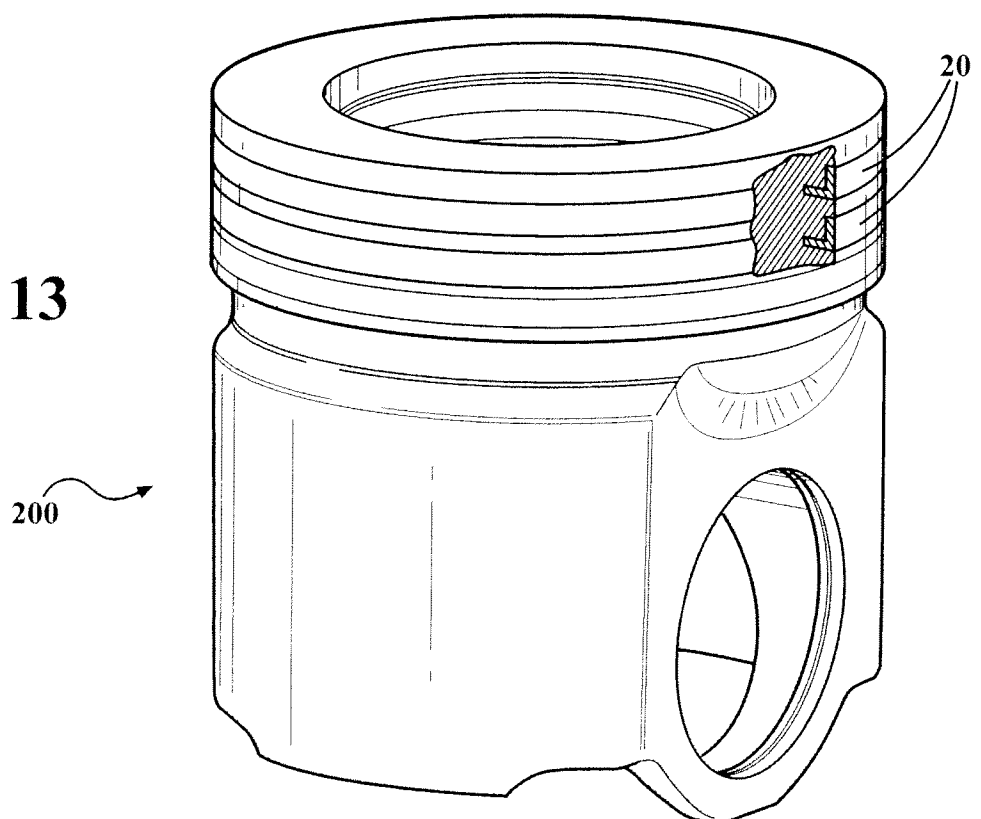
26. A dykes type piston ring as set forth in claim 21 wherein said annular ring body includes an outer circumferential surface having a predetermined profile of arcuate shape.

**FIG. 1****FIG. 2****FIG. 3****FIG. 4**





**FIG. 9****FIG. 10****FIG. 11**

**FIG. 13**

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2014/019714

A. CLASSIFICATION OF SUBJECT MATTER  
INV. B23P15/06 F16J9/02  
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
B23P B23B F16J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 239 926 A (AE PISTON PRODUCTS [GB]) 17 July 1991 (1991-07-17)	1-7,11, 12,16-20
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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

20 May 2014

Date of mailing of the international search report

30/05/2014

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International application No  
PCT/US2014/019714

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