April 22, 1947. W. M. ANDERSON 2,419,192

PISTON AND CYLINDER CONSTRUCTION

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FIG. 1

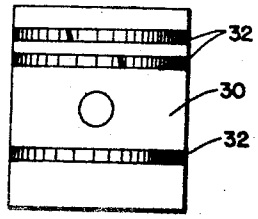


FIG. 2

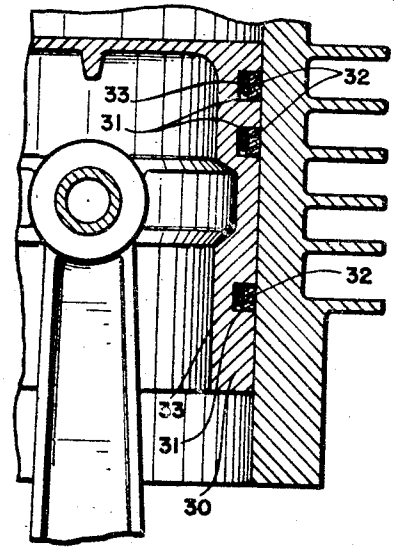


FIG. 3

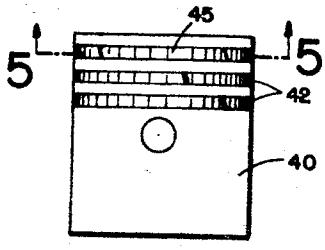


FIG. 4

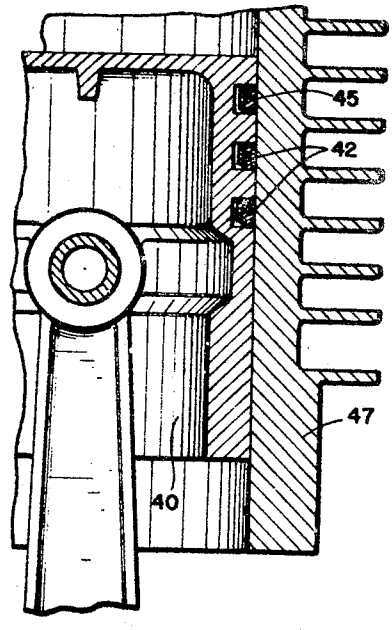
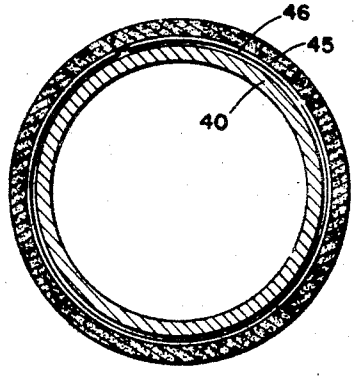


FIG. 5



INVENTOR:-
WILLIAM M. ANDERSON

BY Parry & Miller ATTYS.

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PISTON AND CYLINDER CONSTRUCTION

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FIG. 6

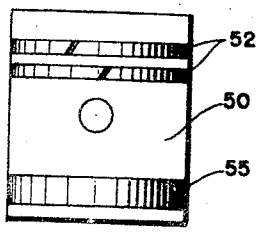


FIG. 7

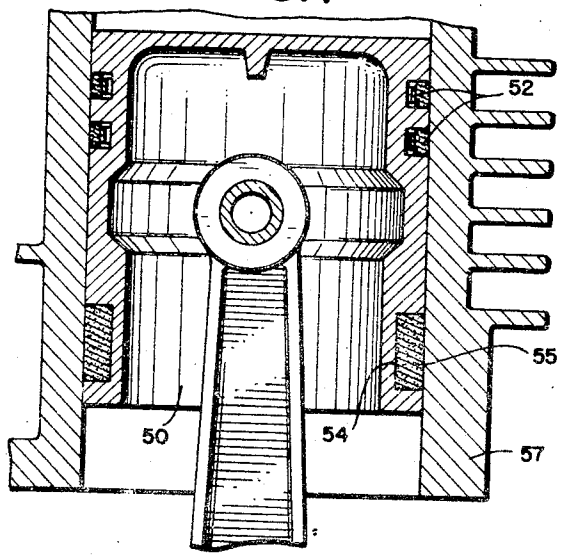


FIG. 8

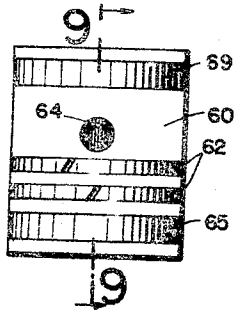


FIG. 9

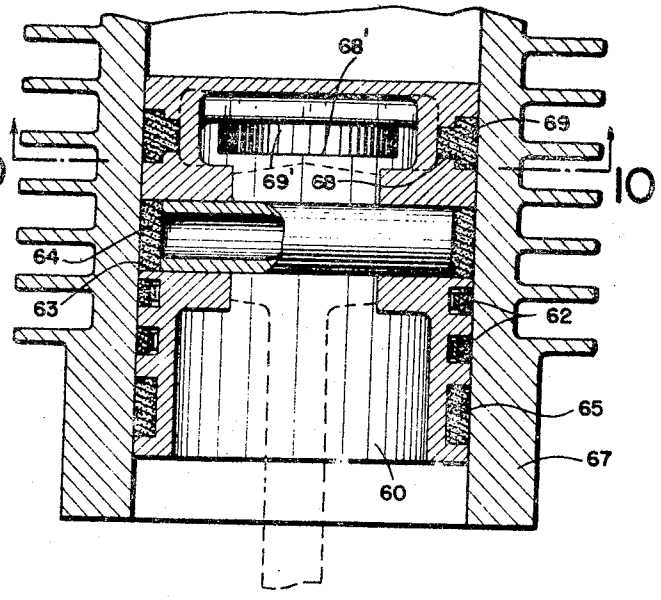
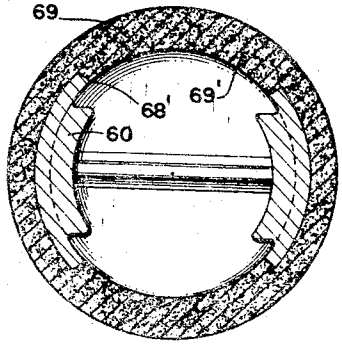


FIG. 10



INVENTOR:-

WILLIAM M. ANDERSON

BY Parry & Miller ATTYS.

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PISTON AND CYLINDER CONSTRUCTION

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FIG. 11

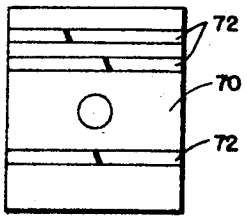


FIG. 12

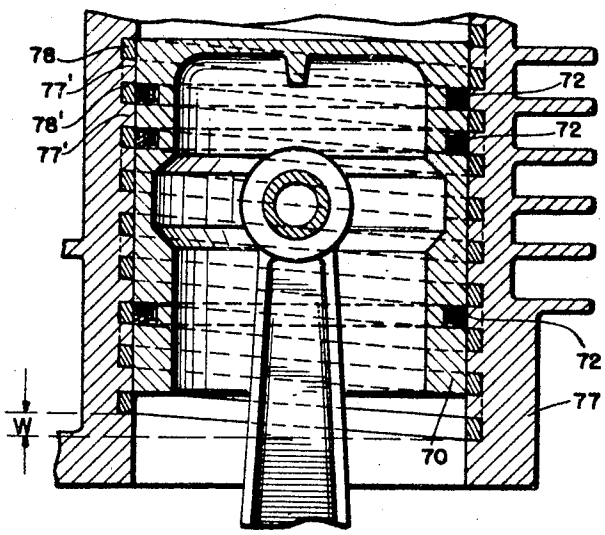


FIG. 13

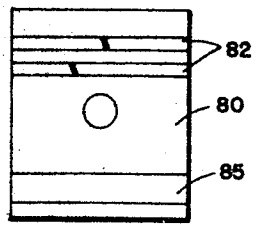


FIG. 15

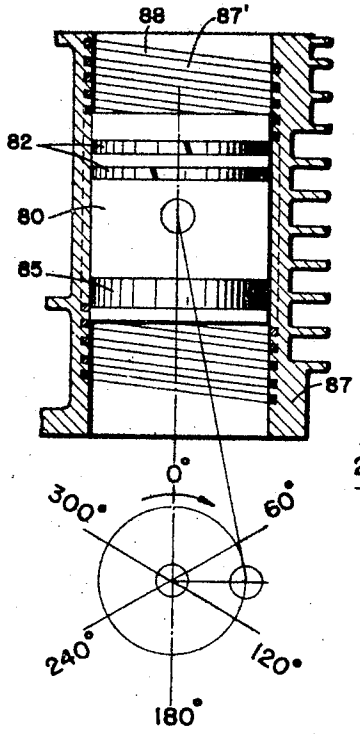
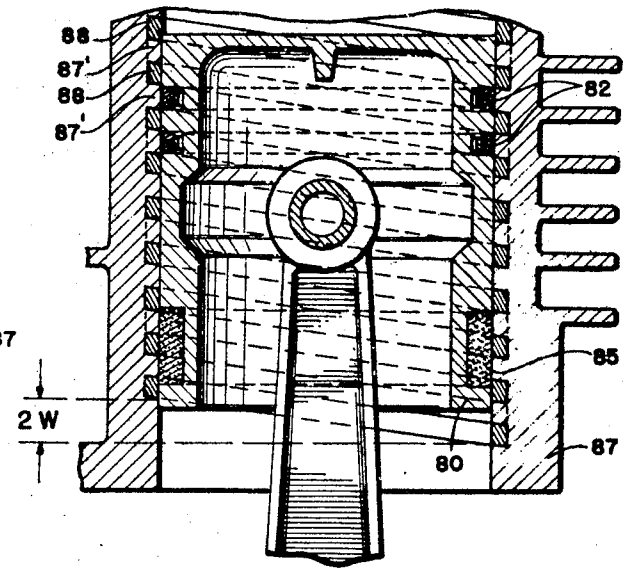


FIG. 14



INVENTOR:-

WILLIAM M. ANDERSON

BY Parry & Miller ATTYS.

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PISTON AND CYLINDER CONSTRUCTION

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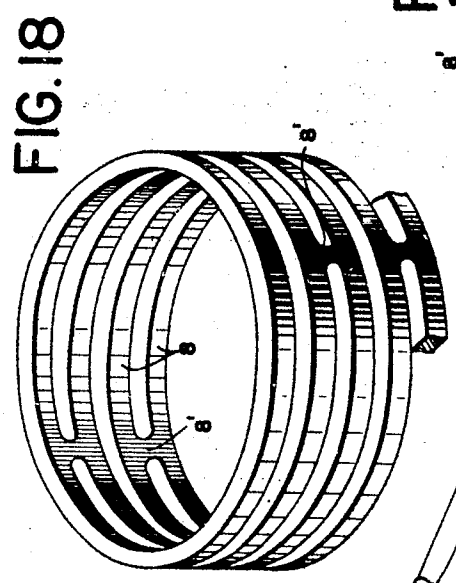


FIG. 18

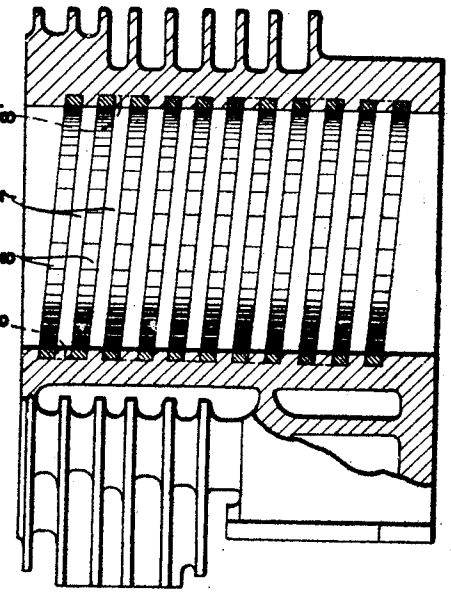


FIG. 17

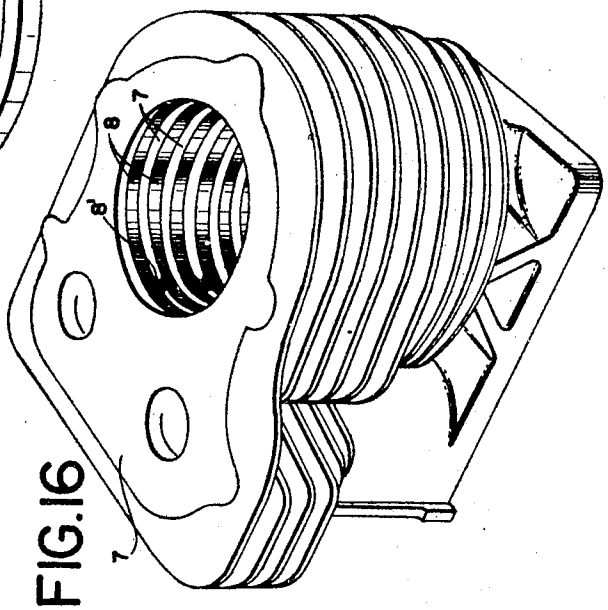


FIG. 16

INVENTOR:-

WILLIAM M. ANDERSON

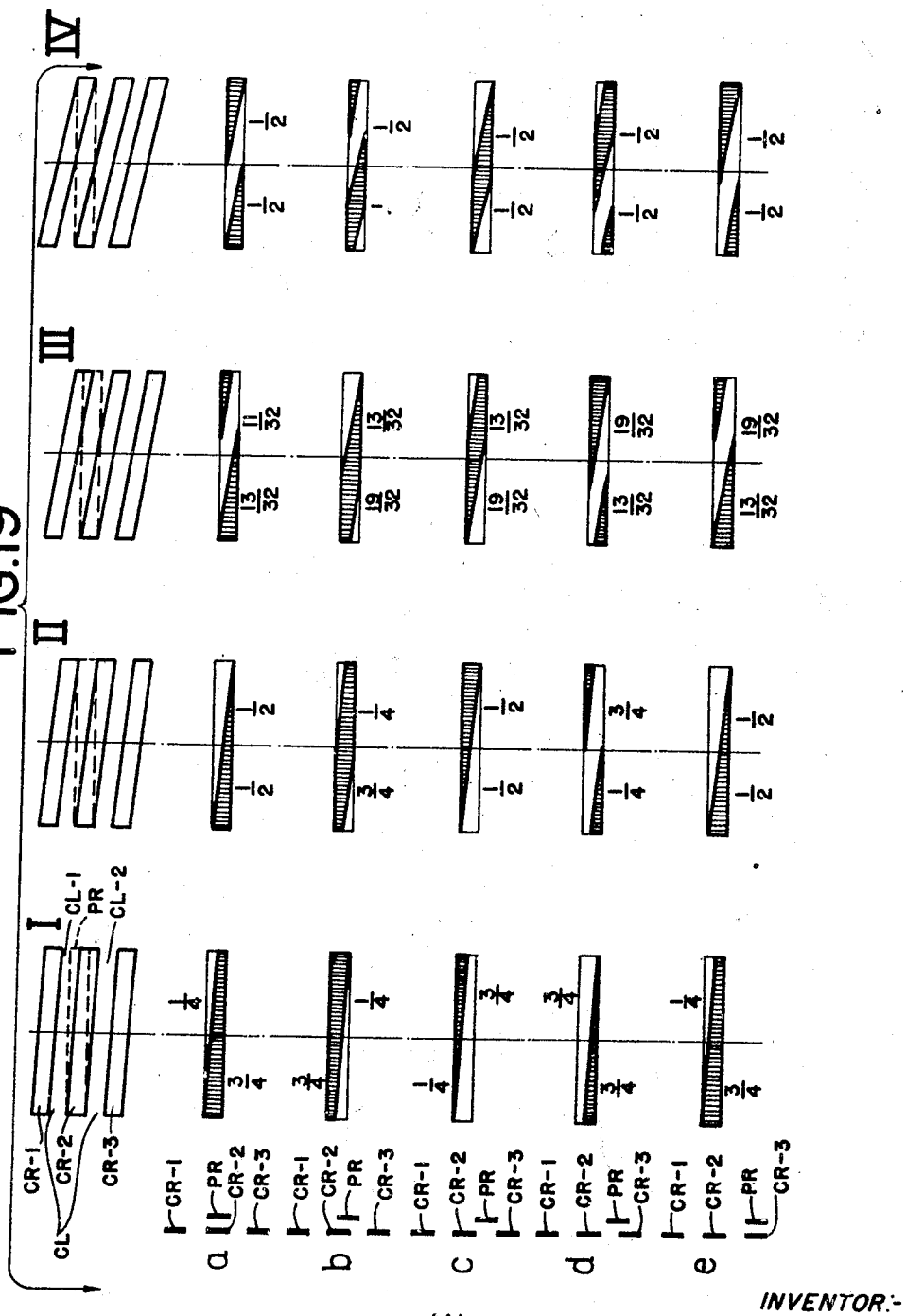
BY Parry & Miller ATTYS.

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PISTON AND CYLINDER CONSTRUCTION

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FIG. 19



INVENTOR:-

WILLIAM M. ANDERSON

BY Parry & Miller

ATTYS.

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PISTON AND CYLINDER CONSTRUCTION

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FIG. 21

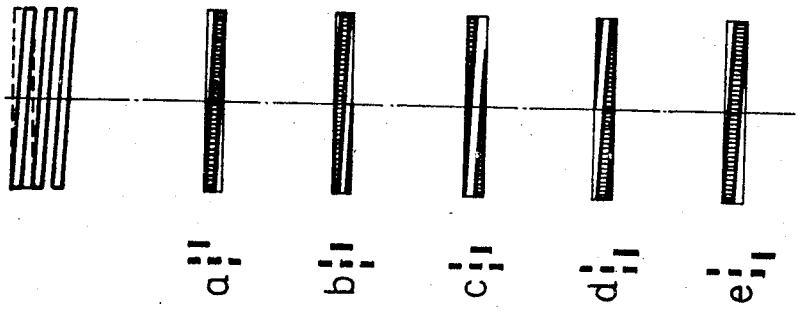


FIG. 22

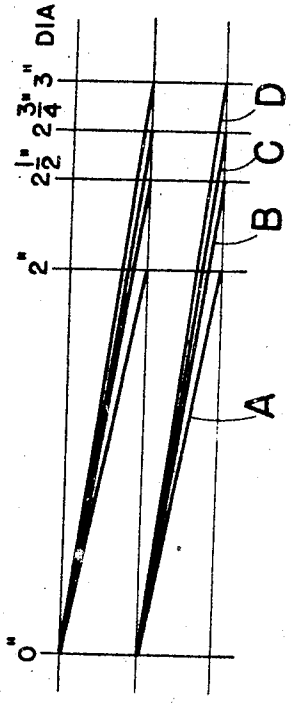
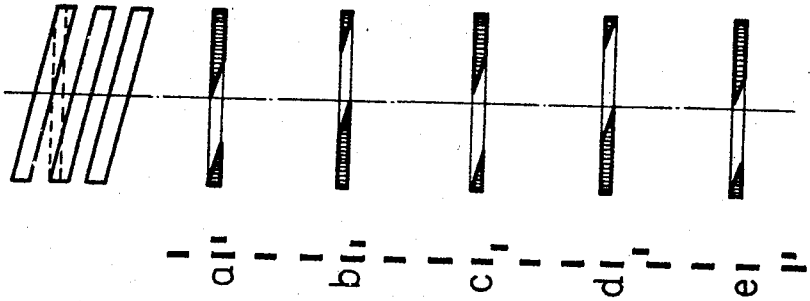


FIG. 20



INVENTOR:-
WILLIAM M. ANDERSON

BY Parry & Miller ATTYS.

Patented Apr. 22, 1947

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UNITED STATES PATENT OFFICE

2,419,192

PISTON AND CYLINDER CONSTRUCTION

William M. Anderson, Minneapolis, Minn., assignor of one-fourth to Oscar W. Giese, Washington, D. C., and one-fourth to Maurice H. Graham, St. Louis Park, Minn.

Application July 18, 1944, Serial No. 545,462

24 Claims. (Cl. 309—1)

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This invention relates to reciprocating piston type engines and is directed to improving the durability and wearing life thereof. More particularly, the invention is directed to reducing friction and wear resulting from sliding contact between cylinders and operating pistons.

While the invention has utility for reciprocating piston engines in general it is primarily concerned with internal combustion engines which, because of high operating temperatures and pressures therein, high wearing side thrust of the piston against the cylinder surface and difficulty of maintaining efficient lubrication between the surfaces of the cylinder and piston parts, present material and construction problems in obtaining long time wear-resistance which, for the most part, are more serious than experienced in other reciprocating engines, such as liquid and gas pumps, steam engines, etc.

Engine cylinders, and internal combustion engine cylinders in particular, are ordinarily formed of cast iron or equivalent relatively hard metal. In some cases the cylinder block has been made of softer metals such as aluminum and aluminum alloys which, because of their lighter weight and better heat conducting properties, provide certain obvious advantages. However, because such softer metals have relatively poor wear-resistance under normal conditions in an engine cylinder under the continual sliding contact of the piston and piston ring surfaces therewith, it has heretofore been found necessary when constructing the cylinder block of softer metals to insert a tubular sleeve of harder metal such as steel as the cylinder wall to obtain satisfactory wearing qualities. Such practice decreases thermal efficiency and other advantages of the lighter metals, and involves various mechanical problems in construction, with the result that ordinarily it has been more usual to construct the entire cylinder block as well as the piston and contacting cylinder walls of hard metals which have reasonably good wear-resisting properties.

Internal combustion engine pistons are usually constructed of iron, although they may be, and sometimes are, constructed of aluminum. Compression seal is obtained with the cylinder wall by expansible rings carried by the piston. Such rings are usually of hard metal and tend to wear the cylinder walls, and this wear is supplemented by additional wear caused by contact of other surfaces of the piston with the cylinder. Of course lubrication of the cylinder walls is provided in all engines to minimize wear, but nevertheless wear is a serious factor.

The problem of wear in reciprocating piston engines is a serious one even when the cylinder bore is composed of hard metals because costly reboring of the cylinder and replacement of at least the piston rings are necessary to overcome its effects after an extended running period. The

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more rapid wear when cylinder bores are composed of softer metals results in such a short running life for such cylinders as to make their use uneconomical and impractical despite inherent advantages for cylinder bore purposes possessed by various of the softer metallic materials over the commonly used harder metals.

It is a general object of the invention to improve the wear-resistance of engines whatever the composition of their cylinder bore.

It is a further particular object of the invention to so increase the wearing life of cylinders of softer metals such as aluminum as to make their use practical and economically sound.

To carry out these objects the invention provides improvements both in the piston assembly and cylinder construction. I prefer to employ a novel piston assembly and novel cylinder construction jointly in order to secure best results, but one of such features may be employed without the other with lesser but at least fair results in improved wearing life. The improved piston assembly and cylinder construction can be used to advantage individually in cylinders of both hard and softer metals to improve wearing properties and minimize lubrication problems. The cylinder construction is of greatest utility for cylinders of softer metals, but may also be employed to increase the wearing life of cylinders of hard metals.

Among the individual features of the invention are the use of non-metallic sealing rings, the use of non-metallic pistons of compositions, such as carbon graphite, having lubricant retaining and/or self-lubricating properties, or alternately, the use of metallic pistons equipped with special non-metallic fixed and/or expansible inserts or rings additional to sealing rings with lubricant retaining and/or self-lubricating properties, and the construction of the cylinders to include a series of small inserts formed and arranged to increase wear-resistance of the cylinder metal.

For internal combustion engines such rings must not only be durable but heat resistant and, to minimize wear of both cylinder and rings, the rings should preferably have lubricant retaining properties. I prefer to employ novel hard, non-metallic rings such as disclosed in my copending application, Serial No. 534,300, filed May 5, 1944, and hereafter to be described.

While the individual features of the piston assembly and the cylinder construction, may be employed independently, best results are secured with all of them jointly. For example, employing an aluminum piston equipped with non-metallic rings in an internal combustion engine aluminum bore cylinder, it was found that the engine still operated satisfactorily without noticeable loss in compression, and the cylinder and the ring showed only a slight degree of wear after some hundreds of hours. By incorporating a series of

small wear-resistant inserts in an aluminum cylinder bore it was found the wear-resistance of the cylinder was greatly increased. By utilizing a non-metallic piston composed of carbon graphite having lubricating properties, a protective film was formed thereby on the cylinder wall which enhanced both the wearing properties of the cylinder and the rings. The latter result was also obtained by employing metal pistons having fixed inserts and/or expansible ring-like carbon graphite inserts.

The novel cylinder insert construction here proposed comprises a series of relatively wear-resisting narrow rings uniformly and narrowly spaced from each other lengthwise of the cylinder and preferably presenting collectively a total area no greater than half the surface area of the cylinder. Preferably also, such rings are inclined relative to the cylinder axis, and by adjustment of the angle of inclination of the inserts in relation to the diameter of the cylinder the proportionate contact of surface parts of the piston assembly made simultaneously with the respective cylinder and insert surfaces under reciprocation of the piston may be maintained constant and equal, all as hereafter more fully explained.

In the drawings:

Fig. 1 is a side view of one embodiment of a piston assembly according to the invention;

Fig. 2 is a fragmentary vertical section of the piston assembly of Fig. 1 in an engine cylinder;

Fig. 3 is a side elevation of a second piston assembly according to the invention;

Fig. 4 is a fragmentary vertical section of the piston assembly of Fig. 3 in an engine cylinder;

Fig. 5 is a horizontal vertical section taken on the line **5**—**5** of Fig. 3;

Fig. 6 is a side elevation of a third form of piston assembly according to the invention;

Fig. 7 is a fragmentary vertical section of the piston assembly of Fig. 6 in an engine cylinder;

Fig. 8 is a side elevation of a fourth piston assembly according to the invention;

Fig. 9 is a fragmentary vertical section of the piston assembly of Fig. 8 in an engine cylinder, and taken on line **9**—**9** of Fig. 8;

Fig. 10 is a horizontal section taken on the line **10**—**10** of Fig. 9;

Fig. 11 is a side elevation of the piston assembly employed in the engine cylinder of Fig. 12;

Fig. 12 is a fragmentary vertical section of a preferred form of cylinder construction incorporating inclined ring-like inserts, and showing one preferred form of piston assembly therein;

Fig. 13 is a side elevation of a piston assembly employed in the engine cylinder of Fig. 14;

Fig. 14 is a fragmentary vertical section of an engine cylinder incorporating ring-like inserts arranged at a different inclination than in Fig. 12, and further showing a piston assembly therein;

Fig. 15 is an explanatory view of a full-length engine cylinder with ring-like inserts in vertical section with a piston in side elevation therein, and diagrammatically illustrating rotation of the crank shaft, the cylinder and piston being in accordance with Figs. 13 and 14;

Fig. 16 is a perspective view looking down on an air-cooled engine cylinder incorporating ring-like inserts in accordance with the invention;

Fig. 17 is a vertical section of the cylinder of Fig. 17;

Fig. 18 is a fragmentary perspective view of

an assembly of ring-like inserts employed in the cylinder of Figs. 17 and 18;

Fig. 19 is an explanatory chart diagrammatically illustrating the area of contact made by piston rings with ring-like cylinder inserts and intervening land portions of the cylinder in five positions *a*, *b*, *c*, *d* and *e* of downward travel of a piston, with four different angles of inclination of the insert rings relative to the cylinder axis represented in columns I, II, III and IV;

Fig. 20 is an explanatory chart along the general lines of Fig. 20, and illustrating the effect of employing piston rings narrower than the cylinder ring-like inserts;

Fig. 21 is a further explanatory chart wherein the piston ring is wider than the cylinder ring-like inserts; and,

Fig. 22 is a diagrammatic view illustrating the relationship between cylinder diameter and cylinder insert angle.

In Figs. 1 and 2 the piston assembly throughout its operative surfaces comprises hard, non-metallic materials adapted to withstand the temperature and pressure conditions encountered in internal combustion engines. Such materials are also adapted to produce a minimum of friction in sliding contact with engine cylinder walls in the presence of a lubricant so as to minimize wear of the cylinder wall under reciprocation of the piston, and be themselves sufficiently wear-resistant to be operative without replacement over prolonged periods of engine operation.

In such embodiment the piston body **30** comprises hard, fine grain carbon graphite such as commercially available on the market in cylindrical stock form from which the piston may be lathed to shape. The piston may be molded from powdered carbon graphite with a suitable heat-resistant binder, such as water glass, under high pressure from thirty to fifty tons per square inch, or more, and baked at high temperature. The carbon graphite employed should have relatively good heat conducting properties, since otherwise the top of the piston tends to spall under operating conditions in an internal combustion engine cylinder, and preferably should have a thermo conductivity of 70–120 B. t. u./hr./sq. ft./°F. The material should have a transverse strength of better than 1500 and a compressive strength of better than 4000. The grain size should be as small as practicable so as to avoid abrasion of the cylinder walls. A hardness of 35 to 45, or better, is deemed desirable to insure prolonged wear-resistance. In order that the piston be of a diameter to rather closely fit the cylinder, it is desirable that the coefficient of expansion of the carbon graphite be no greater than that of the cylinder, and it may be somewhat less. A commercial carbon graphite which has proved satisfactory is Stackpole, grade HC1.

As will be seen in Fig. 2, the carbon graphite piston body **30** is provided with a series of circumferential grooves **31** accommodating sealing rings **32** backed by iron or other metallic expander rings **33**. As conventionally two of the rings are located at the upper portion of the piston. A third ring is located in the lower portion of the piston, although the latter may be dispensed with.

Rings **32** are of a split, expansible type and are comprised of hard, non-metallic material. Preferably such rings are composed of hard molded heat-resistant material such as woven or braided asbestos rope or tubing, treated with a

heat-resistant hardening agent such as water glass and a fire-retardant agent such as Du Pont's "CM," molded under a pressure of between 40 tons and 50 tons per square inch, depending on the width of the rings, and baked at a temperature of about 300° F., for a period of about six hours, the ring and method of making the same being in accordance with my copending application, Serial No. 534,300, filed May 5, 1944.

The operating surfaces of both the piston **30** and the non-metallic rings **32**, while differing in their composition, and despite their hardness, are readily wetted by engine lubricant, and in fact are lubricant absorbing, so as to create only a low amount of friction with the operating surface of engine cylinder **37**. Hence, despite their non-metallic character piston **30** and rings **32** are long-wearing under operating conditions and prolong the life of the cylinder surface against wear.

Cylinder **37** may, as conventionally, be of cast iron, a relatively hard metal. Despite its relatively good wear-resistant properties a cast iron cylinder eventually wears, particularly in the intermediate portion thereof due to the side thrust of the piston against the cylinder wall when the engine crank and connecting arm are substantially inclined to the axis of the cylinder bore. Under such conditions conventional metallic rings employed with conventional metallic pistons due to friction, and despite lubrication, eventually wear the cylinder to an oval cross-section. By employing the described piston and rings the life of the cylinder against such wear is materially prolonged.

It is also contemplated to use a non-metallic piston assembly in an engine with cylinder **37** composed of light-weight metal such as aluminum and aluminum alloys with substantial increase in the wearing life of the cylinder as compared with the employment in such a cylinder of an all-metal piston assembly. While the wear-resistance of aluminum and like softer metals is substantially less than that of cast iron, and in the past has not been found feasible for the cylinder bore, the employment of the present piston assembly so increases the wearing life of such a cylinder as to make it practical, particularly for smaller types of internal combustion engines.

The employment of carbon graphite for cylinder body **30** is preferable over other non-metallic material because carbon graphite itself not only absorbs lubricant, but itself has lubricating properties. In the course of engine operation graphite is deposited in the form of a thin film on the cylinder surface which presents a highly polished appearance, and such film serves to increase the wear resistance of the cylinder bore and minimize wear of the non-metallic piston and rings as well as of the cylinder. A cylinder having a bore of aluminum appears to take the protective graphite film more readily than iron, probably due to the wetting properties of aluminum, and better results are obtained with a piston assembly including graphite operating surfaces than where the piston assembly is composed entirely of other materials.

The entire piston assembly need not be non-metallic, as illustrated in the embodiment of Figs. 3 to 5. Therein the piston body **40** may be made of cast iron, aluminum, or other metallic materials. Sealing rings **42**, here two in number, are again non-metallic, and preferably of the same composition as rings **32** in the embodiment of Fig. 1. An additional ring **45**, here the top ring, although not necessarily so, is composed of carbon graphite, and serves the same film-forming function with reference to the cylinder wall as the piston **30** of similar composition in the previous embodiment. Ring **45** is here shown as a four-section split ring adapted to be expanded by a spring metal backing ring **46**. Such ring tends to form a protective graphite film on the bore of cylinder **47** to protect the same against wear by sealing ring **42** and the metallic working surface of piston **40**.

In the further embodiment of Figs. 6 and 7 the piston body **50** is again composed of conventional metal composition, and sealing rings **52** are non-metallic and of the composition previously described. In the skirt portion of the piston body is an annular groove **54** filled with a carbon graphite ring or insert **55** which functions for the same purpose as the expansible carbon graphite ring **45** in the embodiment of Figs. 3 to 5 with respect to the bore of cylinder **57**. As shown, insert **55** is substantially wider than sealing rings **52**, although this is not considered critical.

In the embodiment of Fig. 8 a metallic piston body **60** is provided with expansible non-metallic split sealing rings **62** as in previous embodiments. In this case the rings are located below the pivotal wrist pin connection of the piston with the usual connecting rod. To avoid loss of compression, the outer ends of the piston bore **63** for the wrist pin are closed by plugs **64**, preferably of carbon graphite. A fixed carbon graphite insert **65** may be located in the skirt portion of the piston below the rings. In addition to, or in lieu of, insert **65**, there is a lubricant absorbing fixed insert ring **69** surrounding the upper portion of the piston and seating in groove **68** formed therein. Groove **68** at a plurality of circumferential points is provided with inward extensions **68'** opening interiorly of the hollow piston body, and such extensions are filled with inwardly projecting portions **69'** of insert ring **69**. The purpose of such arrangement is to permit lubricant from the engine crank case accumulating in the hollow interior of the piston to be absorbed therefrom by ring **69**. Ring **69** is thus rendered lubricating at its working surface to minimize friction with the surface of cylinder **67**. Ring **69** is preferably a hard ring, and of carbon graphite composition to increase its cylinder lubricating action.

Whereas the piston assemblies heretofore described may be employed in cylinders whose bore is constituted throughout of the same metal as the main cylinder casting, improved wearing qualities may be obtained by employing cylinder inserts in the bore of different composition than the cylinder. The advantages are particularly great wherein the cylinder is formed of aluminum, its alloys or other light-weight relatively soft metals. In some instances the inserts may be composed of carbon graphite, but ordinarily I prefer to employ inserts of harder metal than the metal of the cylinder. Because of the difference in coefficients of expansion of different materials, it is important that the inserts be of such form as to minimize the difference in expansion as between the inserts and cylinder, and yet increase the wear-resistant properties of the cylinder bore throughout its circumference, and throughout at least the longitudinal portions of the bore most subject to wear. It is important in this connection that under high temperature conditions such as prevail in internal combustion en-

gines that the inserts shall not become loose from the cylinder wall, or present other than a continuous smooth surface with adjoining portions of the cylinder surface. Further, particularly in the case of cylinders of thermally efficient softer metal such as aluminum, the inserts must be of sufficiently limited total area as not to reduce the exposed surface area of the cylinder to a point where benefits in thermo conductivity resulting from the use of such thermally efficient metals in the cylinder bore are largely lost. That is to say, the use of inserts of substantial length in their greatest dimensions, for example, a perforate or imperforate tubular sleeve or other insert extending uninterruptedly for the length of the cylinder, or a substantial portion thereof, is undesirable. For thermal efficiency the inserts should be separated by continuous and frequent circumferential land portions of the cylinder, and desirably both the inserts and intervening land portions should be continuous and unbroken circumferentially to provide uniform contact circumferentially with the operating surfaces of the piston assembly. That is to say, recurrent small inserts separated circumferentially by intervening cylinder land portions are not desirable as likely to cause non-uniform wear at different circumferential areas of the piston assembly, and as likely to fail to give proper wear-resistance to the cylinder bore.

With the above qualifications in mind the present invention contemplates the use of wear-resisting inserts in cylinders in the form of axially and uniformly spaced relatively narrow rings in the cylinder, and separated by intervening land portions of the cylinder of the same order of width as the insert rings. In order to minimize wear, and to insure contact of one circumferential portion of the piston assembly with insert surface portions while another circumferential portion of the piston assembly is in contact with the cylinder surface, the cylinder insert rings are inclined relative to the cylinder axis and to the piston rings. Through proper selection of the angle of inclination of the insert rings in relation to the cylinder diameter and the width of the piston rings it is possible to secure a constant ratio of contact of the piston assembly with the cylinder insert and cylinder land surfaces as the piston reciprocates in the cylinder.

The cylinder construction embodying inserts as just generally described and preferred forms of piston assemblies adapted to increase the wearing qualities obtainable with the inserts alone will be understood from Figs. 11 to 17.

In Figs. 16 and 17 I have shown a cylinder 7 embodying a series of wear-resisting insert rings 8 arranged in uniform spaced relation lengthwise of the cylinder bore. The cylinder shown is an air-cooled cylinder, but the invention is equally well adapted for liquid cooled cylinders. Ring inserts 8 are firmly anchored in the cylinder bore by casting the cylinder around them.

The cylinder may be composed of cast iron, but the invention is of greatest importance when the cylinder is composed of softer, less wear-resisting metals, usually of lighter weight, such as aluminum and aluminum alloys. The inserts will preferably be of a harder metal than the cylinder. In the case of aluminum cylinders I prefer to employ insert rings of cast iron, whereas in a cast iron cylinder I may employ inserts of chromium steel. In some cases a hard non-metallic insert of a lubricant absorbing or lubricating composition, such as carbon graphite, may be employed, although rings of such composition are better suited to engines other than internal combustion engines, since in the latter engines the expansion of the cylinder under high operating temperatures may cause cracking of the inserts.

As best shown in Fig. 19 the inserts 8 are in the form of complete rings or annuli so as to provide uniform protection throughout the entire circumference of the cylinder bore. The rings may be entirely separate from each other, but for convenience they may be formed as an integral assembly of rings to facilitate the cylinder casting operation and insure uniform spacing between the inserts. As shown in Fig. 19 small spacing and connecting elements 8' are provided between adjacent insert rings. One such element only is preferably used between two rings, and alternate elements are circumferentially spaced from each other, so that the assembly can accommodate itself to longitudinal expansion of the cylinder without loosening or breaking the rings. While desirably insert rings 8 should have a coefficient of expansion as close to that of the cylinder metal as possible, it is found that in view of the relatively small dimensions of the inserts, and their arrangement, that difference in the coefficients of expansion, for example, between cast iron and aluminum, does not cause difficulty.

After the cylinder is cast the bore is machined and finished in the usual manner to provide a continuous smooth working surface made up of surfaces of the insert rings and intervening land portions 7' of the cylinder. The width of the inserts and cylinder land surfaces is preferably equal in order to obtain the full benefits in increased wear from employment of the rings, and provide sufficient surface area of the cylinder metal at the working surface without unduly cutting down the thermo conductivity and other benefits arising from the presence of the cylinder metal at the working bore surface of the cylinder. The width of insert rings 8 and cylinder land portion 7' is relatively narrow, and of the same order of dimension as the width of piston rings being employed in the cylinder. The main aim is to insure against the piston rings traversing a substantial area of the surface bore in contact only with cylinder land portions. I prefer to make the width of the insert rings and cylinder land portions either the same as, or slightly less, than the width of the piston rings, but in some cases, particularly where it is desired to employ extremely narrow insert rings, the inserts and land portions may be wider.

It is an important feature of the invention that the insert rings 8 be inclined to the axis of the cylinder bore so that the piston rings, regardless of their width, shall at all times have bearing contact with one or more of the cylinder inserts and never make bearing contact solely with cylinder land portions. The angle of inclination will vary with cylinders of different bore diameter, and will depend on the width of the inserts and cylinder land portions in relation to the width of piston ring employed, where the benefits of the insert construction are to be realized as fully as possible. It is preferred that the angle should not exceed the minimum necessary to obtain the desired ratio of simultaneous contact of the piston rings and other portions of the piston assembly with the respective surfaces of the cylinder inserts and cylinder land portions. It will be apparent that the greater the angle of inclination of insert rings 8 the greater will be their diameter in relation to the diameter of the cylin-

der, and the total length of the inserts circumferentially should be as small as consistent with the objects to be obtained in order to insure against injury to or loosening of the inserts under circumferential and longitudinal expansion of the cylinder with temperature conditions. Depending on the variables above referred to, the cylinder insert inclination will ordinarily be less than 15° for cylinder diameters not less than two inches, and ordinarily will range between about 5° and 11°. In any event the angle may be determined from the formula

$$\tan \theta = \frac{x.W}{D}$$

where D represents the cylinder diameter, where W represents the width (axially) of the insert ring and/or the width of the cylinder land portions between rings, and x represents the fraction or multiple of W. The edges of the low side of the insert are to be below the diametrically opposed edge portions at the high side of the insert. If the width of the insert and the width of the land portion are equal to each other, and equal to the width of the piston ring, or equal to twice the width of the piston ring, the value of x will be 2, whereas if the width of the insert and cylinder land are equal to each other, but double the width of the piston ring x can be as low as ½. The effect of varying the value of xW will become apparent later.

In the embodiment of Fig. 12 is shown a cylinder 77 such as has been described having insert rings 78 spaced by intervening land portions 77' of the cylinder, the widths being the same. Working in such cylinder is a piston 70 having sealing rings 72, and more clearly illustrated in Fig. 11. Assuming that cylinder 77 is formed of a soft metal such as aluminum the cylinder inserts 78 may be composed of carbon graphite, but preferably will be cast iron. Piston body 70 is non-metallic and composed of carbon graphite, and sealing rings 72 are preferably non-metallic also, and preferably of the composition previously described. The cylinder has a bore diameter of 2¾ inches, and the low side of the insert rings is intended to be half the width of the insert below the high side of the insert. In the above formula for the angle of inclination x equals ½.

With a cylinder formed with inserts a metallic piston may be employed as illustrated in Figs. 13 and 14. Therein the cylinder body 87 is formed with insert rings 88 separated by cylinder land portions 87'. Piston 80 is a metallic piston, for example, aluminum, provided with sealing rings 82. In some cases rings 82 may also be resilient metallic rings, but better wearing qualities are obtained by employing non-metallic composition rings such as before described. An additional non-metallic ring 85 is provided on the piston, preferably comprising carbon graphite and adapted to form a protective film on the cylinder bore. As shown such insert is a rigid insert located in the skirt of the piston, as in the embodiment of Fig. 6, but it will be understood such insert may be located elsewhere on the piston body and/or be of expansible type as, for example, in the piston assemblies of Figs. 3 and 8. The angle of inclination of insert rings 88 is greater than that in Fig. 12. The low side of the inserts are twice the width of the inserts below the diametrically high side of the inserts. In the formula above given x equals 2. As in Fig. 12 the piston rings 82 are of the same width as the inserts 88 and cylinder land portions 87', but it is understood

that they may be wider or narrower. If the piston rings are only one-half the width of the inserts it is preferable to use a steeper angle of inclination for the inserts as in Fig. 14. Again, if narrow insert rings are employed the angle of inclination may be the same, but can be reduced to the angle of inclination in the embodiment of Fig. 12.

The significance of the angle of inclination of the inserts will be understood by reference to Fig. 19. The number of insert rings to be employed is subject to variation. In Fig. 15 the rings are shown as extending uniformly throughout substantially the entire length of the cylinder. However, the inserts may be confined to the portion of the cylinder subjected to greatest wear under reciprocation of the piston, that is, the area traversed when the connecting rod and crank shaft of the engine are at their greatest angles to the axis of the cylinder, which will roughly be between 60° and 120° on the power stroke and between 240° and 300° on the return stroke. As further shown in Fig. 15 the inclination of the cylinder inserts is in a direction at right angles to the engine crank shaft. Since the side thrust of the piston is to the left on the power stroke, and to the right on return stroke according to the showing in Fig. 15, the inclination is towards the direction of movement of the piston. The high side of the insert rings is on the left, and the low side on the right on the downward power stroke of the piston. On the downward or power stroke the piston rings will first contact the left side of the insert rings, whereas on the upward or return stroke the piston rings will first contact the right side of the insert rings.

The significance of the angle of inclination of the inserts previously referred to will be understood from Fig. 19. At the top of the four columns are illustrated diagrammatically a single piston sealing ring PR in broken lines in relation to three cylinder insert rings, CR—1, CR—2 and CR—3. The two spaces CL between the insert rings represent intervening land portions of the cylinder. The inserts are shown at four different angles of inclination in the respective columns. In column I the low side of the inserts are one-half their width below their high sides, and in columns II, III and IV, respectively, the low sides of the inserts are 1, 1½ and 2, times their width below the high side. The five views in each column diagrammatically represent the amount of contact made by the piston ring PR with one or more of the insert rings and one or more of the cylinder land portions under movement of the piston in the cylinder. The five positions are designated *a*, *b*, *c*, *d* and *e*, and the position of the piston ring relative to the insert rings and land portions is shown by the key to the left of column I. In the columns the individual views are hatched to represent portions of one-half the ring as viewed from the side which contact cylinder insert surface and are unhatched in the piston ring surface portion which contacts cylinder land surface.

With the insert angle as in column I the amount of contact of the piston ring made simultaneously with the insert and land surface varies considerably as the piston ring moves axially. In positions *a* and *b*, also in *e* which corresponds to *a*, the piston ring has three-quarters of its working surface in contact with insert surface, and only one-quarter in contact with cylinder land surface, whereas in positions *c* and *d* only one-quarter of the piston ring surface is in contact with

insert surface while three-quarters is in contact with land surface. When the angle of inclination is increased so that the low side of the inserts are the full width of the insert below the high side as in column II, the piston ring makes the same amount of contact with insert surface and cylinder land surface in positions *a*, *c* and *e*, but makes three-quarters contact with the insert in position *b*, and three-quarters contact with cylinder land surface in position *d*. In column III where the angle is further increased so that the low sides of the inserts are one and one-half times their width below their high sides the fluctuations in contact are less, but the piston ring still has a greater amount of contact with the insert surface in some positions and with the cylinder land surface in other positions. In positions *a*, *d* and *e* more than one-half the contact of the piston ring surface is with cylinder land surface, while in positions *b* and *c* more than one-half the contact of the piston ring is with insert surface. In column IV, where the angle is increased so that the low side of the insert rings are twice the insert width below their high sides, a constant 1:1 ratio of contact of the piston ring with the insert and cylinder land surfaces is obtained in all positions. That is to say, one-half of the working surface of the piston ring contacts insert surface, and the remaining half contacts cylinder land surface. Such an operative condition is now considered as ideal for best results, but within the scope of the invention the angle may be made smaller or greater. As will be understood from columns I, II and III the ratio of contact changes when the angle is decreased. When the angle is increased still further from that shown in column IV a constant ratio of contact is still obtained, but as previously pointed out it is desirable to maintain the angle at a minimum so that the circumferential length of the rings is as short as possible for a cylinder of any given diameter.

In Fig. 19 in all instances the insert rings and cylinder land surfaces have been taken as the same width as the piston rings. Such condition is not necessary. For example, the piston ring may be one-half the width of the inserts. With the same angle of inclination of the inserts as in column IV of Fig. 19 the piston ring always will have one-half of its surface in contact with insert surface and one-half in contact cylinder land surface. This is represented in Fig. 21. Again, the inserts and cylinder land portions may be narrower than the width of the piston rings. Where this is true a lesser angle of inclination may be employed for the inserts. Fig. 21 represents a situation where the cylinder inserts and land portions are one-half the width of the piston rings. A 1:1 ratio of contact of the piston ring with insert surface and with land surface is always obtained where the low side of the inserts are one insert width (or one-half piston ring width) below the high insert sides.

It will be of course understood that the angle of inclination of the inserts under any individual set of conditions such as illustrated in Figs. 19, 20 and 21 will vary with the cylinder size as indicated by the formula previously referred to. The greater the cylinder diameter the less angle of inclination is required, as illustrated by Fig. 22 wherein the angles A, B, C and D respectively represent the angles of 2, 2½, 2¾ and 3 inch diameters.

Referring again to Fig. 19 the values of angles A to D under the conditions shown in column I will range from about 2.68° for angle A down to about 1.78° for angle D, assuming that the cylinder inserts and cylinder land portions have a width of $\frac{3}{16}$ inch. The corresponding angle values for column II would range from about 5.36° down to 3.58°, and for columns III and IV respectively the values would range from about 8.05° to 5.36°, and from about 10.72° to about 6.12°. It will be understood that these are merely suggested values, and the angles for any cylinder size may be varied, and to obtain the conditions illustrated in Figs. 19 to 21 will have to be varied depending on the width of the cylinder inserts and land portions. Because the circumference of the inserts progressively increases with the angle of inclination differences in the coefficients of expansion of the inserts and cylinder may result in a tendency of the inserts to loosen or otherwise change their relationship with the cylinder wall if the angle of inclination is increased unduly. It is therefore considered desirable that the angle of inclination be no greater than necessary to accomplish the objects above pointed out, thereby keeping the difference in circumference between the cylinder and the inserts. It now appears to me that the angle of inclination should not exceed 15 degrees.

It will be understood from the various illustrative, but not limiting, embodiments of the invention which have been described that the invention provides increased wearing life for engine cylinders in general and internal combustion engine cylinders in particular, regardless of the composition of the cylinder bore although being most important for cylinders of any appropriate light weight and/or thermally efficient metals whose wear-resistance is objectionably low. The various individual features of the invention while best serving in combination to cooperatively attain the objects of the invention are also asserted one without another, since each is beneficial in itself in engine constructions increasing engine life.

I claim:

1. A piston assembly including a piston body having a cylindrical working surface formed with a plurality of circumferential grooves, molded hard fibrous split sealing rings seating in said grooves, and said piston having at least a circumferential lubricating surface portion of carbon graphite.

2. A piston assembly including a piston body having a cylindrical working surface of hard non-metallic composition, circumferential grooves in the piston, and expansible split sealing rings of hard non-metallic composition supported in said grooves.

3. A piston assembly including a metallic piston body having a cylindrical working surface and being formed with a plurality of circumferential grooves, an expansible lubricant-requiring split sealing ring of hard non-metallic composition seating in one of said grooves, and said piston having a circumferential surface portion in the form of an annular lubricating element of hard carbon graphite seating in another of said grooves.

4. A piston assembly including a metallic piston body having a cylindrical working surface and having formed with a plurality of circumferential grooves, an expansible lubricant-requiring sealing ring of hard non-metallic composition in one of said grooves, and said piston having a circumferential surface portion in the form of a hard expansible lubricating ring in another of said grooves.

5. A piston including a hollow piston body, a circumferential groove in the outer surface of said body, an annular body of hard lubricant-absorbing composition located in said groove, said groove having inward extensions communicating with the hollow interior of the piston body so that lubricant within the piston interior may be absorbed by said annular body.

6. An internal combustion engine piston assembly comprising a piston body having circumferential grooves, heat-resistant expansible sealing rings of lubricant-requiring non-metallic composition seating in at least some of said grooves, and at least an annular zone of the piston comprising heat-resistant lubricating material adapted to apply lubricant to the wall of an engine cylinder.

7. An engine cylinder of relatively soft metal and insert means for increasing the wearing lift of the cylinder comprising a series of relatively narrow insert rings of wear-resisting composition surrounding the cylinder bore and being separated by relatively narrow intervening annular land portions of the cylinder metal.

8. An engine cylinder having a bore and a series of relatively narrow insert rings of wear-resistant composition surrounding said bore and uniformly separated from each other by relatively narrow annular land portions of the cylinder, said inserts being inclined to a transverse plane of the cylinder at an angle measured by not less than one half the axial width of one of said land portions.

9. An engine cylinder having a bore and a series of relatively narrow insert rings of wear-resistant composition surrounding said bore and uniformly separated from each other by relatively narrow annular land portions of the cylinder, said inserts being inclined to a transverse plane of the cylinder at an angle measured by at least twice the axial width of one of said land portions.

10. An engine cylinder according to claim 8 wherein the inserts and intervening land portions surrounding the cylinder bore are of the same axial width.

11. An engine cylinder comprising a metallic cylinder body having a bore, and a series of axially spaced insert rings of harder metal than the cylinder body surrounding the bore and separated by annular land portions of the cylinder metal.

12. A cylinder according to claim 11 wherein the insert rings and cylinder land portions are relatively narrow and are inclined at a relatively small angle to a diameter of the bore.

13. An engine comprising a cylinder body and a piston assembly working in the cylinder bore comprising a piston body formed with sealing ring grooves and having at least an annular portion of its cylinder contacting surface composed of material adapted to apply lubricant to the cylinder bore, and hard lubricant-requiring non-metallic expansible sealing rings seating in the grooves of the piston body.

14. An engine comprising a cylinder body having a bore defined by a metallic interior wall and a piston assembly working in the cylinder bore comprising a piston body having a cylindrical working surface of non-metallic composition, circumferential grooves in the piston body, and hard non-metallic expansible split sealing rings seating in said grooves.

15. An engine comprising a cylinder body of relatively soft metal, a piston assembly working in the cylinder bore comprising a piston body having at least an annular non-metallic surface portion composed of material adapted to lubricate the cylinder bore, circumferential grooves in the piston, and non-metallic sealing rings seating in said grooves.

16. An engine comprising a cylinder body of relatively soft metal, a piston body having a non-metallic cylindrical surface and working in the cylinder bore, grooves in the piston body and hard non-metallic expansible sealing rings seating in said grooves.

17. A reciprocating engine comprising a cylinder body and a piston assembly working in the cylinder bore, said cylinder incorporating a series of axially spaced narrow wear-resistant insert rings surrounding the bore and separated by narrow annular land portions of the cylinder body, and the piston assembly including a piston body having circumferential grooves, and hard non-metallic sealing rings seating in said grooves.

18. An engine according to claim 17 wherein the cylinder insert rings are inclined to the sealing rings on the piston.

19. An engine according to claim 17 wherein the cylinder insert rings and annular cylinder land portions are of the same order of axial width as the piston sealing rings, and the inserts are so inclined to the piston rings that the piston rings simultaneously contact insert and cylinder land surface portions through traverse of the rings of the area of the cylinder containing the insert rings.

20. An engine according to claim 17 wherein the cylinder insert rings and annular cylinder land portions are inclined to the piston sealing rings, the width of the insert rings and land portions, and their angle of inclination, being such in relation to the piston sealing rings that during traverse of the piston the piston sealing rings will continuously make substantially equal contact with insert ring and cylinder land surfaces.

21. An engine cylinder having an interior wall defining a bore and a plurality of insert rings of wear-resistant composition embedded in said interior wall and surrounding the bore, said insert rings being axially spaced from one another by intervening annular land portions of said interior wall of the cylinder.

22. An engine cylinder having an interior wall defining a bore and a plurality of insert rings of wear-resistant composition embedded in said interior wall and surrounding the bore, said insert rings being uniformly inclined to the axis of the bore and being axially spaced from one another by intervening annular land portions of said interior wall of the cylinder.

23. An engine cylinder according to claim 22 wherein the insert rings are inclined at an angle of less than 15 degrees to a diameter of the bore.

24. An engine cylinder having an interior wall defining a bore and a plurality of insert rings of wear-resistant composition embedded in said interior wall and surrounding the bore, said insert rings being of carbon graphite, and being axially spaced from one another by intervening annular land portions of said interior wall of the cylinder.

WILLIAM M. ANDERSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,264,871	Jefferies	Apr. 30, 1918
1,955,292	Heintz	Apr. 17, 1934
1,010,787	Nilson	Dec. 5, 1911