PISTON RINGS IN COMPRESSION IGNITION ENGINES

by

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In the early steam engines it was the practice to fit leather buckets to the piston very much as in the present-day bicycle pump. This was quite satisfactory as the piston of the early atmospheric engines had only one working stroke in which it was forced down by atmospheric pressure above it, the steam being used only to create a vacuum below the piston, which was raised during the idle stroke by the weight of the pump rods and a counterweight and not by the pressure of the steam below.

Thomas Newcomen

The principle of the piston ring was discovered accidentally in 1713 by Newcomen & Cawley, the description of this event being taken from Desaguliers' *Experimental Philosophy.*

" Having screwed a large broad piece of leather to the piston, which turned up at the sides of the cylinder two or three inches, in working it wore through, and cut that piece from the other, which, falling flat on the piston, wrought with its edge to the cylinder ; and having been in a long time was worn very narrow, which, being taken out, the happy discovery was made that a bridle rein, or even a short piece of match or rope going round, would make the piston air and watertight."

Newcomen in 1717 recommends the use of yarn plaited into a square sennit and soaked in tallow (*Thoughts on Mines*), while James Watt in 1782 uses a similar packing in a built-up piston with a junk ring.

Matthew Pitts in 1793 patented a form of piston in which the packing could be forced out against the cylinder as it wore by screwing down on the junk ring, thus making it unnecessary to remove the piston from the engine for this purpose.

James Watt

Another method introduced by Watt as early as 1769 was to cover the piston with water in addition to any other packing, in order to provide a better air seal on the " atmospheric " stroke.

In a recent letter on this subject from Dr. H. W. Dickinson, the Secretary of the Newcomen Society, he mentions that " Watt had a great deal of trouble with packing because of steam on both sides of the piston. Soft packing served his turn and I believe he invented the junk ring."

Edmund Cartwright

In 1797 Edmund Cartwright patented the first known metallic piston ring, which he described as follows :—

" I make the piston entirely of metal, without any packing whatever, which is thus done :—the base of the piston being somewhat less than the bore of the cylinder, and its surface made as true and smooth as may be, a flat metal ring equally true and smooth is laid upon it, divided into segments (whose ends are also accurately fitted to each other), which ring completely fits the cylinder within the ring lies a spring pressing it outward, but so contrived by taking its bearing from two adjoining segments, as that the ring, should it expand, will only open between the segments from which the spring takes its bearings. This opening is secured by a segment of the ring lying on it, and another behind it, which two segments are also kept to their places by springs pressing them outwards. The whole is kept from rising off from the base by another flat ring accurately fitted and held down by an adequate pressure, but not so great as to impede the segment from gliding accurately upon the base."

It is interesting to note that at the same time he patented a metallic gland packing very similar to the United States packing in use at the present day.

This packing seems to have had comparatively little favour, probably due to the large number of springs required which would be very liable to corrode in the extremely wet steam conditions in the early engines.

Sir John Barton

Sir John Barton, of the Royal Mint, patented a segmental piston ring with springs in 1816 and William Jessop introduced in 1823 a ring similar in appearance to a short spring of rectangular wire compressed under the junk ring in the piston. In the same year Jacob Perkins patented a method of sealing the gap in what he described as a ring " as at present used for metallic packing." The sketch accompanying this specification shows a ring of the Ramsbottom type assisted by springs placed behind it.

John Ramsbottom

About this period the piston rings as at present known must have made its appearance, but there appears to be no master patent. Both the turned Ramsbottom and the hammered ring are described in Grier's *Mechanic's Pocket Handbook* of 1848, and the patents from 1823 onwards contain a number of ingenious designs of ring, some of which have since reappeared, but all of which refer implicitly or explicitly to a " metallic packing as normally used " which appears to have been the Ramsbottom ring, or some obvious variant.

Ramsbottom patented in 1852 a rather complicated form of double ring, but the chief contribution that he appears to have made was the idea of fitting several rings to the same piston, which is the invariable present-day practice. It is interesting to note that he does appear to have been the originator of the " pre-formed ring," *i.e.* a ring of non-circular form so designed as to give a true circle and exert an even pressure when compressed in the cylinder, and it is a little ironical that his name should have been handed down attached to a ring that he did not invent, while his real contribution is forgotten. It is, however, quite obvious from the minutes of discussions on the subject at the Institution of Mechanical Engineers that soft packing was in common favour right up to 1855, though it had almost completely disappeared by 1860. By 1865 all the variants of the compression ring now in use were made and employed.

By 1920 the emphasis had shifted to the internal combustion engine, and oil control troubles had begun to appear. The first type of oil control ring fitted as such seems to have been the stepped scraper, displaced very soon by the bevelled and later by the slotted scraper, but again the origin of these designs is wrapped in mystery. In recent years no major advance, except in the matter of materials and manufacturing technique, has been made.

The following remarks are principally concerned with Diesel engines, but most of them are applicable to petrol engine practice as conditions are similar, except that the atmosphere in a Diesel engine cylinder has an oxidising, and that in most petrol engines a reducing, effect ; in Diesel engines this aggravates oil decomposition and consequent ring sticking.

FUNCTION OF THE PISTON RING

The piston ring in an I.C. engine has three duties to perform :—

(i) To seal against the passage of gas down the cylinder.
(ii) To control the passage of oil up the cylinder.
(iii) To conduct heat from the piston to the cylinder wall.

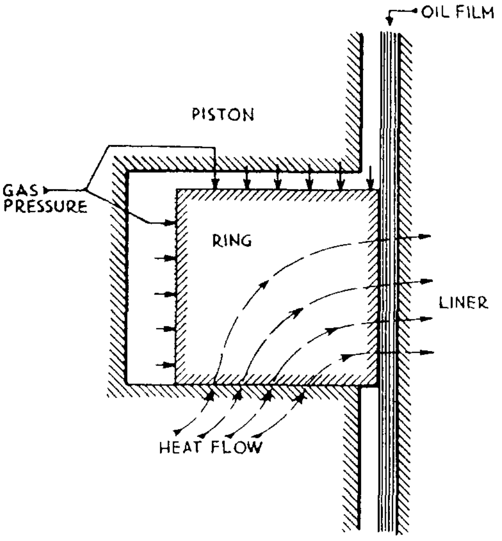


FIG. 1

During the power stroke the piston ring seats on the lower face of its groove and is pressed down by gas pressure above it, and pressed out against the cylinder wall by its own radial pressure, and by the pressure of the gas behind it (Figs. 1 and 2 (A)). The gas pressure behind the top ring is approximately equal to the pressure existing instantaneously in the combustion space and there is a reduced. but similarly fluctuating, pressure behind the lower rings.

During the exhaust stroke the ring remains on the lower face of the groove, the gas pressure above and behind it falling to a pressure intermediate between the exhaust pressure in the cylinder and the pressure at the end of the firing stroke. The higher the revolutions per minute, the greater this residual pressure will tend to be (Fig. 2B).

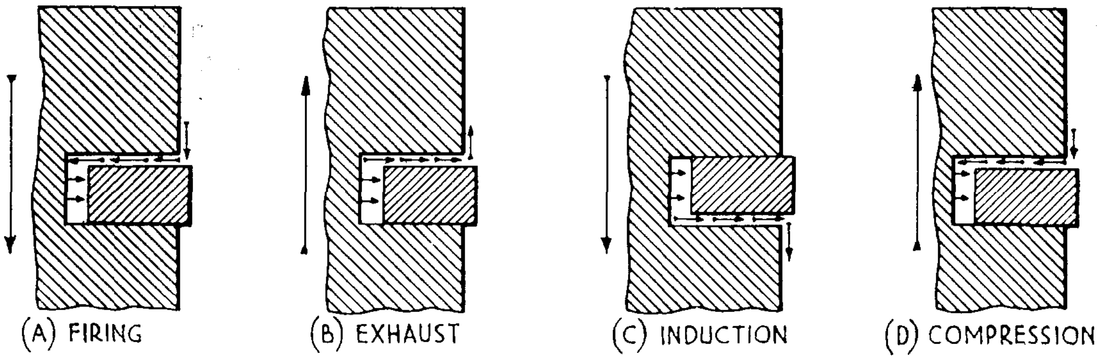


FIG. 2

On the induction stroke, the ring, having no high gas pressure above it, will move to the upper face of the groove, and the residual gas trapped behind the ring will expand down to the next ring : this process continuing in diminishing quantities down the ring belt (Fig. 2C).

On the compression stroke the ring moves again to the lower face of the groove (Fig. 2D), the gas pressure building up above and behind it until the firing stroke.

The ring is normally separated from the cylinder wall by a film of oil which reduces friction and wear, and forms a more effective gas seal than can be obtained by dry contact. The passage of gas behind the ring, however, is only prevented by the metal to metal fit of the ring on the face of the groove. It is therefore obvious that the degree of truth and finish of these mating surfaces is most important.

Oil control is effected by the scraping of the rings on the liner and is affected by the radial pressure and design of the bearing face especially as regards the edges of the ring.

Heat passes up from the lower face of the groove to the ring and thence via the oil film to the cylinder wall. It can here be noted that landing rings form a serious impediment to this flow.

GAS SEALING

There are three paths by which gas can pass the ring.

(i) Through the gap.
(ii) Between the ring and the liner.
(iii) Behind the ring.

Through the Gap

There is very little that can be done concerning the passage of gas through the gap, except to arrange that the gaps are not in line when the rings are assembled. The actual shape or type of gap does not seem to have much bearing on the blow-by except in the case of some of the more complex rings with labyrinth gaps. These, however, are exceedingly expensive to produce. In small high-speed engines with plain butts gaps up to $\frac{1}{16}$ in. have very little effect on the blow-by.

Between Ring and Liner

Passage of the gas over the face of the ring is prevented by the radial pressure of the ring assisted by the gas pressure behind it, the oil film providing the seal. As the total radial pressure increases with the gas pressure, the ring is self-adjusting to a considerable degree, the limit being reached when the radial pressure is such as to destroy the oil film completely.

At top dead centre, the film almost invariably does break down, due to the high pressure and temperature, reversal of motion and general lack of oil at this point, so that zero blow-by is in practice unobtainable. A copious supply of lubricant and/or an increase in its viscosity or wetting qualities help in this direction, but may introduce difficulties in lubrication and oil control.

A stuck ring cannot exert its radial pressure and therefore will blow more or less seriously according to how badly it is stuck.

Another cause of blow-by, especially in highly rated high-speed engines, is "flutter." As can be seen from Fig. 2, the ring remains seated on the lower face of the groove throughout the compression and firing strokes, the gas pressure above the ring preventing it from moving to the upper face of the groove when the piston starts to move down. At the top of the compression stroke, the inertia of the ring may be enough in a very high-speed engine to cause it to continue to travel up the cylinder when the piston stops and reverses. Should this occur, the very high pressure gas behind the ring is suddenly vented downwards when the ring moves off the lower face of the groove. This will cause the ring to be given an impulse to spring inward, and the ring may then begin to vibrate as a tuning fork, and, as such, it has a natural frequency, the butts moving in and out, and the whole ring opening and closing. When this occurs the ring travels down the bore in a series of "grasshopper leaps," allowing blow-by to increase rapidly. After some time this produces a characteristic banded appearance on the liner (Fig. 3).

The natural frequency of the ring may quite easily be calculated, but this calculated frequency has no practical application due to the very complex

FIG. 3.—BANDS ON CYLINDER LINER (SEE PAGE 55)

system of exciting and damping forces to which the ring is subject. If ring flutter is found to occur at all it will usually do so over a wide speed range, and the only means of attacking the problem are either (*a*) to increase the natural frequency of the ring, or (*b*) to increase the damping forces on the ring. The frequency of the ring may be increased by making the ring of smaller section for the same stiffness, and the damping forces enlarged by increasing the radial pressure, especially at the butts.

This second method is that normally employed as it entails no modifications to the piston grooves, and the increased radial pressure helps to prevent the ring from moving up the bore due to inertia. It usually improves the sealing at all speeds although perhaps at the expense of increased cylinder wear.

It is principally to overcome ring flutter that the radial pressures in aero engines are so high ; up to 20 to 25 lb./sq. in., as against 12 to 15 lb./sq. in. in less highly rated engines.

Behind the Ring

Leakage behind the ring is prevented by the fit of the ring against the lower face of the groove. The ring is held in place by the gas pressure above it, and is therefore also to some degree self regulating. It will be obvious, as mentioned above, that the truth and finish of the mating surfaces is most important, and great care should be taken over this point when fitting rings. Before rings are fitted they should always be tried by pressing the ring on to a surface plate, when any portions of the ring not bearing on the plate can usually be detected. If any such points are found to exist the ring should be lapped true. In a used ring dark patches on the lower surface are an indication of warping. A convenient jig for this purpose may be made by turning a groove in the face of a flange about $\frac{1}{32}$nd of an inch shallower than the width of the ring, and of breadth and diameter as to hold the ring in the same state of compression as when it is fitted in the cylinder. The ring can then be lapped on to a surface plate that can conveniently be made of a mild steel flange three to four inches wide and of the same mean diameter as the ring, using fine grinding paste (Fig. 4). It is a good practice to do this even if the ring seems to be true, and it should always be done when replacing used rings. This treatment is not normally applicable to rings under 6 in. diameter, as such rings, if wavy, will flatten out under the weight of the jig, reverting to their waves when removed after grinding. Small rings found to be warped should be discarded.

As an example of what a difference this treatment can make, a single cylinder engine, 14½ in. bore, 15 in. stroke, 460 r.p.m., in use at the Admiralty Engineering Laboratory, was found to have a blow-by at full power of about 200 lb./sq. in. On examination the grooves we found to be in very bad condition and the rings warped. The rings were lapped true and replaced, nothing being done to the grooves. After a few hours' running to allow the rings to settle in the blow-by had fallen to between 100 and 200 lb./sq. in.

A good finish on rings and grooves also helps to obviate ring sticking, by making it easier for the deposits to be washed away by the oil before they can build up to such an extent as to jam the ring in its groove.

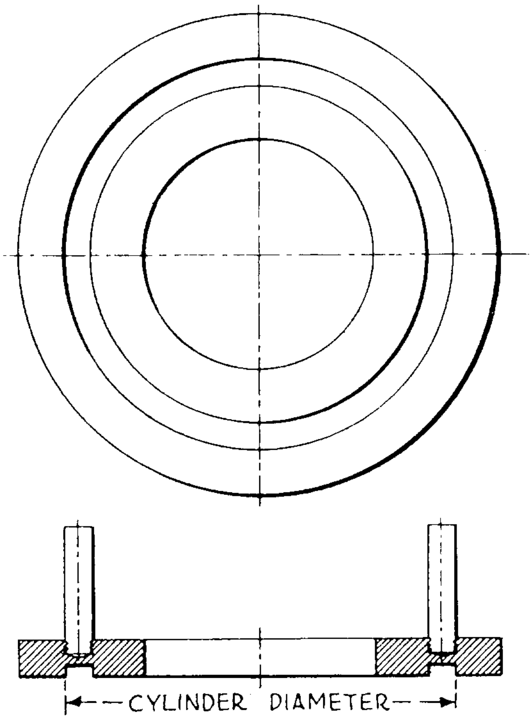


FIG. 4

It will be seen from Fig. 2 and the explanation on page 54 that the ring tends to act as a check valve, passing a little gas downward at each stroke, but not venting upwards. If wide shallow radial grooves are cut in the upper face of the ring any gas that has passed the ring, either by this check valve action or by blow between the ring and the liner, is vented upwards during the induction stroke. This reduces blow-by to a quite surprising degree. One experimental engine, 9¾ in. × 10½ in., 920 r.p.m. with four compression rings, under test at the A.E.L. suffered so badly from blow-by, due chiefly to piston distortion, that special ventilation had to be fitted to remove the fumes pouring from the crankcase breather. Blow-by pressure was of the order of 400 lb./sq. in. Slots, as described above, were filed in the top ring, and while this did not cure this extreme case of blow-by, the blow-by pressure fell to about 80 lb./sq. in. and the output of fumes from the breather fell to quite manageable proportions. The treatment has also been used with success on an " S " class engine with the lower face of the ring grooves damaged, cutting the blow-by from 200 lb./sq. in. to 40 lb./sq. in.

CYLINDER LUBRICATION AND OIL CONTROL

To gain some conception of the problem of cylinder lubrication and oil control, it may be stated that in the case of a six cylinder high-speed engine consuming oil at the fairly high rate of one gallon in 15 hours, one cubic 32nd of an inch of oil passes each piston at each stroke. This amount of oil spread over the cylinder walls produces a film of microscopic thickness which can be increased or decreased by the most minute details.

There is a strong tendency in many quarters to make a fetish of low lubricating oil consumption, and to attain this end by the fitting of fiercer and yet fiercer scraper rings. It is rarely desirable to increase the degree of scrape that the makers of the engine have seen fit to provide, and such a practice will frequently defeat its own object. For the first 100 hours or so a gratifying reduction of oil consumption will be noted, followed usually by a rapid increase until matters are far worse than before. What happens is this : The oil supply to the liner is reduced so that the oil film between the rings and the cylinder wall is thinner than before. Whilst still enough to prevent seizure this film keeps breaking down and allowing momentary metal-to-metal contact between the rings and liner. This, in turn, produces a much higher rate of wear, accompanied, in extreme cases, by scuffing and scoring. After a time, the ring and bore wear increases to such a degree that the rings lose their scraping powers, and pass large quantities of oil. When this stage has been arrived at no further wear takes place, but the damage has been done. Cases have even been known where this increase in oil consumption was taken to indicate that the scraping was still inadequate, and yet more scrapers fitted. In one case of this type, on a Diesel generator similar to those in use in H.M. ships, the final result was that the engine seized two pistons simultaneously on full load, the subsequent repair bill being of the order of £400.

It should be borne in mind that a slightly underscraped engine means a correspondingly increased oil bill, but no more, while even a slightly over-scraped engine will require an expensive rebore long before it should be necessary. A series of experiments carried out by a private firm on a wide range of types indicates that a Diesel engine whose oil consumption is less than $\frac{3}{4}$% of its fuel consumption is heading for trouble.

Special rings are sometimes fitted to keep down oil consumption during the running-in period. This is a thoroughly undesirable practice, as, until the machining roughnesses are worn off and the work-hardened skin or " Beilby Layer " has formed on the rings and liner, any breakdown of the oil film will cause much more serious wear and " scuffing " than when the engine has run-in.

Lubrication of the Piston

The lubrication of the piston is affected by :—

(i) Method of oil supply.
(ii) Temperature and viscosity of the oil.
(iii) Speed of the engine.
(iv) The design of the compression rings.
(v) The design of the piston skirt.
(vi) Any oil control arrangements fitted as such.

Oil Supply

The normal method of oil supply to the cylinder, in all except the largest engines, is by oil flung out from the rotating parts ; which can be aided by a timed squirt from a hole through the large end bearing which mates once per revolution with another hole drilled through the crankpin to the main oil supply. In the larger medium, and low speed engines and, of course, in all double-acting engines, oil is supplied directly to the liner by means of a separate pump. This may supplement or replace splash supply according to the design of the particular engine. Individual cylinder lubrication is not often found in H.M. Service outside submarines.

It will be seen that the splash or squirt method has the serious disadvantage that on starting no oil can be supplied to the bore until the engine has completed at least one revolution. The exact period of delay depends on the viscosity of the oil and the design of the engine. A splash lubricated engine running at a low speed may suffer from lack of cylinder lubrication if it is not specially designed to run at such speeds.

Temperature and Viscosity of the Oil

It would appear fairly obvious and it has been established by experiment, that the more viscous the oil the less is the likelihood of the oil film on the cylinder walls breaking down under running conditions. Unless special arrangements are fitted, the use of an extremely viscous oil is, however, disadvantageous in that, on starting, there is a greater delay before a sufficiency of oil reaches the bore, and the bearing temperatures are liable to be increased throughout the engine.

Temperature, as well as effecting viscosity, exerts an independent influence. It has been shown that of two oils of the same viscosity but with differing temperatures (other things being equal) the oil at the higher temperature is an inferior lubricant. And as, of course, for any given oil the lower the temperature the greater the viscosity, it would seem that, from the piston lubrication point of view, the lower the piston temperature the better. If, however, the cylinder wall temperature is below the dew point of the exhaust gases, extremely corrosive constituents will condense on the cylinder walls and can cause considerable damage.

The trend of modern design has been to put the piston and, therefore, the ring, temperatures up as far as possible, to cut down losses to cooling water, and thus improve fuel economy ; and to develop lubricants that will operate satisfactorily at these high temperatures.

Speed of Engine

Other things being equal, lubrication improves as the speed rises, due to the better supply in splash lubricated engines and the closer approximation to Michell conditions existing in the oil film. On the other hand, as the engine speed increases cylinder temperatures usually tend to rise, and the optimum speed from the point of view of cylinder lubrication will vary with the design of the individual engine.

Design of the Compression Rings

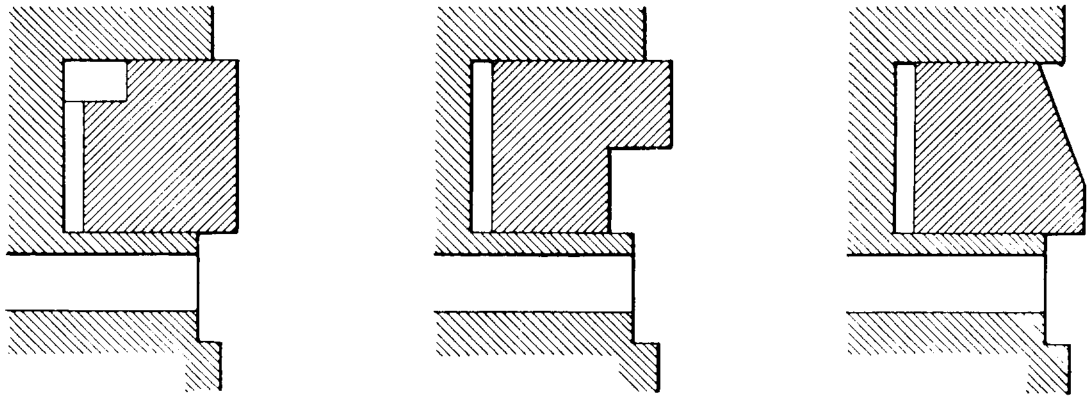
The compression rings exercise a considerable scraping effect that may be much increased if the rings are not truly rectangular in section. It has been found by experiment that a set of five compression rings with the bearing faces tapered to the extent of $\frac{1}{4}°$ can vary the oil consumption in a single cylinder engine from 2% to 12% of the fuel consumed, according to which way up they are fitted.

On the larger engines it is often advantageous to put a $\frac{1}{32}$ in. radius on the outside edges of the rings. This facilitates lubrication of the top ring by ensuring that the oil is not scraped off the liner by the lower compression rings. No advantage is gained by radiusing the edges of rings under 6 in. diameter.

Piston Skirt Design

The piston skirt usually exercises a mild scraping effect dependent, of course, on the clearance. If, however, the skirt is tapered so that the diameter at the bottom is less than at the top, a considerable increase in oil consumption may result, due to the wedge-effect on the oil film producing such high pressures in the vicinity of the scraper rings that they cannot operate satisfactorily. In a single cylinder motor-cycle engine of $3\frac{1}{4}$ in. bore, a taper of .001 in. per inch on the skirt has been found to very nearly double the oil consumption. Any taper in the other direction exerts no appreciable effect.

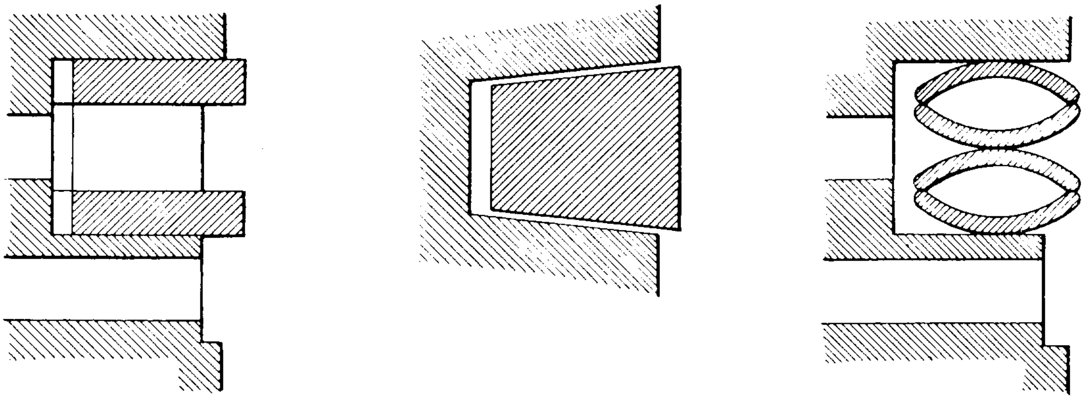
It is occasionally found helpful to give a slight inclination inwards to the bottom surface of the skirt to help to cut down excessive oil supply to the bore.



A. INTERNALLY STEPPED RING

B. STEPPED SCRAPER RING

C. BEVELLED SCRAPER RING



D. SLOTTED SCRAPER RING

E. TAPER RING

F. CORD RING

FIG. 5

Oil Control Arrangements

As mentioned above, plain compression rings can and do scrape oil from the bore, but this is usually insufficient to provide adequate oil control in modern high-speed engines. Scraper rings are made to fulfil this duty only, and are normally quite useless as a gas seal. Two main features govern their design :—

(i) The oil is scraped from the cylinder by the high wall pressure of the ring (up to 100 lb./sq. in.) usually obtained by reducing the effective contact width of the ring.

(ii) This oil must be allowed to flow away easily, or a build-up of pressure will take place below the ring preventing further scraping. To attain this, the skirt is usually relieved below the scraper ring and holes are provided to allow the scraped oil to flow freely to the inside of the skirt. These holes are often inclined downwards, but it has been found that for greater efficiency they should be drilled normal to the piston face, as the oil does not flow through these holes by gravity but is forced through by the pressure built up below the scraper ring. In extreme cases oil may even be forced up through inclined drain holes by inertia, supplying oil to the region below the scraper.

The internally stepped ring (Fig. 5A) is seldom found in internal combustion engines but is not infrequently fitted to air compressors as a combined compression and scraper ring. The cutaway at the top corner of the ring causes it to twist in its groove, and the lower corner to bear strongly on the cylinder wall producing a scraping action. Unlike other forms of scraper its effectiveness decreases as the ring beds in and it is therefore useful to " hold the fort " until the normal scraper rings have bedded. It has the further advantage that at light loads the twist causes the ring to fill the groove, preventing oil pumping. As the pressure on the top of the ring rises, the twist comes off thus freeing the ring in the groove, and ring sticking is prevented.

Stepped and bevelled scrapers (Fig. 5B and C) are plain rings having the effective bearing area of the ring reduced, producing a radial pressure of 30 to 50 lb./sq. in. The bevelled scraper has the advantage of riding over the oil film during the up stroke but the disadvantage of a comparatively rapid loss of radial pressure with wear. Bevelled scrapers should be fitted with the cutaway corner nearest the piston crown, stepped scrapers with the cutaway at the lower corner.

The slotted oil control ring (Fig. 5D) is really a development of the stepped ring but provides two scraping edges, and allows an additional escape for oil through the middle of the ring. Various forms of this ring exist, designed to assist the flow of oil from the ring or to produce variations in radial pressure for the same ring width ; but in one form or another the one illustrated is the commonest type fitted. For most purposes a radial pressure of 50 lb./sq. in. is quite adequate.

Heat Transfer

As previously stated heat is conducted from the groove to the ring and thence to the cylinder wall. The heat transfer by this means exerts a very profound influence on piston temperature, even where oil or water cooling is fitted, and is the dominating influence where uncooled pistons are concerned.

The top ring in an uncooled four-stroke piston normally leads off to the liner about 40% of the total heat entering the piston. This means that it is passing between 30 and 60 B.Th.U./sq. in./min. If any obstacle to this flow, such as a landing ring, is set up, the piston temperature in the vicinity of the groove will rise rapidly. This will cause heating of the oil with consequent deterioration in its lubricating properties, and if the temperature rises much above 280° C. most oils will decompose rapidly into sticky products that will gum the ring in its groove. The precise danger point varies with the oil used.

FAULTS AND TROUBLES IN PISTON RINGS

Most of the faults and troubles in piston rings have already been touched on but will be summarised here for convenience.

Ring Sticking

Ring sticking may be due to one of two causes :—

(i) Breakdown of lubricating oil due to too high a piston temperature.
(ii) Deposition of gummy products of inefficient combustion.

(i) Breakdown of lubricating oil will usually take place in Diesel engines at temperatures above 280° C. and in petrol engines above 300° C. The lower breakdown temperature in Diesel engines is due to the oxidising effect of the gases in the cylinder. This decomposition and consequent sticking may be obviated by keeping the ring groove temperature down, by arranging a supply of good oil to flush out the decomposition products before they can build up to such a degree as to jam the ring in its groove, and by paying attention to the surface finish of the ring and the groove so as to make it more difficult for these deposits to find lodgment. If the ring is prevented from turning while running, by pegging or by fitting it too tightly in its groove, it will stick more readily than a free ring, as the turning of the ring in its groove helps to rub away decomposition deposits. Decomposition may be considerably accelerated by the presence of various impurities in the oil which act as catalysts ; copper oxide has a particularly strong influence in this respect. Moral : don't leave oil too long in the engine.

(ii) Inefficient combustion is usually associated with running at loads and speeds widely different from those for which the engine is designed. It is often thought that the tendency for gum or lacquer deposits to form when engines are run light is due to the comparatively low temperature of the piston and combustion space. It can, however, be shown that this is not the case, and that this is due only to the deterioration of injection characteristics under these conditions.

Packing Out

In certain instances, the temperature of the groove may be such as to cause a breakdown of the lubricating oil, but the flushing effect of the oil supply and movement of the ring in its groove is sufficient to prevent sticking. In such cases the decomposition products tend to collect at the bottom of the groove and there bake to carbon. This deposit of very hard carbon, if allowed to build up, can cause the ring to be packed out proud of the piston causing ring seizures and occasionally even more serious damage.

Ring Flutter

Ring flutter is the vibration of the ring with the butts moving in and out. If flutter is found to be taking place the usual remedy is to increase the radial pressure of the ring, especially at the butts.

Ring Scoring and Scuffing

This defect usually arises during the running-in period and in most cases is a sign of over scraping.

Where steel or chromium-plated liners are fitted, it may be found that the rings will not bed themselves in, however copious the oil supply. In such cases the only remedy is to try another make of ring, as with these liners very small differences in the composition of the ring metal produce wide variations in the rate of wear. The exact cause of this phenomenon is not understood.

SPECIAL RINGS

A very large number of special types of ring have been devised for various purposes by ingenious inventors during the last thirty years. Not very many of these are worth serious consideration.

Taper Rings

These are sometimes fitted in engines, such as high-speed two-strokes, running with unavoidably high piston temperatures, as they have less tendency to stick than a plain ring (Fig. 5). They are expensive to produce, difficult to fit, and are particularly liable to pack out. They should therefore be examined and the grooves cleaned at regular intervals.

Fire Rings

These rings are really a type of split junk ring, and are fitted to small high-speed two-stroke engines, such as the Coventry K.F. engine as installed in 16 ft. dinghies (Fig. 6). They protect the top compression ring and are also useful because in these engines compression is designed to begin when the piston crown has passed the ports, but with a plain piston, when starting from cold, the piston clearance allows leakage back until such time as the top ring has passed the ports. This reduces the effective compression ratio and causes poor starting.

Special Scraper Rings

Many of these have been manufactured from time to time, but there are only three types that require serious notice. They are :—

(i) The Cord ring.
(ii) The Clupet ring.
(iii) The Wellworthy Simplex ring.

These types may sometimes be found under other names.

(i) The Cord ring consists of four or more steel rings, being in effect dished spring washers. These are fitted in the groove in pairs (Fig. 5F) and have a " windscreen wiper " action. Many spectacular improvements in engine performance have been claimed for these rings, principally due to the fact that they are really a very mild scraper and have, therefore, a beneficial effect when fitted to over-scraped engines. If these rings are fitted care must be taken to change the oil frequently during the running-in period, as a considerable amount of ring wear takes place at first with consequent adulteration of the oil with metallic powder.

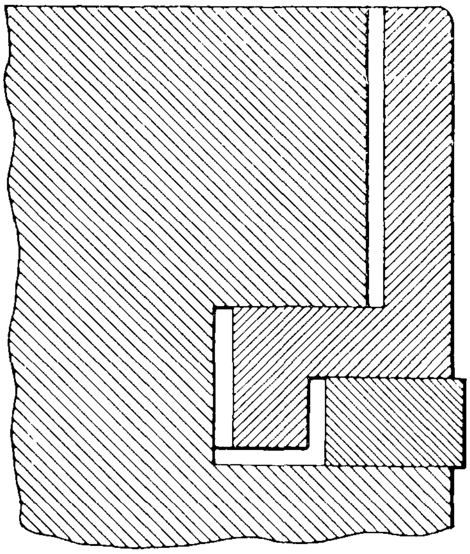


FIG. 6

(ii) The Clupet ring resembles two stepped scrapers attached to each other at four points and fitted in the same groove. The ring is a fairly effective scraper at first but clogs up readily in running. Its chief advantage is that it is so flimsy that it will adapt itself to an oval bore. A compression ring of similar design is also manufactured and has the same quality of suiting itself to a worn liner. They are therefore useful in postponing rebores. They have the disadvantage that they are very expensive and have a particular liability to break in the piston.

(iii) Wellworthy Simplex rings are similar to the Clupet but are much stiffer and attain their effect by an extremely high radial pressure. A steel expander ring is always fitted behind a Simplex ring. They should not normally be used except as a last resort as they can cause heavy liner wear.

Coated Rings

Rings are often coated with various substances designed to assist running in. Popular coatings are tin, which flows easily and facilitates bedding in by filling irregularities on the bore, iron oxide, which acts as a mild lapping agent, and various patent substances which provide an oil absorbent layer. The ring surface is sometimes etched to improve its oil retaining qualities.

FITTING OF RINGS

It is emphasised that the figures given are intended only as a general guide. Many engine makers have their own limits, notably Vickers who recommend much smaller clearances. Such recommendations should be followed, bearing in mind, however, that it is better on the whole that clearances should be a little too free rather than too close.

New rings should be tested by pressing on a surface plate to see if they are warped. Rings under 5 in. to 6 in. diameter should be discarded if warped ; larger rings may be lapped flat. If rings are even lightly corroded it is best to lap in any case so as to form a good surface on the bottom of the ring. The axial clearance of the ring in the groove should be about .0005 in. per in. bore, and not less than a total of .002 in. in the smallest sizes. A ring so fitted can be expected to pack out rather than stick. Some people prefer to fit with a closer axial clearance on the grounds that it is better that a ring should stick than pack out. This is, of course, largely a matter of opinion.

The radial clearance between the back of the ring and the bottom of the groove should be two to two and a half times the axial clearance, not less than .010 in. to .015 in.

The gap should be .002 in. to .003 in. per in. cylinder diameter. For liquid cooled engines the total gap should be not less than .010 in. to .015 in. ; for air-cooled engines it should be 1½ times this figure. It should always be remembered that rather too wide a gap will do little harm while serious damage can result if the ring, in expanding, closes the gap and forces itself out on to the cylinder wall.

The method given below for finding the radial pressure of a ring from the tangential load required to close it cannot be employed on used rings as a criterion of their suitability for re-use. This method determines the mean radial pressure only, and it is quite possible for a used ring to have a mean pressure almost the same as that of a new ring, while at the same time the local pressure at some points on the ring has fallen to zero.

Reject or re-lap warped rings, reject any ring whose fitted gap has doubled, and otherwise go by appearance. If in doubt fit a new ring.

EMERGENCY RING MANUFACTURE

The correct rings should *always* be used if available. If, however, in emergency, it is found necessary to make rings on board it is not normally worth while attempting any other than the plain "Ramsbottom" ring. If a high-grade grey cast-iron is not available, phosphor bronze or even gunmetal should be used in preference to white or low grade grey cast-iron.

Hand peening of rings is better not attempted, even by a good tradesman in the general way; the ring will probably finish up with a worse pressure distribution than a plain "Ramsbottom."

The ring, if cast iron, should be turned .035 in. per in. bore diameter oversize, inside and out ; if bronze, .09 in. per in. bore diameter. This will ensure a radial pressure of at least 6-7 lb./sq. in. for a normally proportioned ring, which is the least pressure to which I.C. rings should be made.

To find the radial pressure exerted by a ring, clamp one end and apply a tangential load to the periphery of the other end in order to close the gap to the fitted distance. A suitable method of doing this is to clamp a bight of wire to the outer surface of the ring near the free end and exert the pull through a spring balance. Knowing the load necessary to close the ring the radial pressure may be found from the empirical expression :—

$p = \frac{2L_t}{wd}$ where L_t = tangential load to close gap (lb.)
p = mean ring pressure on cylinder wall (lb./in^2.)
w = effective width of ring in contact with cylinder (inches)
d = cylinder bore diameter (inches).

The design method given above does not represent the latest or even the best practice, but a ring so made will " keep the flag flying " until proper replacements can be obtained. The method given is that used about 25 years ago, but the more modern technique calls for resources and specialised skills not available afloat, or in a dockyard.

It is appreciated also that the clearances, fitting methods, etc., given are not those used by everyone but, in the opinion of the author, they do represent a safe and reasonable practice.