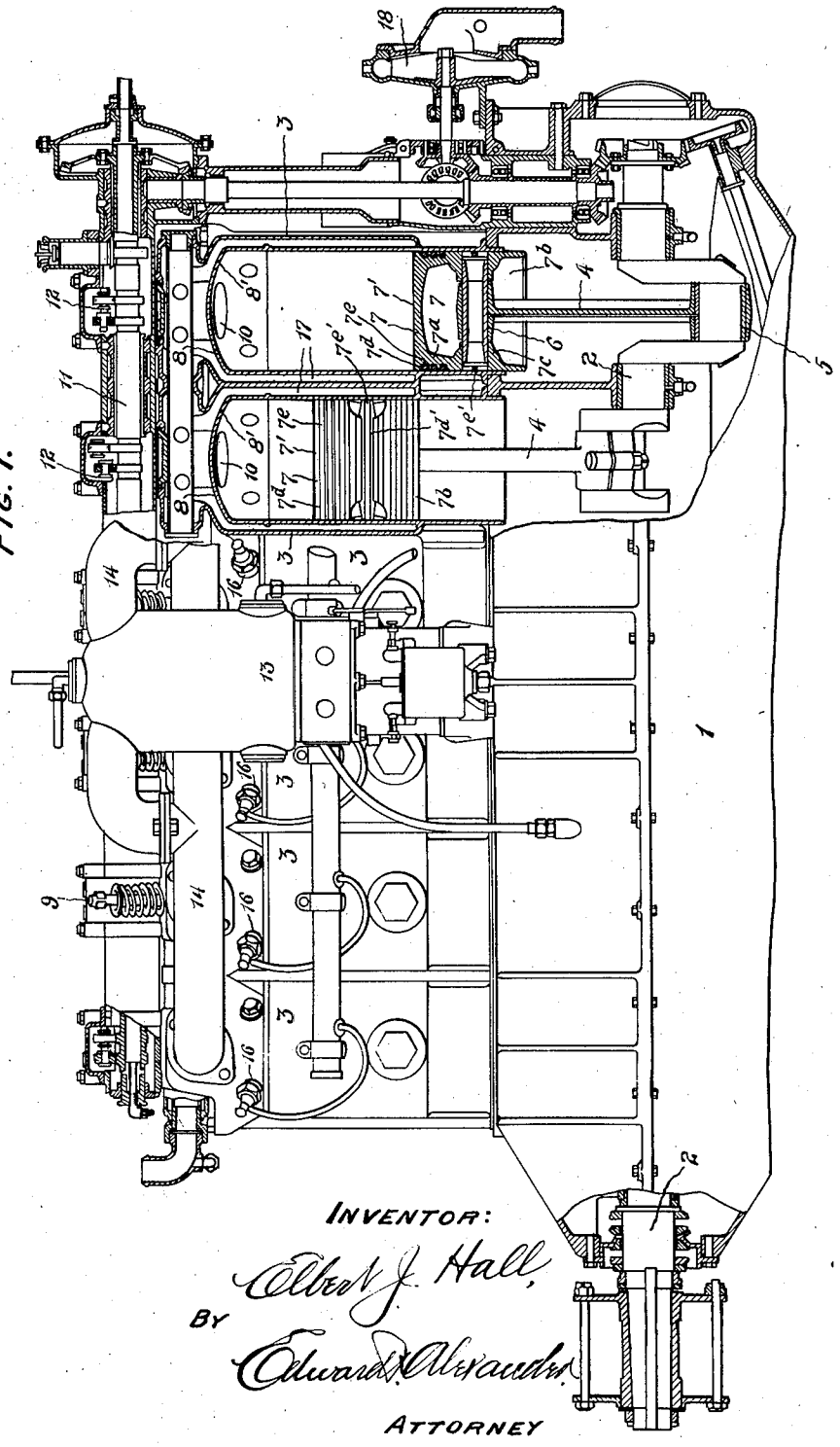
Aug. 11, 1925. **1,549,486**

E. J. HALL

INTERNAL COMBUSTION ENGINE

Filed Dec. 14, 1917 3 Sheets-Sheet 1.

FIG. 1.



INVENTOR:
Albert J. Hall,
BY
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Aug. 11, 1925. 1,549,486

E. J. HALL

INTERNAL COMBUSTION ENGINE

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FIG. 2.

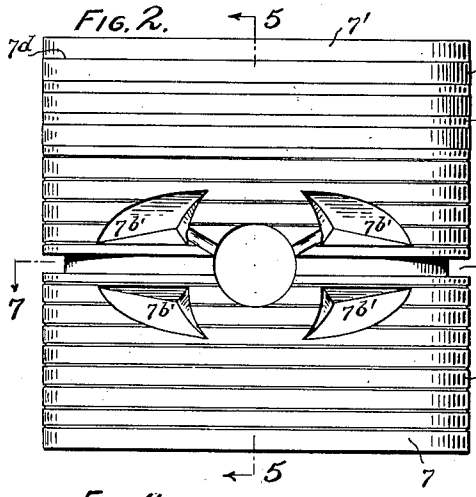


FIG. 3.

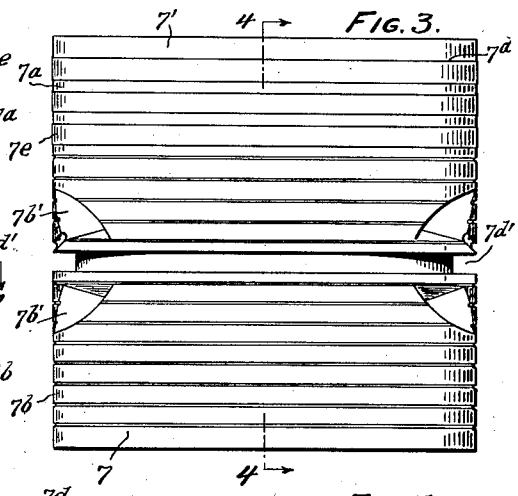


FIG. 4.

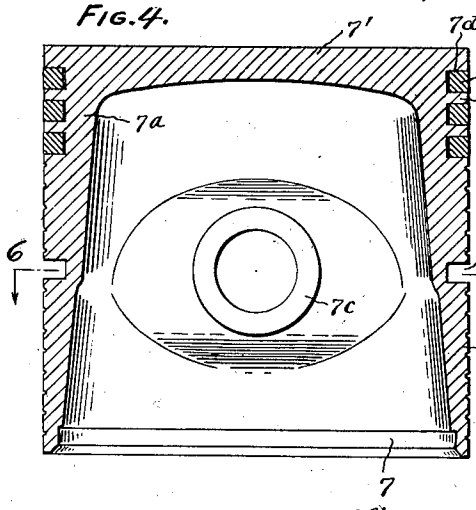


FIG. 5.

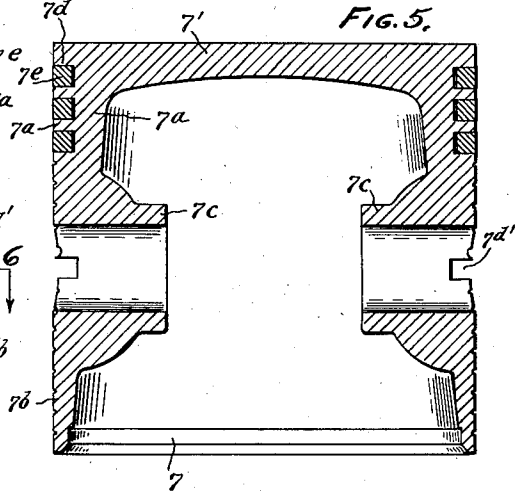
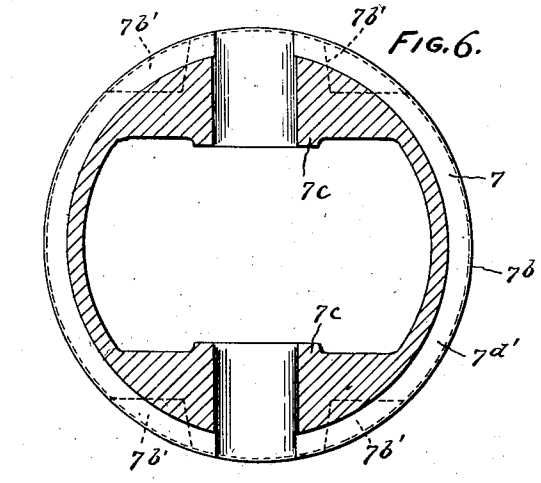


FIG. 6.



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Aug. 11, 1925. 1,549,486

E. J. HALL

INTERNAL COMBUSTION ENGINE

Filed Dec. 14, 1917 3 Sheets-Sheet 3

FIG. 7.

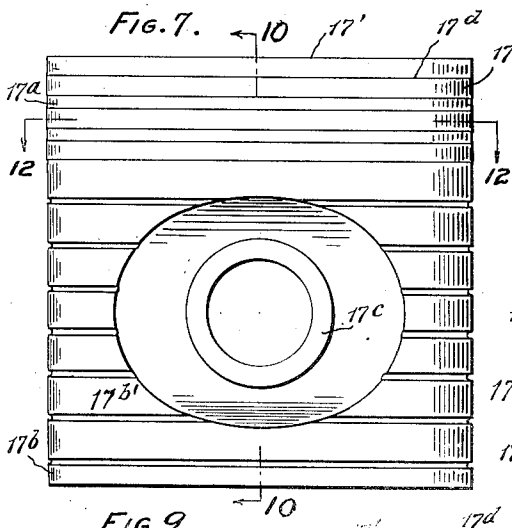


FIG. 8.

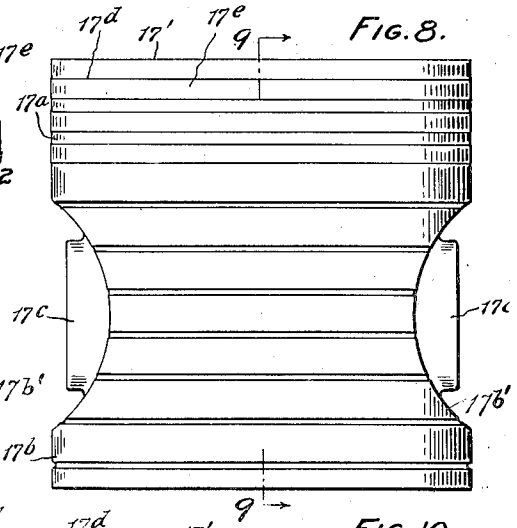


FIG. 9.

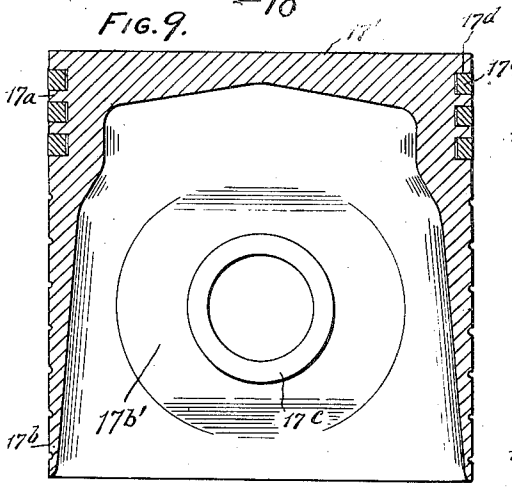


FIG. 10.

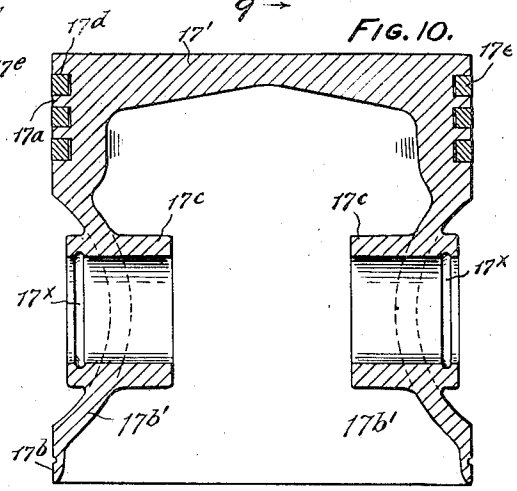
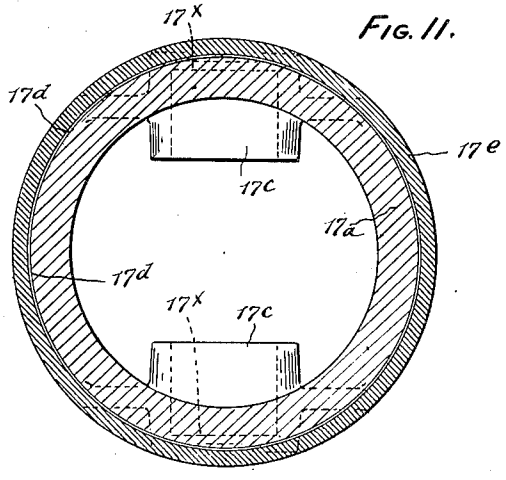


FIG. 11.



Albert J. Hall,
INVENTOR

BY Edward P. Alexander

ATTORNEY

Patented Aug. 11, 1925. 1,549,486

UNITED STATES PATENT OFFICE.

ELBERT J. HALL, OF DETROIT, MICHIGAN.

INTERNAL-COMBUSTION ENGINE.

Application filed December 14, 1917. Serial No. 207,200.

To all whom it may concern:

Be it known that I, ELBERT J. HALL, a citizen of the United States, residing at Detroit, in the county of Wayne and State of Michigan, have invented certain new and useful Improvements in and Relating to Internal-Combustion Engines, of which the following is a specification.

My invention relates to improvements in internal combustion engines, which enable me by expedients of marked simplicity materially to increase the reliability, efficiency and capacity of such engines, to increase greatly the time of continuous operation and especially of full load operation of such engines, and to economize materially in the use of lubricants. The said improvements are especially useful in connection with engines of the types used for automotive purposes but are applicable also to engines of other types.

One object of my invention is by simple expedients to avoid self-ignition of the combustible mixture in an internal combustion engine thereby enabling me to increase the compression of the engine.

Another object of my invention is to minimize carbon deposits above and substantially eliminate them below and on the sides of the piston of an internal combustion engine.

Another object of my invention is to preserve the quality of the lubricant in the crank case of an internal combustion engine for a much greater period of time than has been the case heretofore.

Another object of my invention is by the same simple expedients to minimize carbon deposits above and substantially eliminate them below the piston of an internal combustion engine and to preserve the quality of the lubricant in the crank case for a much greater period of time than has been the practice heretofore in such engines.

Another object of my invention is to prevent the decomposition of the lubricant in the crank case of an internal combustion engine and the formation of moisture therein due to burning of hydrogen set free during such decomposition.

Another object of my invention is by simple expedients to improve the volumetric efficiency of the engine.

Another object of my invention is by simple expedients to reduce the necessary clearance between the cylinder walls and the piston of an internal combustion engine.

Another object of my invention is to improve the internal combustion engine by simplifying the construction and making more efficient and economical the operation of the piston thereof.

Another subsidiary object of my invention is to improve the construction and operation of an internal combustion engine piston carrying piston rings in such way that said rings are maintained at low temperature in operation.

The defects or inefficiencies of internal combustion engines implied by the above statement of objects of the present invention, when superficially considered, may seem unrelated; but I have discovered that they are in reality closely related and are in fact due in a large measure to high working temperatures of the pistons of such engines as heretofore constructed and operated, especially those used for automotive purposes.

I have also discovered that by the use of structural materials which have comparatively recently become available for parts of internal combustion engines, such as the metallic alloys of aluminum possessing low specific gravity, high specific heat and high heat conductivity and capable of satisfactory commercial fabrication, it has become possible to so form and co-ordinate the parts of a piston of permissible weight that it will effectively conduct waste heat absorbed by it to the cylinder walls of the engine at such a rate that the temperature of its surfaces may be maintained sufficiently low to overcome the defects or inefficiencies referred to above.

Therefore, to the ends above noted in connection with the above objects, my invention consists in the provision of a simple and reliable construction and correlation of the cylinder and piston of an internal combustion engine, whereby the waste heat absorbed by the piston is dissipated and the piston is maintained at a low working temperature in such manner as to accomplish such objects.

Other objects of my invention will appear to one skilled in the art from the following descriptions of it, as embodied in use in an internal combustion engine of well known design. Purely for the purpose of illustration I have chosen in this connection one of the so-called Hall-Scott engines, more particularly adapted for aircraft use.

Fig. 1 is a view, partly in side elevation

and partly in section, of an internal combustion motor embodying my improvements, the lower portion of the crank case being broken away.

Fig. 2 is an elevation of one of my improved pistons, looking into one of the wrist pin bosses thereof.

Fig. 3 is a side elevation of the same piston illustrated in Fig. 2 from a position at 90° therefrom.

Fig. 4 is a section on the line 4—4, Fig. 3.

Fig. 5 is a section on the line 5—5, Fig. 2.

Fig. 6 is a section on the line 6—6, Fig. 2.

Figs. 7 to 11, inclusive, are views corresponding to those in Figs. 2 to 6, inclusive, but of a modified form of piston embodying my invention, section lines being numbered to correspond with figures.

In the drawings, 1 indicates the crank case of the engine and 2 the crank shaft suitably mounted, in a well known manner, in bearings therein. 3 represents a cylinder, the motor illustrated having six thereof. 4 is a connecting rod. 5 is the bearing between the lower end of the connecting rod and the crank shaft. 6 is a wrist pin between the upper end of the connecting rod and the piston, which latter is indicated by 7. The engine has cup-shaped sections 8, the inner walls of which comprise the inner walls of the cylinder. The head 8′ of each such section is formed with inlet and outlet ports controlled in a well known manner by inlet and exhaust valves 9, 10, respectively. These valves are shown to be operated in the well known manner by an overhead cam shaft 11 suitably geared to one end of the crank shaft 2, rocker arms 12, suitably journaled relatively to the cam shaft 11 in the cam shaft housing, being adapted to actuate said valves in the well known manner. The carburetor 13, of any well known construction, supplies the fuel to the intake manifold 14, which conducts it to the gas inlet chambers controlled by the inlet valves 9. Suitable ignition apparatus, such as magnetos (not shown) suitably geared to the crank shaft and electrically connected to the spark plugs 16, furnishes the required fuel igniting sparks at the proper time intervals in the various cylinders in the well known manner. Each cylinder section 8 is shown to be partially surrounded by a water jacket 17. Water is circulated through the jackets of the various cylinders by means of a circulating pump 18 geared to the crank shaft and properly connected by water conduits (not shown) to the water jackets of the engine and a suitable radiator (not shown) of any well known construction.

Referring to Figs. 2 to 6 inclusive, the construction of one form of my improved pistons is more clearly illustrated. It comprises a head 7′ having side walls 7^a, a skirt 7^b and wrist pin bearing bosses 7^c. The side walls 7^a are peripherally grooved in a well known manner as indicated at 7^d to receive piston rings 7^e of suitable construction.

As I have already indicated, I have found that a number of the serious troubles encountered in the use of internal combustion engines are due to the high working temperature of the pistons, reference being had especially to engines such as are used for automotive purposes and which do not permit of the use of special apparatus for the cooling of the pistons. And, as I have also stated above, I have discovered that it is possible by the use of certain materials of construction now available for engine pistons, to produce a cylinder and piston apparatus in which the piston, while light in weight, is adapted to convey to the cylinder walls, and thence to the cooling water, or other cooling medium, the waste heat absorbed by the piston with such rapidity that the surfaces of the piston are maintained at a temperature sufficiently low to obviate the troubles in question. Indeed my invention, in its preferred form, consists essentially in making the engine pistons of metal having a low specific gravity and a high coefficient of heat conductivity, and preferably having a high specific heat, and in so disposing the constituent material of each piston as to provide a heat conducting path from the center of the piston head outward to and through the side walls of the piston of a capacity adapted to conduct the heat absorbed through the upper surface of the piston from said surface to the cylinder walls rapidly enough to maintain the piston surfaces at the low temperature referred to, with only a slight loss of heat from the piston to the crank case and the lubricant.

Since it is desirable to keep the weight of the piston as low as possible I prefer not to exceed the cross sectional dimensions necessary for the various parts of the piston walls for the free conduction of the waste heat, in so far as such dimensions are structurally practical. Considering the piston simply from the standpoint of dissipation of waste heat absorbed by it, it will be seen that the thickness of the piston head should increase from zero at the center of the piston outward to the side walls of the head so as to provide a heat conducting path of sufficient capacity to freely conduct the waste heat absorbed at all points of the upper surface of the head to said side wall and thence to the wall of the piston skirt. In other words, the conducting areas of concentric cylindrical cross sections of the piston head must increase from the center outward at least at the same rate as the quantity of heat to be handled at these sec-

tions. To get this result with the minimum weight it is necessary that the thickness of the head be increased from the center of the piston outward in such a manner that the cylindrical cross-sectional areas at different radii vary substantially as the quantity of heat to be conducted away from these areas. Also since the heat passes from all points of the outer surface of the piston skirt to the cylinder wall in contact therewith it is permissible to taper the skirt from the top downward. Furthermore to prevent overheating of the piston rings with the resultant carbonization of the lubricant and sticking of the rings, the side wall of the piston head should have a sufficient thickness inside the ring grooves to freely and unrestrictedly conduct the waste heat from the end wall of the head past the rings to the piston skirt.

However for obvious practical reasons it is not desirable to reduce the thickness of the head to zero at the center, and it is possible, also, to somewhat vary the cross sectional dimensions from the values theoretically indicated for heat transmission without seriously increasing the weight of the piston; indeed such moderate variations may be found desirable for practical reasons incident to the fabrication of the piston.

The piston illustrated in Figs. 2 to 6, inclusive, is formed preferably as a casting of metallic alloy having relatively high heat conductivity, high specific heat and low specific gravity, in comparison with iron. Certain of the metallic alloys of aluminum, now extensively used in the manufacture of pistons, I have found to be advantageous for the purpose, such, for example, as an aluminum alloy consisting of approximately aluminum 88%, copper 10% and other elements not to exceed 2%, such as magnesium, iron, nickel and titanium or any of them. The specific gravity of such an alloy is approximately one-third that of iron while its coefficient of heat conductivity is approximately twice that of iron.

The thickness of the piston head 7′ at its center, as illustrated in Figs. 4 and 5, having been determined by practical considerations other than heat conducting capacity, the thickness of the head is increased in all directions radially from the center outward to such an extent that the areas of cylindrical cross sections of the end wall of the piston coaxial therewith are proportional to the increasing amounts of heat to be conducted radially outward to the side walls, thus insuring that no part of the upper surface of the piston head will become unduly heated in operation. For example with an aluminum alloy piston for an aircraft engine having a diameter of approximately five inches, I have found that a thickness at the center of the piston head of approximately one fifteenth of the diameter will give satisfactory results.

The wall 7′ of the piston head merges into the side wall 7^a thereof, which latter preferably has a thickness great enough to enable it to conduct the heat to the skirt 7^b as rapidly as said heat is delivered to it from the end wall 7′, so that a minimum amount of the heat is conducted to the piston rings and thence to the cylinder wall. As the outer surface of the skirt 7^b contacts directly with the cylinder wall from top to bottom of said skirt, the thickness of the latter is diminished from the top downwardly so as to avoid undue weight without interfering with the requisite heat conducting capacity of the skirt.

While, as stated above, I prefer to minimize the amount of heat conducted through the piston rings to the cylinder walls, it is to be observed that my invention in its broader aspects, as indicated by certain of the appended claims, is not limited to this feature, the essential thing, in the broadest aspect of the invention, being that the waste heat shall be conducted sufficiently rapidly from the upper surface of the piston to the cylinder wall regardless of what proportion of such heat is conducted through the piston rings.

I have provided novel means for connecting the wrist pin bosses 7^c to the skirt 7^b so as to attain distinct mechanical and thermal advantages. The skirt is indented at $7^{b'}$ around the adjacent wrist pin boss and connected to said boss intermediate its ends so as to distribute the pressure from the piston head more uniformly upon the boss. Again, such heat as is conducted by the skirt to the bosses 7^c is distributed more uniformly to them so as to render their temperature more uniform. Furthermore, these results are secured by the use of a minimum amount of material with corresponding light weight. A piston ring groove $7^{d'}$ is formed in the piston, substantially in the plane of the axis of the wrist pin bosses, to receive a wiping ring $7^{e'}$ (Fig. 1), said ring serving also to prevent longitudinal displacement of the wrist pin.

The piston illustrated in Figs. 7 to 11, inclusive, comprises a head 17′ having side walls 17^a, a skirt 17^b and wrist pin bosses 17^c, the skirt wall having indented sections $17^{b'}$ which join the bosses 17^c at the center parts thereof. The side walls 7^a of the piston head are formed with grooves 17^d to receive piston rings 17^e of any well known or suitable construction. The cross sectional dimensions of the piston walls approximate the values theoretically indicated for heat transmission somewhat more closely than do the dimensions of the construction illustrated in Figs. 2 to 6, inclusive. However,

the distribution of the material in the piston walls is determined by the same principles and the structure does not call for further description except with respect to the wrist pin boss. The wrist pin is held against longitudinal displacement by means of spring rings (not shown) of well known construction inserted in the grooves 17^x in the outer ends of the bosses 17^c. This form of retaining means for the wrist pin permits a somewhat simpler and lighter form of the skirt wall where it is indented to join with the bosses 17^c.

It is to be noted that the rate at which heat is absorbed through the upper surface of the piston head is the main factor determining the dimensions of the piston walls for a constituent material of given heat conductivity; and as I am at present advised I believe it desirable if not necessary that the heat conducting capacity of the piston walls should be great enough to conduct the waste heat from the upper surface of the piston head substantially as rapidly as it is absorbed through such surface. However, I do not wish to thus limit my invention as it may be possible to prevent the temperature of the piston rising above a suitable working temperature if the rate of heat conduction away from the upper surface of the piston head is not as rapid from instant to instant as the absorption of heat at said surface providing that the average rate of said heat conduction during the engine cycle or a given part or parts of said cycle is substantially the same as the average rate of the heat absorption at the upper surface of the piston head during said cycle, or said part or parts thereof.

I have explained above that the areas of the cylindrical cross sections of the end wall of the piston should increase from the center of the piston outward at least as rapidly as the amount of heat to be conducted through the respective cross sections, but it may be pointed out further that while the circumferential lengths of the various cylindrical cross sections of the head vary directly as their respective radii, the corresponding areas of the upper surfaces of the piston head circumscribed by said sections and exposed to and absorbing heat from the combustion gases, vary as the square of the radii. It is obvious, therefore, that in order to secure conducting capacities for the said cross sectional areas substantially equivalent to the absorption capacities of the corresponding head areas, it is necessary that the thickness of the head be increased from the center outward at a rate corresponding to the difference between the arithmetical and geometrical variables refered to.

The significance of the character of my improvements and of the manner in which an engine embodying them operates will now be readily understood. By reason of the high heat conducting capacity of the piston the heat absorbed at the upper surface of the piston head is conducted by the piston walls to the cylinder walls at a rate such that the average rate of dissipation of heat by the piston during the engine cycle or a given part or parts of said cycle is substantially equal, as I now believe, to the average rate of absorption of heat by the piston during the said cycle, or said part or parts thereof.

The result is a working temperature of the engine pistons much lower than it has heretofore been possible to attain in engines having no special means for cooling the pistons. Indeed I have found it possible to attain a working piston temperature low enough to practically wholly eliminate the engine troubles which I have heretofore referred to, and at the same time increase the compression of engines, to the operation of which such troubles have been incident.

In the carrying out of my invention use is made of a novel process of disposing of the waste heat incident to the operation of the engine. In said process waste heat is absorbed at the upper surface of the piston in contact with the combustible mixture in the cylinder of the engine, is then conducted by a metallic heat flow path from such surface to a discharge area in sliding contact with the cylinder walls and thence to said cylinder walls at such a rate that said surface is maintained at a temperature sufficiently low to avoid self-ignition of the gases at a predetermined compression pressure. This heat flow path from the surface of the piston, besides being of high heat conductivity, is preferably of high specific heat so as to insure a low temperature of such path in the carrying out of the process. Furthermore, the heat flow path is preferably of low specific gravity so as to reduce materially its weight as a reciprocating mass. The rate of conducting the waste heat absorbed at the piston surface in contact with the combustible mixture in the cylinder to the cylinder walls is such that the temperature in the crank case is maintained sufficiently low to preserve the lubricating quality of the lubricant therein substantially indefinitely, so far as deterioration due to heat is concerned, or in other words, below the point at which it will decompose.

As I am at present advised, I believe the above process can also be properly characterized by the statement that the waste heat, after being absorbed at the upper surface of the piston head, is conducted from said surface to the cylinder wall by a metallic path of low specific gravity and high heat conductivity (and preferably also high

specific heat) adapted to conduct the heat as aforesaid at an average rate during the engine cycle or a given part or parts of said cycle substantially as great as the average rate of heat absorption at said upper surface during said cycle or the said part or parts thereof.

The beneficial results flowing from my solution of the problems in question are many. It will be noted that in the operation of my improved engine the piston, in addition to serving as a medium for the transformation of heat into work, also constitutes an efficient heat conductor for conducting away waste heat absorbed by its upper surface at such a rate that the temperatures of such surface in contact with combustible mixture in the cylinder shall be lower than that necessary to ignite said mixture. In other words, the temperature of the piston head is maintained relatively low and hot spots upon it are avoided. The sliding contact between the piston skirt or heat discharge area and the cylinder walls insures highly efficient transfer of the heat from the outer surface of the skirt in engagement with the cylinder wall to the latter and thence to the cooling medium for the cylinder wall. Since with my invention the surface of the piston in contact with combustible mixture in the cylinder is maintained at temperatures lower than are customary with engines having no special cooling means for the piston, the engine may be operated with a higher compression and compression ratio and thereby increase the thermal efficiency and the capacity of the engine.

It will be further noted that by transferring the waste heat absorbed by the piston to the cylinder walls, in accordance with my invention and maintaining the relatively low working temperatures at the surfaces of the piston in contact with the gases in the cylinder, the temperatures of such surfaces will approach the temperatures of the incoming charge with corresponding improvement in volumetric efficiency of the engine.

By avoiding hot spots on the upper surface of the piston head I find that I have to a large extent, if not altogether, eliminated so-called detonations, which are known to take place in the cylinder above the piston, the phenomenon being one not clearly or generally understood at the present time.

Furthermore, the piston provides a movable metallic path for conducting heat from the upper surface of the piston head to the cylinder wall at such a rate that the temperatures of the piston surfaces shall be low enough greatly to reduce the formation of carbon above and substantially eliminate its formation below the piston and on the outer surfaces of its skirt. The formation of carbon may be due to such phenomena as cracking, distillation and decomposition of the fuel and lubricant or either of them. The working temperatures of the upper surface of the piston in my improved engine are low enough materially to reduce such phenomena above the piston and the under surfaces of the piston walls are maintained at such low temperatures and such a small amount of heat is transferred from them to the lubricant in the crank case that such phenomena are substantially prevented on the under side of the piston.

By dissipating the waste heat absorbed at the upper surface of the piston, according to my invention, I am enabled to operate the engine with largely reduced crank case temperatures in that heat which has heretofore been dissipated from the lower surfaces of the piston to the crank case is by my invention transferred to the cylinder walls and thence to the cooling water in the jacket.

With a piston of my improved construction interior strengthening and radiating ribs are eliminated, thereby reducing the amount of radiating surface on the interior of the piston with incident reduction of the amount of heat radiated from the inner surface of the piston.

By preventing the decomposition, cracking and distillation of the lubricant below the piston and the burning of hydrogen and lighter fractions set free during such reactions, I have eliminated the formation of moisture in the crank case and its resulting disadvantages.

As, in the preferred construction, an adequate heat flow path is provided back of the piston rings, the temperature of the piston rings is maintained relatively low with the result that the formation of carbon deposits in the ring grooves is minimized and the sticking of the rings, as the result of such carbon formation, is avoided.

It will be understood that to avoid the deposit of carbon on a piston head and within the combustion chamber of the cylinder is highly desirable and particularly on the piston head since the carbon is a non-conductor and tends to attain a high temperature from contact with the burning gases; and the higher the temperature maintained in the cylinder throughout the total cycle, the lower the volumetric efficiency. Also, where the carbon thus deposited is responsible for temperatures high enough to cause self-ignition, it is of serious moment and a great disadvantage. Prior to my invention, engines of the aircraft type equipped with earlier types of piston had relatively limited full load capacity, some of the best approximating 24 hours, during which time the power curve would show a decided decrease in power as time increased. The same en-

gines with such earlier types of pistons replaced by my improved pistons and with no other change, have attained a full load capacity several times the said twenty-four hour period, their power curves meanwhile showing little or no dropping off.

It will be noted further that owing to the low temperatures at which the piston operates, it is possible substantially to reduce the necessary clearance between the outer surface of the piston and the cylinder walls, a feature of considerable advantage in the matter of reduction and substantial elimination of piston slapping, undesirable transfer of lubricant from below to above the piston and undesirable transfer of liquid hydrocarbon from above the piston to the crank case.

Where the piston material has a higher coefficient of expansion than the walls of the cylinder with which it cooperates, the use of my invention is of great advantage in reducing necessary clearance therebetween.

Furthermore, the working temperatures of the piston are such as to insure the proper functioning of the wrist pin bearings under all normal conditions and to maintain the proper physical characteristics of the material of which the piston is constructed.

I have also discovered that a piston constructed in accordance with my invention of a metallic alloy having relatively low specific gravity and relatively high heat conductivity has approximately the correct weight to perform its mechanical functions properly in relation to the bearing pressures on the crank shaft and connecting rod, and that such a piston will be lighter than the ordinary iron pistons generally in use at the time of my invention.

My invention is particularly applicable in connection with internal combustion engines employing compression pressures from sixty pounds upwards. I have used it to great advantage in airplane engines having as high as one hundred and thirty pounds compression pressure.

While the pistons illustrated are such as I prefer, it is to be understood that the specific construction illustrated is shown for purposes of explanation and that many alterations in and differing embodiments and applications of my invention within the scope of the appended claims will suggest themselves to those skilled in the art.

What I claim is:

1. In an internal combustion engine, the combination with a cylinder, of a skirted piston mounted to reciprocate therein and made of metal of low specific gravity and high coefficient of heat conductivity in comparison with iron and having the cross sectional areas of its head and skirt walls great enough to conduct heat, up to the full load capacity of the engine, from the upper surface of the piston head to the cylinder walls at an average rate during the engine cycle as great as the average rate of heat absorption at said upper surface during said cycle.

2. In an internal combustion engine, the combination with a cylinder, of a skirted piston mounted to reciprocate therein and made of metal of low specific gravity and high coefficient of heat conductivity in comparison with iron and having the cross sectional areas of its head and skirt walls great enough to conduct heat, up to the full load capacity of the engine at compression pressures upwards of sixty pounds, from the upper surface of the piston head to the cylinder walls at a rate which will maintain the surface of the head in contact with the combustible gases at a temperature sufficiently low to avoid self-ignition of said gases thereby.

3. In an internal combustion engine, the combination with a cylinder, of a skirted piston mounted to reciprocate therein and made of metal of low specific gravity and high coefficient of heat conductivity in comparison with iron and having the cross sectional areas of its head and skirt walls great enough to conduct heat up to the full load capacity of the engine at compression pressures upwards of sixty pounds, from the upper surface of the piston head to the cylinder walls at a rate which will maintain the surface of the head in contact with the combustible gases at a temperature sufficiently low substantially to prevent decomposition, distillation or cracking of the lubricant in the crank case due to transfer of heat thereto from the inner surfaces of the piston.

4. In an internal combustion engine, the combination with a cylinder, of a skirted piston mounted to reciprocate therein and made of metal of low specific gravity and high coefficient of heat conductivity in comparison with iron and having the cross-sectional areas of its head and skirt walls great enough to conduct heat, up to the full load capacity of the engine, from the upper surface of the piston head to the cylinder walls at an average rate during the engine cycle as great as the average rate of heat absorption at said upper surface during said cycle, the various cross-sectional areas of the head and skirt walls being approximately proportional to the amount of heat per second to be conducted by said cross-sections from the upper surface of the piston head to the cylinder walls.

5. In combination with a cylinder for an internal combustion engine, a piston having a head in contact with the gaseous mixture in the cylinder and an integrally formed skirt in sliding contact with the cylinder walls, the piston being constructed of a

metal of low specific gravity and high heat conductivity as compared with iron and with a heat flow path between the head and the skirt having a capacity at all cross sections to conduct unrestrainedly the heat absorbed by the head to the skirt and thence to the cylinder walls at a rate which will maintain the surface of the head in contact with combustible gases in the cylinder at temperatures sufficiently low to avoid self-ignition of said gases thereby up to the full load capacity of the engine at compression pressures upwards of sixty pounds.

6. In combination with a cylinder for an internal combustion engine, a piston having a head in contact with the gaseous mixture in the cylinder and an integrally formed skirt in sliding contact with the cylinder walls, the piston being constructed of a metal of low specific gravity and high heat conductivity as compared with iron and with a heat flow path between the head and the skirt having a capacity at all cross sections to conduct unrestrainedly the heat absorbed by the head to the skirt and thence to the cylinder walls at a rate which, up to the full load capacity of the engine at compression pressures upward of sixty pounds, will maintain the surface of the head in contact with combustible gases in the cylinder at temperatures sufficiently low to avoid self-ignition of said gases thereby at a predetermined compression pressure and will preclude transfer from the inner surfaces of the piston to the crank case of sufficient heat to cause decomposition, distillation or cracking of the lubricant therein.

7. In combination with a cylinder for a high compression internal combustion engine of a piston having a head in contact with the gaseous mixture in the cylinder and an integrally formed skirt in sliding contact with the cylinder walls, the piston being constructed of a metal of high heat conductivity, low specific gravity and high specific heat as compared with iron and with a heat flow path between the head and the skirt of a capacity at all cross sections to conduct unrestrainedly the heat absorbed by the head to the skirt and thence to the cylinder walls at a rate which will maintain the surface of the head in contact with combustible gases at a temperature sufficiently low to avoid self-ignition of said gases thereby up to the full load capacity of the engine at compression pressures upwards of sixty pounds.

8. In an internal combustion engine, the combination with a cylinder, of a skirted piston mounted to reciprocate therein, said piston having packing rings mounted in the side wall of the piston head, being made of metal of low specific gravity and high coefficient of heat conductivity in comparison with iron and having the cross sectional dimensions of its head and skirt walls, including the side wall of the head within the packing rings, great enough to conduct heat, up to the full load capacity of the engine, from the upper surface of the piston head to the cylinder wall at an average rate during the engine cycle as great as the average rate of heat absorption at said upper surface during said cycle.

9. A piston for internal combustion engines made of metal of low specific gravity and high coefficient of heat conductivity having a head section with end and side walls, a cylindrical skirt section, and wrist pin bosses carried by the skirt section, the cylindrical walls of the skirt being indented adjacent the bosses and joined to the latter at points distant from their ends, whereby a light strong structure and a uniform distribution of heat through the bosses are secured.

10. A piston having a head and peripheral walls formed from a metal having relatively high heat conductivity as compared with iron, the central portion of the head being sufficiently thick to insure that it will not become unduly heated and develop hot spots during the operation of the piston, the thickness of the head from said central section increasing radially towards its periphery in such manner that cylindrical cross-sectional areas at different radii vary substantially in the same ratio as the quantities of heat absorbed through those parts of the upper surface of the head circumscribed by the respective cylindrical cross-sections, and said peripheral walls having a heat conducting capacity sufficient to conduct the heat from the head unrestrainedly and rapidly to the discharge area of said peripheral walls.

11. A piston having a head and peripheral walls formed from a metal having relatively high heat conductivity as compared with iron, the central portion of the head being sufficiently thick to insure that it will not become unduly heated and develop hot spots during the operation of the piston, the thickness of the head from said central section increasing radially towards its periphery in such manner that cylindrical cross-sectional areas at different radii vary substantially in the same ratio as the quantities of heat absorbed through those parts of the upper surface of the head circumscribed by the respective cylindrical cross-sections, and said peripheral walls adjacent said head wall being grooved for piston rings and having a heat conducting capacity sufficient to conduct the heat from said head wall unrestrainedly and rapidly to the discharge area below said ring grooves.

12. A skirted piston for internal combustion engines made of metal of low specific

gravity and high coefficient of heat conductivity in comparison with iron and having the areas of cylindrical cross sections of the end wall coaxial with the piston approximately proportional to the areas of the upper head surfaces circumscribed by said sections, respectively, and the wall of the skirt diminishing in thickness from the top downward.

13. A piston for internal combustion engines formed from a metal having a relatively high heat conductivity as compared with iron and having a head of sufficient thickness at its center to insure that the center will not become unduly heated from the heat absorbed by it during the operation of the piston, the thickness of the head increasing from its center outwardly at least sufficiently to provide an increasing heat conducting capacity which will accommodate the increasing total input of heat from such center outwardly and thereby insure that no part of the upper surface of the piston will become unduly heated while the piston is in operation, there being a peripheral wall depending from said head and having heat conducting capacity sufficient to transfer the heat conducted to it by said head rapidly and unrestrainedly to the cylinder walls, so that a relatively small amount of heat is radiated from the inner surfaces of said piston.

14. A piston for internal combustion engines having a head provided with an annular integrally formed skirt depending from its periphery and grooved to receive piston rings, said head and skirt being formed of a metal of relatively high heat conductivity as compared with iron and said head having heat conducting areas at concentric cross-sections which increase outwardly from its center at least at as great a rate as the quantities of heat absorbed through those parts of the upper surface of the head circumscribed by the respective concentric cross-sections and thus insure that no part of the upper surface of said head will become unduly heated while the piston is in operation, and said skirt having a sufficient heat conducting capacity to by-pass rapidly and unrestrainedly about said piston ring grooves the heat conducted to it by said head, whereby the walls of said grooves are maintained at relatively low temperatures and a relatively small amount of heat is radiated from the inner surfaces of said piston.

In testimony whereof I affix my signature.

ELBERT J. HALL.