M. R. WOLFARD.

INTERNAL COMBUSTION ENGINE.

APPLICATION FILED FEB. 17, 1915. RENEWED OCT. 23, 1918.

1,305,580.

Patented June 3, 1919.

2 SHEETS—SHEET 1.

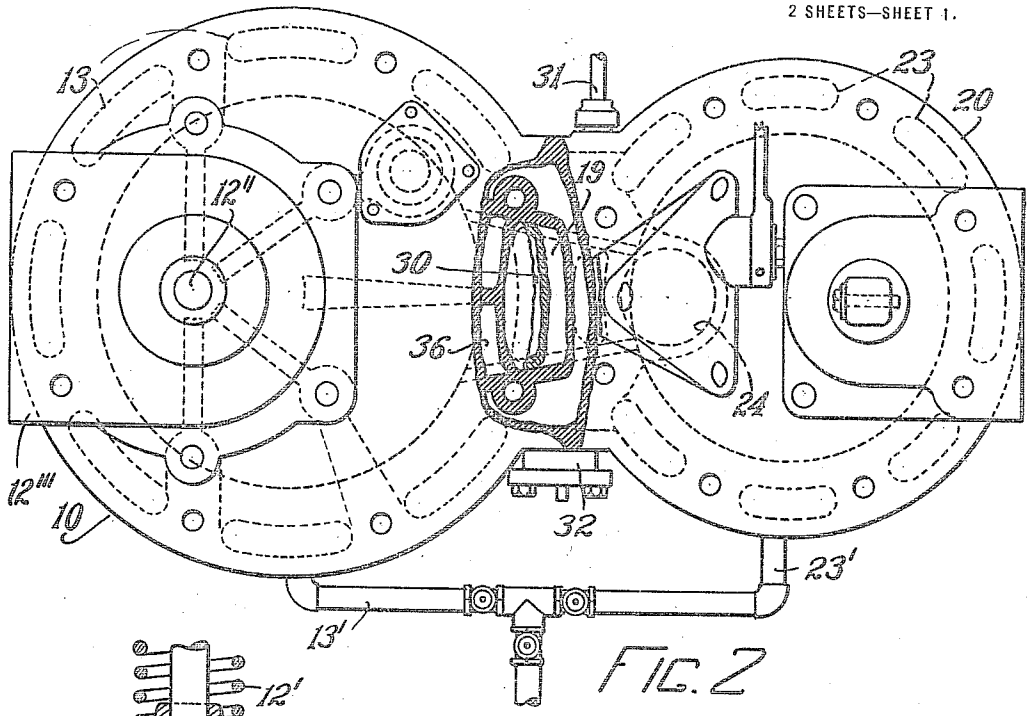


FIG. 2

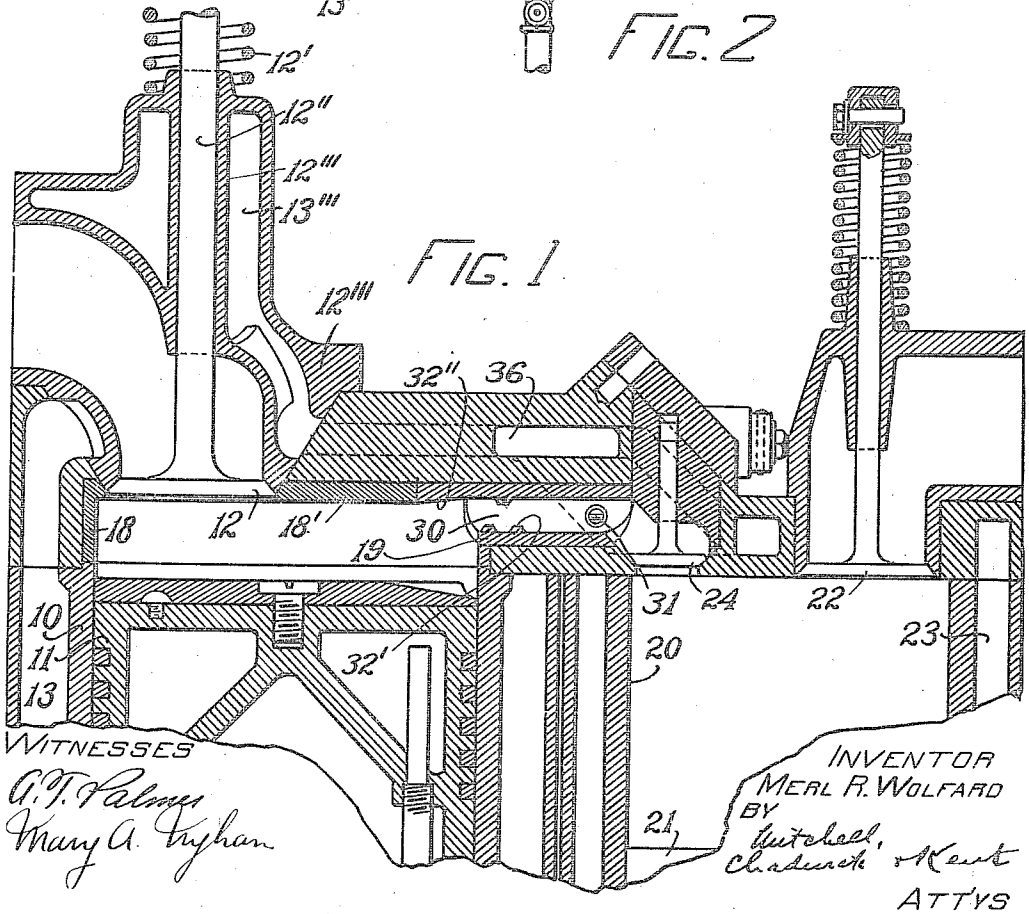


FIG. 1

WITNESSES

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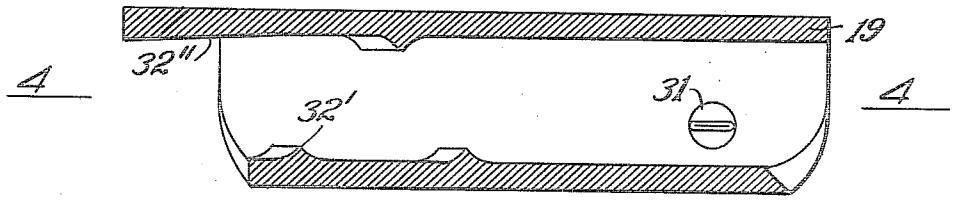


FIG. 3

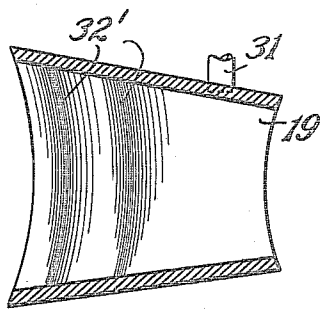


FIG. 4

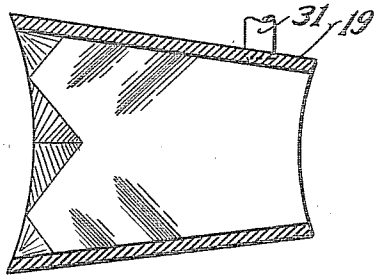


FIG. 5

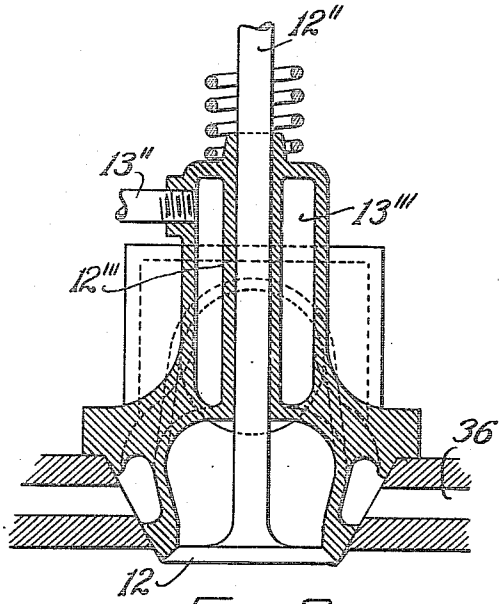


FIG. 6

WITNESSES

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UNITED STATES PATENT OFFICE.

MERL R. WOLFARD, OF CAMBRIDGE, MASSACHUSETTS, ASSIGNOR OF ONE-FOURTH TO LEROY A. AMES, OF SPENCER, MASSACHUSETTS, AND ONE-FOURTH TO EVERETT E. KENT, OF NEWTON, MASSACHUSETTS.

INTERNAL-COMBUSTION ENGINE.

1,305,580. Specification of Letters Patent. Patented June 3, 1919.

Application filed February 17, 1915, Serial No. 8,829. Renewed October 23, 1918. Serial No. 259,457.

To all whom it may concern:

Be it known that I, MERL R. WOLFARD, a citizen of the United States, residing at Cambridge, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Internal-Combustion Engines, of which the following is a specification.

This invention relates to improvements in internal combustion engines. More particularly it relates to the construction of the combustion chamber and adjacent parts of such an engine. The object of the invention is to provide a construction by which this part of the engine may safely carry very high interior temperatures with relatively thin walls; and in particular to relieve the walls both from excessive temperatures and also from those internal stresses due to unequal expansion and contraction which naturally accompany high temperature differences between closely adjacent portions of a metallic wall to provide for durability of the interior surfaces withstanding high temperatures; and to provide means for differing cooling effects upon adjacent parts. These problems having come to my attention more particularly in connection with a new type of engine which I have invented, one form being shown here, and more fully claimed and set forth in my application for U. S. Letters Patent Serial No. 8828 in which a complete power unit consists of a power cylinder and an air compressing cylinder joined by a short direct passage in which liquid fuel is at each stroke first volatilized and then burned, the invention further comprises means for accomplishing certain related objects in that particular type of engine, or in variations thereof. Among such may be classed the provision of means by which a portion of the head end of the cylinder is kept too cool for the ignition of the fuel charge, while another adjacent portion is maintained constantly at ignition temperature, thereby providing a stratification of engine contents during combustion. Other objects are to provide a durable lining for the particular part of the engine which is subjected to the flame and to the greatest extremes of temperature, in order to overcome the tendency of the metal to crystallize and become brittle, or to break under internal stresses due to temperature, or due to the combination of temperature and stresses imposed by the engine contents. It is also the object of the invention to provide the other improvements which are characteristic of the structure herein set forth; and it is the purpose of the patent to cover by suitable expression in the appended claims whatever features of patentable novelty exist in the invention disclosed, within the general scope above disclosed. These objects are accomplished by providing an interior lining made in several pieces which fit each other and the cylinder walls loosely, so that they inclose the combustion chamber and the head end of the cylinder and initially receive the very high temperatures thereof while being themselves balanced against the high pressure of the gaseous contents and therefore free from stresses due thereto. Such pressures are sustained on the cylinder walls which, however, are free from exposure to said high temperatures. This is because the lining diffuses such heat as it transmits both in locality and in time, distributing it to adjacent parts of itself and radiating it gradually so that the heat received by the walls of the cylinder is more uniform; and because heat is transmitted thereto only slowly, owing to the necessity of its passing out from a surface across a gap, and into another surface, to wit, out of the outer surface of the lining and into the adjacent surface of the cylinder walls. This gap may be very small indeed; and hence may constitute no appreciable part of the clearance, and may not afford space for any substantial circulation of gaseous contents of the cylinder. Further objects of the invention are accomplished by making the lining of an alloy of pure iron and nickel, and by providing its surface with certain grooves and ridges directed so as to heat certain areas more than others, and also by providing a circulation of cooling water through jackets surrounding the cylinders, combustion chamber and exhaust valve, the water being in abundant volume to insure easy working of a mechanically operated valve, without cooling the valve itself, nor cooling the other parts too much, by flowing through two parallel courses, one or both of which is controllable so that the water can be divided at will between them. After arrang-

ing so that a sufficient total of cooling water is flowing for the needs of the exhaust valve stem, the temperature of the early part of the combustion passage can be regulated by regulating that branch of the water supply which flows to it past the air cylinder. The latter part of the combustion passage may then be kept at ignition temperature, or it may be included in the path of the other stream of the cooling water. While the invention is illustrated as it may be applied to engines of one particular type, many features of it are applicable to other types of engines and may indeed be applied in various ways without departing from the scope of the invention.

In the drawings:

Figure 1 is an elevation in medial section through two cylinders and the combustion passage joining them, of an engine embodying the invention;

Fig. 2 is a plan of the same;

Fig. 3 is an enlargement of a detail of Fig. 1 showing the lining of the combustion passage;

Fig. 4 is a plan of the same lining, in section, on the line 4—4 of Fig. 3, viewed from above on a smaller scale;

Fig. 5 is a plan of a modification of the same on the same section line, viewed from above;

Fig. 6 is an elevation, in section, through the exhaust valve.

Referring to the drawings, 10 indicates the power cylinder, 11 the power piston, 20 the air compressing cylinder, 21 the piston therein, 30 a short direct combustion passage joining the head ends of the two cylinders; the passage being continuously open into the power cylinder, and intermittently receiving air by a valve 24 and liquid fuel through a nozzle 31. The air cylinder has an inlet valve 22 and water jacket 23. The combustion passage has an ignition device 32 for starting, and a water jacket 36. The power cylinder has an exhaust valve 12 and water jacket 13. The jackets 13 and 23, which have separate inlets 13′ and 23′ with means for controlling the quantity of water flowing through each, have a common discharge 13″ at the top of the exhaust valve cage, which is reached by water from the jacket 23 through the jacket 36 of the combustion passage. The exhaust valve is of mushroom type, normally held seated by a spring 12′ acting upon its stem 12″ which has a long and relatively loose bearing through the central part of the conical cage 12‴. This stem being surrounded by the jacket 13‴ through which the whole quantity of water coming through both inlets passes, may have a very long bearing, which because of the conicality can extend close to the valve seat and because of its length can be a rather loose fit. By suitable manipulation of the valves in inlets 13′ and 23′ the proportion of water flowing through these separate paths can be controlled at will, so that the cooling effect applied to the combustion chamber 30 can be regulated, while the amount flowing through the jacket of the power cylinder 13 may be substantially uniform at all times, and an abundance of water passes the exhaust valve stem's bearing. With such liberal cooling surfaces around and near the exhaust valve's seat as well as in its entire case, including the stem guide. and with the positiveness of circulation, it seems that water cooling of the valve itself will be unnecessary unless for large engines. The valve in pipe 13′ may be omitted if desired. In the operation of the particular type of engine described the power piston 11 travels very close to the top of its cylinder, forcing nearly all the contents of the cylinder into the near end of the combustion passage 30. For efficiency it is desired to maintain those parts which are exposed to flame at a high temperature. With ordinary materials, such parts are likely to crack or to burn, or both; and if the exposed metal were continuous with the walls, as is customary, there would be at some places a very great range of temperature difference between the exterior and the interior of the wall, as well as an undesirable loss of heat by conduction. The invention provides a lining of tenacious and fire resistant metal inclosing the combustion chamber and the head end of the power cylinder, consisting of the piece 18 having cylindrical walls, a removable piece 18′ resting loosely thereon, and the piece 19 lining the combustion chamber and projecting into the cylinder head where it fits loosely into the pieces 18 and 18′. For these I have found that a composition of 64% pure iron and 36% nickel withstands the high oxidizing temperatures and conditions without being observably affected and that this composition has a coefficient of expansion less than that of the iron of the cylinder head and cylinder, so that it can be placed and will remain loosely in position. The discharge end of the combustion passage may be formed so as to direct the flow of gases by providing certain shallow grooves separated by ridges 32′, and by forming the roof of the lining piece 19 downward slightly at 32″ where it projects into the power cylinder. Thus by agitation and mixture of fuel and air the mixture is perfected, and the completion of combustion is expedited. A hot tube 32 may be provided, and heated temporarily by suitable means such as an external gas flame, to put the apparatus initially into action, but this is not necessary after the lining has acquired sufficient heat to act as igniter, which happens in a few seconds. The slight air crack existing between these loosely fitting linings and the adjacent walls

of the cylinder of the chamber is small enough so that there is no appreciable circulation of gases in it; and yet it has the effect of breaking the outward flow of heat by conduction, and of materially retarding its escape. This has the result of relieving the cylinder walls of the difference of temperature between inside and outside of the wall which they would otherwise sustain, which would be productive of internal stresses so dangerous to the continued integrity of the metal. In fact, I believe that construction has hitherto never been regarded as safe, in cases where high temperatures and pressures coincide, except by making the metal walls very thick, or by restricting the diameters of cylinders to certain limits known to be safe, or both. In such a lining. the upper portion of the part 18 may be incompletely cylindrical owing to the opening for communication with the combustion chamber. This gap permits a greater freedom of distortion of the metal. The exhaust valve 12 is preferably placed in that part of the cylinder head which is remote from the combustion chamber; and the circular opening in the lining, made for this valve, may be extended toward the combustion chamber and filled by a loose piece 18′ fitting therein in position to receive more of the blast of flame than the adjacent parts at the top or sides of the lining. Consequently this particular piece 18′ may safely expand, during operation of the engine, in even greater ratio than the other parts of the lining, without any undue stresses resulting.

It is to be noted that by this device no insulating filling or other fragile or crumbly material is employed within this part of the engine. The material which is employed is of such tensile strength that it may possibly assist to some minor extent in resisting the stresses, considering the rapidity of the successions of pressure changes, and considering the narrowness of the crack for flow of gases into and out of the space behind the lining, but generally speaking, the walls are relied upon for resisting all bursting forces; and any assistance from the lining may be ignored except as it is effective to separate the temperature problem from the pressure problem. The lining protects the walls from all excessive temperature effects; and the lining is free from the tensile stresses due to pressure of gases. At the same time neither is made of insulating or non-heat-conducting material, which is usually brittle; but both may be made of tough materials, even though they are also good conductors of heat. The gap or gas crack between the lining and wall is as durable as the engine itself, and even if carbon were to be deposited therein its presence would not affect either the efficiency or the heat losses of the engine. Experimental evidence indicates that such carbon deposits as may be formed when the engine is first started are automatically cleared when the parts get hot under normal conditions of operation, owing presumably to the increased amount of heat in the region of the gap, resulting from the increased conductivity caused by the presence of the carbon. While such a lining appears not to be feasible when constructed of material such as iron, ordinarily used in the construction of engines, I have discovered that it is feasible with the composition of nickel and iron made in the proportions stated, and experimental evidence indicates that satisfactory results could be had with compositions containing 30% to 60% of nickel with iron. The combination of these two metals does what neither alone will do; the nickel prevents the iron from oxidizing, and the iron prevents the nickel from crystallizing and cracking under the temperature conditions.

In practical use the division of cooling water into two streams enables water which flows by the power cylinder and out through the exhaust valve to be of relatively high temperature while the water that flows in the other stream can be of a lower temperature since it is not necessarily much heated in passing the cylinder wherein the air is compressed, and keeps down the temperature uniformly and controllably, of the part of the combustion passage where the air and fuel enter, to a degree sufficient to volatilize the atomized liquid fuel promptly yet not sufficient to ignite it or to be conducive to its combustion. The latter part of the combustion passage, adjacent to the power cylinder, is more under the influence of the hotter walls of the power cylinder, is more remote from the cooling water, and is kept sufficiently hot by the rapidly succeeding flames which bathe it. This lining being set loosely, and being itself in separable pieces put loosely together, can distort itself by uneven expansion and contraction without damage either to itself or to the surrounding walls. Being free from constituent carbon it does not oxidize. Having a lower co-efficient of expansion than the walls of the engine it does not impose any stress thereon when the walls are sustaining pressure of hot gaseous contents. Both the lining and the engine walls, each being free from a combination of high temperature and high pressure, are free from those conditions under which the tough crystalline or other internal structure of metal tends to break down into brittleness.

As applied to engines of the particular type illustrated, the construction gives the further advantage of durability, in an irregular construction such as where a hot passage joins two cylinder heads, all being

sometimes hot, in which case the two cylinders approach each other and the connection expands instead of contracting proportionality, and sometimes cold; and where parts when hot have different degrees of temperature and therefore of expansion. The provision for maintaining heat in a part of the chamber, coupled with the arrangement of cooling water jackets by which the flame may be prevented from running back too far in the combustion chamber, facilitates the operation of the apparatus on principles of stratification or separation of the volatilization of liquid fuel from the combustion thereof. This in turn contributes to the attainment of high efficiency, both because of the more thorough mixture of fuel with air which this arrangement promotes, and because the deflecting ridges and grooves as illustrated in Figs. 2–4, past which the gaseous contents must flow, produce a certain agitation or further mixture of gaseous contents which makes early and efficient combustion more certain.

It will be understood that in the particular type of engine illustrated the air piston lags about 45° behind the power piston, so that while the power piston is at its inner dead center and proceeding outward, air is entering through the valve 24, and liquid fuel through the nozzle 31. The liquid is immediately volatilized, burns in the latter part of the passage, and expands in the power cylinder, till the exhaust valve opens. On inward stroke, this closes at about 40° from the end of that stroke, and the gases thus entrapped are compressed in the power cylinder and adjacent end of the combustion passage. Simultaneously with this compression air is admitted to the other end of the combustion passage where pressure is built up by the air piston, so that the spent gases and the air are stratified, and neither before nor during the compression does fresh air reach and cool the hot part of the lining. During all of this cycle it is part of the problem to keep part of the lining at ignition temperature; to keep the combustion chamber hot, for efficiency; to keep the cylinder walls from excessive heat that might endanger their characteristic toughness under the prevalent high pressure; to maintain a considerably lower temperature around the exhaust valve, so that it can operate smoothly, although unprotected by lining, and without internal circulation of water through valve or stem; and to volatilize heavy liquid fuel upon its entrance, before allowing it to burn. To this the described arrangement of cooling jackets and chamber lining afford a solution. The conicality of the exhaust valve cage permits ample cooling areas with good circulation close to the valve seat; and because of the larger area in the outer part of the valve cage afforded by the conical construction, there is room for the cooled valve stem guide to be made close to the valve itself, while still allowing ample passage for the flow of exhaust gases.

I claim as my invention:

1. In an internal combustion engine, the combination, with an air cylinder, a power cylinder, a connecting passage, and means for mixing fuel in said passage, of heat-controlling means for the walls; comprising courses for water through the walls, past the power cylinder, one of them also passing said passage; and means for controlling the proportion of flow which goes past said passage.

2. In an internal combustion engine, the combination, with an air cylinder, a power cylinder, a connecting passage, means for mixing fuel in said passage, and an exhaust valve in the head of the power cylinder having a stem with a hooded bearing, of heat-controlling means for the walls; comprising courses for water through the walls past the power cylinder and around the bearing of the exhaust valve, one of them also passing said passage; and means for controlling the proportion of total flow which goes past said passage, whereby the cooling of the region of said passage is separately controllable and its water is also utilized for cooling the exhaust region.

3. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the side of the head end of said cylinder in a direction approximately parallel to the face of the piston while said piston is at and near its inner end of stroke, the head end of said piston being approximately a plane surface, whereby excessive impact of the burning contents on the face of the piston is avoided.

4. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the head end of said cylinder, and a metallic heat-conducting lining for the part of said passage where com-

bustion occurs and for the adjacent head part of the cylinder, formed in portions which are loose, with respect to the main pressure sustaining part of the wall and with respect to each other, to an extent sufficient to permit them to expand and be distorted independently of said wall and of each other, whereby said wall is shielded from the effects of the excessive heat of the interior.

5. In an internal combustion engine, a chamber in one part of which combustion occurs while liquid fuel is being vaporized in an adjacent part of the same, combined with a lining for the chamber within and separate from its pressure sustaining walls, said lining having relatively good heat-conducting properties, having the property of tenacity under extreme temperature difference, and having a portion exposed to heat from the combustion and adapted to remain at a temperature sufficient to ignite fuel, while an adjacent portion, where said vaporization is occurring, is at a temperature too low to ignite fuel; the heat-conducting quality of said lining preventing overheating and breakdown where the combustion occurs.

6. In an internal combustion engine, a chamber in one part of which combustion occurs, while liquid fuel is being vaporized in an adjacent part of the same, combined with a lining of about one-third to two-thirds of nickel alloyed with iron for the chamber, separate from its pressure-sustaining walls, adapted to have a portion exposed to heat from the combustion and maintained at a temperature sufficient to ignite the said fuel, and an adjacent portion where said vaporization is occurring at temperature too low to ignite the fuel.

7. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the head end of said cylinder; and a lining for the part of said passage where combustion occurs and for the adjacent head part of the cylinder composed of about one-third to two-thirds of nickel alloyed with iron.

8. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the head end of said cylinder; means to circulate a cooling medium around the passage; a lining for the pressure sustaining walls, where the combustion occurs, having relatively good heat conducting properties, the said heat conducting material and the said cooling medium coöperating to control the temperature, thereby preventing overheating and breakdown of said lining.

9. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the head end of said cylinder; means for circulating a cooling medium around the passage; and a lining comprising about one-third to two-thirds nickel alloyed with iron surrounding the place where the combustion occurs.

10. The combination, in an internal combustion engine, having a power cylinder and a piston therein traveling close to the head of the cylinder, of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the head end of said cylinder; means for circulating a cooling medium around the passage; and means to shield the pressure sustaining walls around the discharge end of the passage from the extreme temperature developed in that region, comprising a metallic lining separate from the pressure sustaining walls and composed of a plurality of pieces arranged and adapted to expand and contract independently of each other and of the pressure sustaining walls.

11. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and fuel for each cycle introduced into and ignited within it and to discharge the burning contents during the progressive combustion of the same into the head end of

said cylinder, and a lining of good heat-conducting material for the combustion passage walls and for the walls in the vicinity of the discharge therefrom, arranged with a slight gap between it and the walls which it protects, to which gap the fluid contents has access, whereby the lining sustain the main stresses due to temperatures and the wall beyond the gap sustains the main stresses due to pressures.

12. The combination, in an internal combustion engine having a power cylinder and a piston therein traveling close to the head of the cylinder; of a combustion passage discharging into the head end of the power cylinder, there being means for compressing air into the combustion passage, said passage being adapted to have the main charge of air and atomized liquid fuel for each cycle introduced into and mixed within it, the fuel being vaporized in said air at or near the place of fuel introduction; a lining of relatively good heat-conducting material in said passage, the part thereof located where said vaporization occurs being maintained below ignition temperature and a nearby part beyond it exposed to heat from the combustion being maintained at a temperature sufficient for ignition, the whole arranged and adapted for the combustion of said charge to occur progressively; and means to circulate a cooling medium around said passage whereby in coöperation with the conductivity of said lining the said temperatures are maintained.

Signed by me at Boston, Mass., this 15th day of February, 1915.

MERL R. WOLFARD.

Witnesses:
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