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**Showalter et al.**

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[54] **ISOTHERMAL VALVE SEAT FOR INTERNAL COMBUSTION ENGINE**

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[52] **U.S. Cl.**......... **123/41.16,** 29/156.7 A, 123/41.2, 123/41.77, 123/41.85, 123/188 S, 165/105
[51] **Int. Cl.**.............................. **F01l 3/14,** F02f 3/18
[58] **Field of Search**........... 123/41.16, 41.85, 41.41, 123/41.2, 41.76, 41.77, 188 S; 29/156.7 A

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[57] **ABSTRACT**

A valve seat for internal combustion engines including a heat pipe passage around the seat to assure that the valve seat is uniformly the same temperature all around even if the cooling of the valve seat from the engine head is not even all around. The heat pipe passage is a gas tight passage including wicked surfaces to assure that the valve seat is uniformly wet and containing a working fluid which is a liquid with a high vapor pressure under the operating temperature range of the valve seat. When the valve seat is heated, fluid evaporates from hot portions, absorbing the heat of vaporization, and the vapor flows hydrodynamically to of vaporization, cooler portions of the heat pipe surface, where the vapor recondenses at the same temperature, giving up its heat of vaporization. The gas contained in the heat pipe volume is totally or predominantly the working fluid vapor, so that the heat pipe always responds to maintain its entire surface area at an even temperature (this temperature will vary from time to time, but at any given time the entire surface of the heat pipe passage will be isothermal). Uniform valve seat temperatures produce uniform expansion so valve seats stay in round, leak less unburned hydrocarbon, and last longer.

**8 Claims, 5 Drawing Figures**

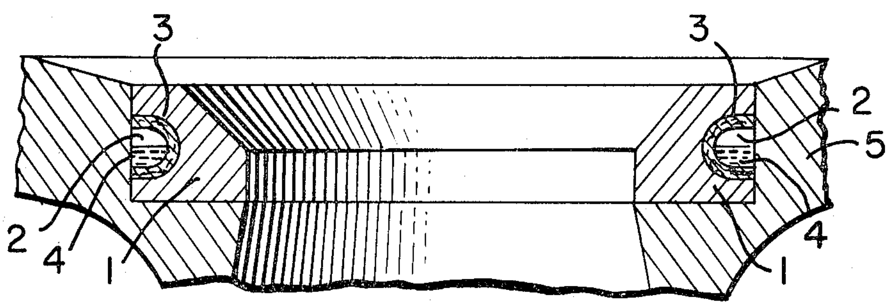


FIG. 1.

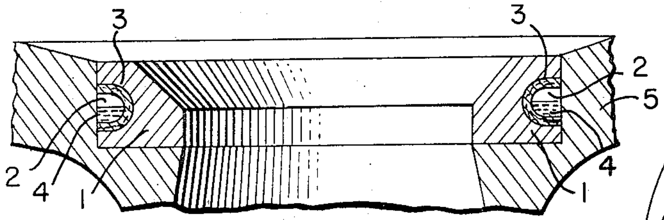



FIG. 2.

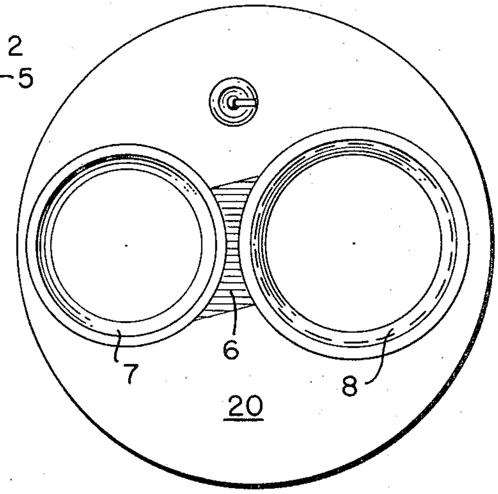



FIG. 3

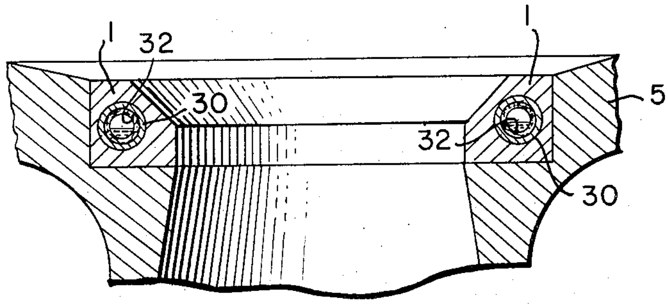



FIG. 3A.

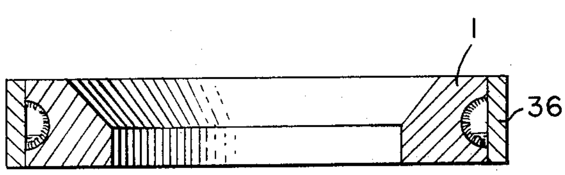
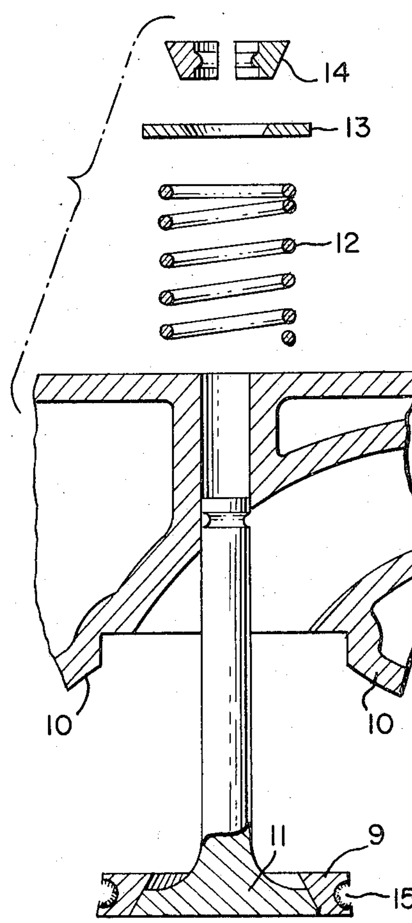



FIG. 4.



# ISOTHERMAL VALVE SEAT FOR INTERNAL COMBUSTION ENGINE

## SUMMARY OF THE INVENTION

Ever since the beginning of poppet valve internal combustion engines, valve seats have been distorted out of round in service by uneven cooling and the uneven expansion resulting from uneven valve seat temperatures. In engine service the resulting leakage is never eliminated, but may vary over a substantial range. Minimizing the problems of valve seat distortion has always been a large part of the job of developing head castings. The problem is made worse in practice because the thickness of castings between the coolant and the combustion chamber varies randomly in production, so that thinner sections are cooler and thicker sections are hotter than they were designed to be. As a result, valve seats always have and probably always will distort, and the resulting leakage reduces valve seal life, and valve life, and results in some leakage of raw fuel into the exhaust manifold prior to spark ignition. The problem is made worse by anthing which raises the heat rejection rate to the head and valve (lower compression ratio, slower combustion, higher combustion turbulence). Requirements that engine durability be improved and exhaust emissions be drastically reduced have made this problem particularly pressing at the moment. Engine designs which otherwise seem quite favorable to emission control can result in enough valve seat distortion that they produce unacceptable unburned hydrocarbon emissions and reduced engine life.

It is the purpose of the present invention to eliminate the temperature variation normally found around valve seats to eliminate thermal distortion. This is accomplished by providing valve seats with an encircling heat pipe cooling passage equidistant from the valve seating surface, where said heat pipe passage assures that the temperature at all points of the heat pipe passage surface are equal because the heated parts are cooled by evaporation and the cooling surfaces are heated by condensation at the same temperature (at equal pressures and vapor partial pressures the temperature of evaporation equals the temperature of condensation). In this way valve seat distortion can be very nearly eliminated.

It is a further purpose of the present invention to provide an isothermal heat piped valve seat with the well known wear advantages of inserted valve seats, and one which can be produced at a very low cost with automated equipment without disrupting current assembly procedures unacceptably. It is a further purpose of the present invention to provide a valve seat insert which does not result in the increased valve seat temperatures common with other inserted valve seats, but which actually reduce valve seat surface temperatures and therefore results in lower valve temperatures and increased valve life.

## DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a heat piped valve seat where the head into which the valve seat is inserted forms part of the sealed heat pipe cooling passage.

FIG. 2 is a plan view of a head with inserts installed, showing an example of valve seat heat pipe maintaining uniform temperature where head cooling is not uniform around the valve seat. FIG. 3 is a section view of a heat piped valve seat where heat piped passage is inside a ring shaped tube cast into the valve seat.

FIG. 3A is a section view of a heat piped valve seat where the seat is shrink fitted to a ring.

FIG. 4 is a schematic view of method of inserting valve seat in head as part of valve installation procedure.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows valve seat insert 1 which is shrink fit to form a gas tight seal in head casting 5. Ring shaped heat pipe passage 2 in insert 1 is sealed during the shrink fit process and contains wick 3 and working fluid (preferably water) 4. The gas content of sealed passage 2 is totally or predominantly working fluid vapor to eliminate the possibility of noncondensing gas pockets producing uneven cooling on the head surface portion of head pipe passage 2. Assuming that the only gas in passage 2 is the vapor of working fluid 4 and that fluid 4 is essentially narrow distillation fluid (water as opposed to a wide distillation range oil), total temperature uniformity is ensured over the surface of heat pipe passage 2 since evaporation will move heat very rapidly away from any surface marginally above average while condensation will transport heat rapidly to any surface marginally below average temperature. This equilibrating process is quite fast: the effective thermal diffusivity of passage 2 as a water based heat pipe is several thousand times that of copper. Wick 3 assures that the surface of insert 1 will stay wet — the capillary liquid returning action of the wick is necessary to assure temperature equalization, since any dry surface cannot be cooled by evaporation.

Wick 3 can be a metal wool, a cotton or other fabric, or a porous plastic foam. Its purpose is to assure that the wicked surfaces are always completely wet by capillary action. The wick can be made to fill the entire volume of passage 2. The flow of vapor is somewhat obstructed in this way, but the temperature differences and heat flow reduction involved is quite small.

It is vital that the seal between the head 5 and the insert 1 seal passage 2 gas tight manner, since the heat pipe often functions at quite high pressures and since noncondensing gas in passage 2 hinders the operation of the heat pipe. The outside edges of insert 1 can be coated with a sealer (for instance by dipping in molten lead) prior to shrink fitting into head 5 to assure a good gas tight seal between passage 2 and the outside.

The amount of working fluid 4 in passage 2 can vary substantially without producing problems, but it should (as a liquid) have much less volume than passage 2 and it must be enough so that some fluid remains in liquid state at the highest temperature passage 2 will ever encounter in normal service. As a liquid, fluid 4 should be between 5 percent and 20 percent of the total volume of passage 2.

Heat pipe passage 2 will equalize temperatures very much more efficiently if it is free from noncondensing gases which can stratify to permit hot spots or cold spots. Therefore, assembly 1, 2, 3, 4, 5 must either be assembled in a vacuum or the noncondensable gases must be eliminated by some other means. Probably the easiest and cheapest way of doing this, since insert 1 must be installed cold as a shrink fit anyway, is to install insert 1 with passage 2 containing the working fluid (preferably water) as ice and also containing dry ice (solid $CO_2$) and a small quantity of calcium oxide either in the water ice or in the wick. As the insert assembly warms up the dry ice will sublime, driving off air so that passage **2** is flushed with $CO_2$. The shrink fit should be relatively tight before the water ice melts but when the dry ice is essentially gone. As insert **1** comes to the same temperature as the head **5**, it will be a gas tight shrink fit sealing off passage **2**. The noncondensable gas in passage **2** will be $CO_2$ which will quickly react with the CaO aqueous phase to form $CaCO_3$, so that the only remaining gas in passage **2** will be water vapor. The small amount of chalk in passage **2** will cause no problems. Using the ice, dry ice and quicklime technique, problems with eliminating noncondensable gases and producing the proper amount of working fluid in passage **2** are eliminated, since the fluids can be handled as solids. Other chemical combinations can also be made to eliminate non-condensable gases from the passage without the requirement that the valve be added in a vacuum.

The operation of the heat pipe passage in the valve seats compensates for uneven cooling of the cylinder head in service. See FIG. **2**, which shows a cylinder head **20** with heat piped valve seats **7** (exhaust) and **8** (intake) installed. In service it is generally found that the cooling of the portions of the valve seats nearest together (shown in the drawing as in contact with shaded region **6**) are less well cooled than the other areas around the valve seat, with the result that these less cooled areas expand more than average and force the valve seat out of round. With the heat piped valve seats installed, the temperature of the surface of the heat piped passages in valve seats **7** and **8** are maintained uniformly around each valve seat, so that very different cooling efficiencies around the valve seats do not result in very different valve seat temperatures. However, it can be seen that the heat piped cooling passages cannot eliminate the effect of different head temperatures around the valve seat entirely, owing to the metal-to-metal contact between the head and the valve seat. In the case of the exhaust valve seat, which is always rejecting a great deal of heat, thermal distortion is very much reduced, since the valve seat is maintained nearly isothermal all around, and the cooling load of the portions of the head nearest the valve seat come predominantly from the valve seat.

Heat piped valve seats can be built where the heat pipe passage is sealed prior to insertion into an engine head. This is advantageous from the point of view of installation in the head but reduces the cooling efficiency of the valve seat since heat piped seats such as shown in FIG. **1** employ the head as part of the cooling surface of passage **2**, whereas sealed heat pipe passages mean that heat transfer to the head must occur totally through metal-to-metal contact, and the cooling efficiency of even the best shrink fits or press fits in less than would occur for total molecular contact.

FIGS. **3** and **3A** show two types of presealed heat piped valve seats. FIG. **3** shows a valve seat **1** with a ring of tubing **30** complete with wick **32** (for instance, of asbestos) cast into the valve seat. After machining, a small hole is drilled from the side to insert working fluid, and then sealed. A heat piped valve seat **1** with the heat pipe sealed prior to installation results. FIG. 3A shows a presealed valve seat **1** constructed in the manner of the seat in FIG. **1**, but sealed by shrink fitting into a ring **36** prior to installation in the head.

FIG. **4** shows the preferred way of installing a shrink fit valve seat of the type shown in FIG. **1** in production. The valve seat **9** contains water ice and dry ice in its wicked ring shaped passage **15** and is installed at dry ice temperatures into the head **10** as a part of the valve installation procedure. Valve seat **9** will be cold and will have a layer of frost over it so that it will stick (with the water ice frost serving as a glue) to the valve **11** so that it can be installed under tension of spring assembly **12, 13, 14** as part of the valve installation procedure. The valve spring tension will serve to force the seat into centered contact with the bottom surface of the machined cylindrical hole provided for it in the engine head. After the valve seats are clamped in place by the valve-valve spring installation, the subliming dry ice in passage **15** will flush this passage free of any gas save $CO_2$ and a gas seal will be established after the dry ice has sublimed, but prior to the melting of the water ice. When seat **9** comes to equilibrium with head **10** a gas tight seal on passage **15** will be established, and the CaO in passage **15** will react with the $CO_2$ in the passage so that the only remaining gas in passage **15** will be water vapor. In this way, the installation of the valve seats becomes only a slight complication of the valve installation procedure.

The working fluid in the heat pipe passage may, of course, be something besides water. Methanol, ethonal, heptane, hexane and some other liquids will work in the temperature range required. The technique will work with any liquid which is on the high vapor pressure portion of its evaporation curve at the working temperatures of the valve seat.

We claim:

**1.** A valve seat having no thermal distortion of the valve sealing surface, said valve seat having a valve sealing surface, a gas tight hollow annular passage radially symmetric with the valve sealing surface, said annular passage containing part of its volume as liquid and part as gas, said liquid having a vapor pressure in excess of atmospheric pressure at normal valve seat operating temperatures, said annular passage being substantially free of non-condensable gas pockets, the surface of said annular passage being covered by a wicking means, the annular passage containing sufficient liquid so that all of the wicking means is maintained wet at the highest operating temperature of the annular passage whereby evaporation and condensation of the liquid in the passage virtually eliminates temperature differences between points on the passage surface, and therefore produces a more nearly radially symmetric temperature distribution in said valve seat so that unsymmetric thermal stresses cannot occur to cause distortion of the valve sealing surface.

**2.** The invention as set forth in claim **1** and wherein a portion of the wicking means is rust formed from the material forming the passage.

**3.** The invention as set forth in claim **1** and wherein a portion of the wicking means is a chemically formed porous surface formed from the material forming the passage.

**4.** The invention as set forth in claim **1** and wherein the hollow annular cooling passage radially symmetric with the valve sealing surface of the valve seat structure is formed by the joining of a valve seat insert including an encircling groove with the head structure of an internal combustion engine.

5. A method of assembling a heat pipe valve seat having an encircling groove therein into the head of an internal combustion engine by shrink fit comprising the steps of

A. cooling the heat pipe valve seat to a temperature below the freezing point of the heat pipe working fluid,
B. introducing into the encircling groove the following:
   1. flowing the heat pipe working fluid into the encircling groove where it freezes,
   2. introducing into the aforesaid groove a solid substance which sublimes to a gas at a temperature below the melting point of said working fluid,
   3. introducing a chemical substance which reacts with gas formed by said subliming substance at a temperature above the melting point of said working fluid,
C. inserting said valve seat with a cylinder head where the shrink fit contact between said valve seat and said head forms a gas tight seal.

6. The invention as set forth in claim 5 and wherein the chemical substance which reacts with gas formed by said subliming substance is a part of the structure of said valve seat.

7. A method of assembling a heat pipe valve seat having an encircling groove therein and its associated valve into the head of an internal combustion enging of shrink fit comprising the steps of

A. cooling the heat pipe valve seat to a temperature below the freezing point of the heat pipe working fluid,
B. introducing into the encircling groove the following:
   1. flowing the heat pipe working fluid into the encircling groove where it freezes,
   2. introducing into the aforesaid groove a solid substance which sublimes to a gas at a temperature below the melting point of said working fluid,
   3. introducing a chemical substance which reacts with gas formed by said subliming substance at a temperature above the melting point of said working fluid.
C. attaching the valve seat to the valve head,
D. inserting said valve seat-valve assembly into a cylinder head wherein said valve-valve seat assembly is placed under compression by installation of the valve spring on said valve, where the shrink fit contact between said valve seat and said head forms a gas tight seal.

8. The invention as set forth in claim 7 and wherein the method of attaching the valve seat to the valve head is by freezing a liquid between said valve head and said valve seat to hold said valve head and valve seat together.

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