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ALUMINUM VALVE

Filed July 2, 1959

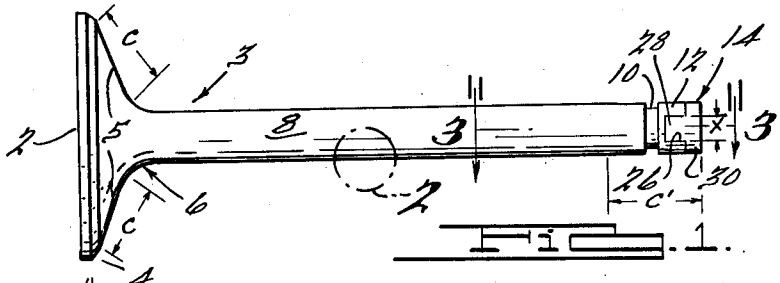


Fig. 1.

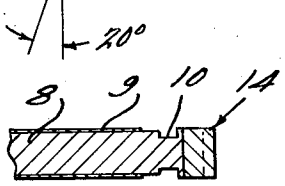


Fig. 3.

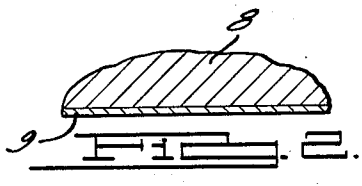


Fig. 2.

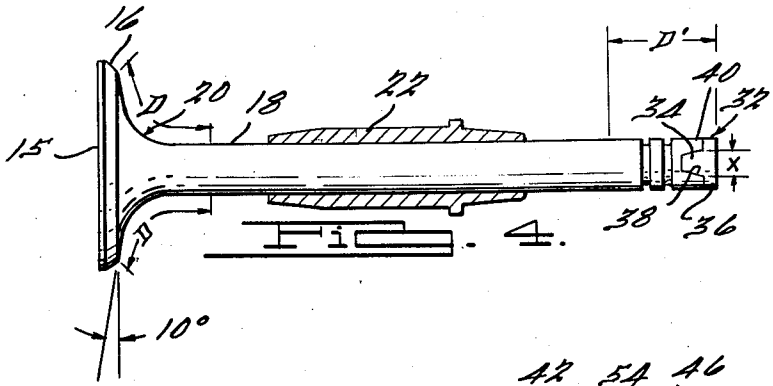


Fig. 4.

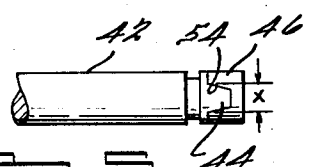


Fig. 5.

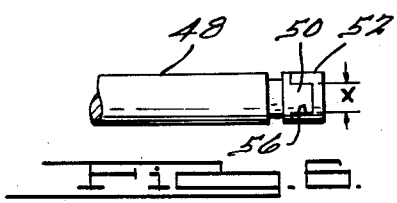


Fig. 6.

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ALUMINUM VALVE

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19 Claims. (Cl. 123—188)

This invention relates to aluminum valves for use in internal combustion engines.

With the passage of time, the development of higher octane fuels and the trend toward higher operating engine speeds and temperatures internal combustion engine parts have been subjected to increasingly severe mechanical and thermal stresses. The continuing attempt to improve engine efficiency has led researchers to evaluate materials lighter than steel for making such moving engine parts as pistons, tappets, and the like, in the hope that such lighter materials would decrease the stresses and permit more complete utilization of the power contained in the higher octane fuels. It was anticipated that aluminum, because of its light weight, high heat conductivity, and resistance to corrosion would make an excellent material for valves. When tried, however, it was found that pure aluminum valves had a number of serious drawbacks including low compression, creep and fatigue resistance and poor resistance to abrasion and corrosion of the engine gases particularly under the elevated temperature conditions which are prevalent in high speed, heavy load operation of an internal combustion engine. Pure aluminum was far too weak in compression, creep and fatigue strength to resist the forces existing when the valve face repeatedly contacts the valve seat under high pressure gas loading due to combustion within the cylinder, and under high mechanical loading due to impact between the valve and the seat during valve closure.

It is the primary object of this invention to provide an aluminum alloy valve which is characterized by improved compression, creep and fatigue resistance, and having sufficient abrasion and corrosion resistance to enable it to be used satisfactorily in internal combustion engines.

In accordance with this invention it has been found that certain wrought aluminum alloys containing more than 90% aluminum and varying proportions of copper, manganese, magnesium and/or zinc as the alloying ingredients, and that alloys of aluminum containing about 1% to about 20% of aluminum oxide fabricated by powder metallurgy techniques which are described more fully below, exhibit sufficiently high compression, creep and fatigue resistance to make them suitable for use as valves in internal combustion engines. These alloys are improved, in accordance with this invention to render them suitable for both light and heavy duty applications by treating the surface of the valve in selected locations to form a surface protecting layer which improves the corrosion resistance and enhances the compression and creep resistance of the valve during use. The preferred method for treating the surface is an anodizing treatment which forms an anodized surface layer which is thick relative to many conventional anodized layers produced heretofore primarily for corrosion resistance purposes.

The wrought aluminum alloys which have been found to be suitable for the purposes of this invention may contain, as alloying ingredients, copper 1.2–4.9%, manganese .1–1%, magnesium .2–2.9%, zinc when present 5.1–6%, a maximum of 1.4% of impurity elements including iron, chromium, titanium and zinc, with the balance being aluminum.

When zinc is present in substantial alloying quantities, as indicated, the copper and manganese content should be lower relative to the quantities thereof which are present

in the absence of zinc, and in this case copper should not exceed about 2.0%, manganese should not exceed about 0.3% and the magnesium should be in the range of about 2.1–2.9%. A number of typical, specific wrought aluminum alloys which have been used will be more particularly identified as to composition in the examples which are disclosed hereinbelow.

The aluminum powder metallurgy alloys containing about 1% to about 20% of aluminum oxide are superior in their stress-rupture characteristics to the wrought aluminum alloys at temperatures above about 500° F. and represent the preferred composition for use, particularly in valves intended for heavy duty, high temperature operation. The stress-rupture properties improve as the proportion of aluminum oxide which is present increases up to a maximum of about 17%–20%, by weight, of the alloy but as the proportion of oxide increases the difficulty of cold working also increases and better overall results have been obtained with alloys containing about 6%–8% aluminum oxide. The presence of 1%–3% aluminum oxide in an aluminum alloy renders the stress-rupture properties at 600° F. equivalent to the stress-rupture properties of the best wrought aluminum alloys. When the proportion of aluminum oxide exceeds about 20% however the resulting alloy is insufficiently homogeneous to retain its shape during use. These powder metallurgy alloys are satisfactorily formed from aluminum powder or aluminum flake by oxidizing the powder to a controlled degree to produce the desired aluminum oxide content and thereafter extruding a heated compact of the oxidized particles through a relatively severe reduction to thus form a sound aluminum alloy having particles of aluminum oxide distributed therethrough. It is also feasible to form these alloys by a similar extrusion process employing finely divided aluminum metal and aluminum oxide powders, but the former procedure is preferred.

As above suggested, it has been found that the complete coverage of the surface of the valve with an anodizing coating is, although beneficial in improving the corrosion resistance of the valve, sufficiently detrimental to the high temperature fatigue resistance to make the valve unsuitable for use in an internal combustion engine except for very light duty applications. In accordance with this invention it is preferred to anodize the surface of the valve in certain areas and to protect certain critical portions of the surface from the anodizing treatment in order to maintain a sufficiently high fatigue strength in the valve, and these critical regions may be best seen by referring to the drawings in which:

FIGURE 1 is an elevation view of a valve embodying the invention and illustrating the critical portion of the undersurface of the valve head which should be protected from the surface treatment of this invention;

FIGURE 2 is a partial sectional view illustrating the portion of the surface of the valve of FIG. 1 encircled by the circle designated 2;

FIG. 3 is a sectional view of the valve stem end of the valve of FIG. 1 showing one form of valve stem cap;

FIG. 4 is an elevation view showing a modified form of valve stem cap and illustrating the permissible degree of masking of the surface from the protective coating which can be used on the valves of this invention;

FIG. 5 is a view showing a modified form of valve stem cap; and

FIG. 6 is a view showing a further modified form of valve stem cap.

Referring to FIG. 1, the valve there shown, generally designated 3, comprises a valve head 2, a valve face 4, and lower valve head surface 5 which is planar and extends from a point adjacent to the inner surface of valve face 4 and gradually blends with the fillet portion, gen-

erally designated **6**, which joins surface **5** and valve stem **8**. The valve stem terminates at its outer end in a cap receiving portion **12** which is separated from the main portion of valve stem **8** by a spring washer-retaining groove designated **10** and the outer portion **12** is capped with a wear-resistant, hard metal cap member, generally designated **14**, which will be described in greater detail below.

The shape of the head portion of the valves of this invention has been found to be important from the standpoint of providing a valve having the least possible weight for any given stress resistance. The maximum stress resistance is dictated by the requirements of the particular engine, and the lightest weight valve to give this necessary maximum stress value is obtained, in each case, by shaping the head portion of the valve so as to have uniform stress throughout, the stress referred to being that primarily resulting from pressure loading during combustion. Such a uniform stress is obtained by providing a planar portion between the inner surface of the valve face and the fillet which blends that planar portion into the valve stem, and by employing a fillet of small radius to join that planar portion and the valve stem and preferably by employing the smallest radius fillet which will smoothly and uniformly join the two planes. The referred to configuration is shown in FIG. 1 and should be compared to that of FIG. 4 which illustrates a conventional non-uniform stress type in present day commercial use. In FIG. 1 it should be noticed that the surface **5** which connects the inner edge of the valve face **4** with the stem **8** is a planar portion which is disposed at an angle of about 20 degrees from the plane of valve head **2**. The inner end of the planar surface **5** smoothly blends into fillet **6** which gradually unites the stem **8** and the planar surface **5**. In a conventional automotive engine valve, typical dimensions of the valve illustrated in FIG. 1 would be 4.8 inches in length overall from the valve head **2** to the outer end of cap **14**, a head diameter of 1.9 inches, a stem diameter of about 0.37 inch and a ¼-inch radius fillet connecting the planar face **5** with valve stem **8**. The valve face **4** has a thickness of about 0.07 inch while the thickness of the valve head above the point of intersection of the valve head and the valve face is about 0.09 inch. This valve provides a uniform stress in the head portion of about 5000 p.s.i. when subjected to a cylinder pressure of 500 p.s.i. It will be noted that the configuration of the valve shown in FIG. 4 employs a much larger radius fillet **20**, which extends from the inner surface of the valve face **16** to the valve stem **18**, than the corresponding fillet **6** of the valve shown in FIG. 1. Moreover, the thickness of the face **16** is relatively thinner than that of the valve of FIG. 1, and there is no planar portion between the valve face and the stem on the lower surface of the valve head. The same principles may be employed to provide a substantially uniform stress design having the desired maximum stress by merely varying the angle of the planar surface **5** from the plane of valve head **2**. As this angle decreases, the uniform stress in the planar surface **5** increases, and vice versa. Typically suitable dimensions for this valve used in an automotive engine are about 4.75 inches total length, 1.65 inches in valve head diameter, 0.373 inch stem diameter, the fillet **20** having a radius of about 0.36 inch, the thickness of the valve head above the upper surface of the valve face about 0.06 inch and the valve face having a dimension along the face of about 0.12 inch.

The surface of the valve, other than the portion of the surface designated C, FIG. 1, including part of the planar areas designated **5** which lie between the inner surface of the valve face and extend approximately one-fourth to one-third of the distance into the fillet **6** when moving in the direction of the stem from the valve head should be anodized to give a surface layer **9** as shown in FIGS. 2 and 3. Masked areas C confer upon the resulting valve greatly improved fatigue strength while the anodized layer adds to the creep, compression and corrosion resistance of the valve. While unnecessary in certain applications, it is preferable to mask the area encompassing the key groove toward the end of the valve stem, as indicated at C' and D' in FIGS. 1 and 4, respectively. These masked areas preferably extend from a point slightly inwardly from the key groove to the end of the stem **8**.

Although the section of the lower surface of the valve head indicated by the area C, FIG. 1, represents the preferred area for masking a larger area can be masked, if desired, with satisfactory results. Such larger area is indicated by the letter D on the valve shown in FIG. 4 which extends from the lower surface of the valve seat **16** to a point on the valve stem **18** past the end of the fillet **20** but spaced from the inner end of the valve guide bushing **22**. The portion of the valve stem **18** which moves within valve guide bushing **22** is preferably all subjected to the anodizing treatment and the extremity of the masking from the point of intersection of the fillet **20** and the stem **18** which is employed should, in all cases, be less than the amount which will leave a portion of the surface of valve stem **18** non-anodized when the valve moves through its normal oscillatory motion for opening and closing. The only disadvantage of extending the masked area to the greater extent illustrated in FIG. 4 is that the extended portion may show somewhat less corrosion resistance when the valve is used as an exhaust valve than the preferred form shown in FIG. 1. With respect to fatigue resistance, the difference in degree of masking does not appreciably affect the results obtained.

It has also been found that the greatest increase in compression and creep resistance, as well as abrasion resistance of the valve seats, is obtained when the depth of the anodized layer on the surface of the valve is substantial, and it has been found that the anodized layer should have a minimum depth of between 0.0015 and 0.02 inch. The greater the depth of the anodized layer the greater improvement in operating life of the valves and anodized layer depths between 0.006 and 0.007 inch are desirable, where obtainable. One of the difficulties which has been encountered in forming the improved valves of this invention is in obtaining a substantial depth in the anodized layer. In this connection, it has been found that the use of a sintered aluminum powder composition, of the type above indicated to be useful, enables the formation of an anodized layer which is greater in depth than can be formed when employing wrought aluminum alloys of the type above described. The best results which have been obtained with and the preferred form of this invention is a sintered aluminum powder alloy having a surface anodized layer of a thickness in the range of about 0.004–0.007 inch and in which the area extending from the inner surface of the valve face and covering at least the first one-fourth of the fillet which connects the valve face to the valve stem is free of the anodized layer.

One of the important advantages which is obtained from this invention is that a valve is provided which operates at substantially lower temperatures than are characteristic for steel valves operated under similar conditions. Even though the formation of an anodized coating on the surface of the valve reduces the rate of heat transfer from the valve face to the valve seat and from the valve stem to the valve bushing relative to the rate of heat transfer for pure aluminum, the heat developed is transferred from the valve much faster for the aluminum valves of this invention than for steel valves. For example, a single cylinder engine operating at 2000 r.p.m. produced an aluminum valve temperature of 385° F., while steel valves in the same engine had a temperature of about 565° F. At 3000 r.p.m. in the same engine the aluminum valve temperature was about 485° F. whereas the steel valve temperature was about 610° F.

Another feature of this invention which has been found to be important to the successful continuous utility of the aluminum valves of this invention is the valve stem

end protection. It was found that the valves failed in use unless the extreme end of the valve stem was protected by a hard wear-resistant cap capable of receiving and withstanding the wear from contact of the end of the valve with the valve lifter or rocker arm. A number of modifications of satisfactory valve end designs are shown in FIGS. 1, 4, 5 and 6. In the valve shown in FIG. 1, the valve end portion 12 is provided with a centrally disposed aperture 26 which is adapted to receive nail portion 28 of the cap member 14. It will be noticed that the nail portion 28 has substantially parallel sides which intersect the cap portion 30 substantially at right angles.

In the modification illustrated in FIG. 4, the cap member generally designated 32 comprises a nail portion 34 and a cap portion 36. Nail portion 34 is tapered so as to closely interfit and fill the correspondingly shaped recess 38 in the end portion 40 of the valve stem 18. The sides of the nail portion 34 taper inwardly toward the central axis of valve stem 18 and intersect the cap portion 36 at an obtuse angle. In the case of both forms of the caps 14 and 32, they are attached to the end of the stem either by bonding or by using a press fit. When a press fit is used it is desirable to insure that the diameter of the cavities 26 and 38 are made sufficiently smaller than the diameters of the nail portions 28 and 34, respectively, so that under the temperatures existing during operation of the valve the cap members 14, 32 will not become loose in the receiving cavities. In assembling the caps 14 and 32 in the valve stem end portions 12 and 40, respectively, the parts may be pressed together or the valve stem can be heated and the caps 14 and 32 inserted while the cavities 26 and 38 are in an extended or enlarged condition. Upon cooling the caps 14 and 32 are securely held in place.

The cap modifications illustrated in FIGS. 5 and 6 employ a tubular form of cap which surrounds an outwardly extending projection formed on the outer end of the valve stems. In the modification shown in FIG. 5 the stem 42 is provided with a tapered projection 44 of frusto-conical shape and an overlying cap member 46. Cap member 46 is provided with a correspondingly tapered cavity 54 which surrounds and encompasses the projection 44 and is secured in place by welding or a press fit, as indicated above as suitable for the modification shown in FIG. 4.

In the modification shown in FIG. 6, valve stem 48 is provided with a substantially square end projection 50 which is covered by a cap member 52. Cap 52 is provided with an aperture 56 which corresponds in configuration to the shape of projection 50 on the end of valve stem 48 and is secured in place in a similar fashion. In the case of the modifications of FIGS. 5 and 6 the assembly can be effected by lowering the temperature of or freezing the valve stem 48 to shrink it relative to the cavities 54, 56 prior to mating the parts together.

Cap members 14, 32, 46 and 52 may be suitably formed from a variety of materials which have greater resistance to abrasion and impact than is characteristic of aluminum, such as steel, iron, tool steel, cemented tungsten carbide, or the like. In all cases, however, it was found that the impact forces which the end extremity of the valve stems must absorb during use are such that the relationship of the diameters of the securing portion of the cap and the diameter of the stem is relatively critical if fatigue failure is to be avoided. It was found that the nail portions 28 and 34 of the cap members 14, 32 should have a diameter dimension, represented by the dimension X on FIG. 4, that is a minimum of one-third of the diameter of the cap portions 14, 32, respectively, and preferably should be in the range of one-half the diameter of the cap portions 14, 32. A similar relationship was found between the diameter of the projections 44, 50 in the modifications of FIGS. 5 and 6, respectively, and the cap members 46, 52, that is, the major diameter of the projections 44, 50, represented by the dimension indicated at X, should be a minimum of one-third the diameter of the caps 46, 52 and preferably should lie in the range of about one-half the diameter of the caps 46, 52. Caps of the design shown in FIGS. 1, 4, 5 and 6 were found to fail when the nail portions 28, 34 and the projecting portions 44, 50 were at a diameter between one-fifth and one-fourth of that of the cooperating cap members 14, 32, 46 and 52, respectively. When, however, the diameter was increased to a minimum of one-third of the diameter of the cap members, fatigue failure was not encountered. While the above description has indicated that anodizing is the preferred method for treating the surface of the valves of this invention, substantially similar improvement in corrosion, creep and fatigue resistance has been obtained when the surface is coated with a layer of hard chromium or is metalized with a corrosion-resistant metal, such, for example, as molybdenum, tungsten, or alloy thereof in which molybdenum or tungsten is the predominant metal. When a metalized coating is employed the minimum thickness which is capable of substantially improving the compression, creep and fatigue strength, as well as providing improved corrosion resistance is a coating having a thickness of about 0.002 inch. Coatings having a thickness as great as 0.05 inch can be easily applied and a coating of this type having a thickness in the range of about 0.005 to about 0.020 inch is preferred. The heavier coatings can be employed by proper preliminary surface preparation and by giving due consideration to the fit between the valve stem and valve guide bushings, and the valve seat and valve face. It is often advantageous to coat the valve face with a somewhat heavier coating than is prevalent on the other portions of the valve, other than the specifically masked area so that the valve face can be final-ground and yet leave a protective surface coating on the valve face. When a hard chromium coating is employed, a coating having a thickness in the range of about 0.002 to about 0.040 inch gives satisfactory results. It is preferred that the coating have a minimum thickness of about 0.005 inch and the preferred range is about 0.010 inch to about 0.030 inch. As above indicated in connection with anodized coatings, it is desirable to apply the hard chromium coating or the metalized coating to the portion of the valve surface other than the areas indicated in FIGURES 1 and 4 by the letters "C" and "D" respectively.

The below-given examples will illustrate in greater detail a number of specific aluminum alloy compositions which have been employed in accordance with the method of this invention and it is to be understood that the methods of anodizing, metalizing, and hard chromium plating are merely illustrative of methods and means by which such coatings can be formed and that other methods known to those skilled in the art for this purpose are equally satisfactory.

Example I

A two-inch bar of aluminum powder alloy containing about 7% aluminum oxide and about 93% aluminum powder was formed into a valve having the form shown in FIGURE 1 having the typical dimensions recited in the specification. The alloy employed is commercially available from Aluminum Company of America under the designation M-257.

The valves were given a hard anodized surface layer coating by using the following process: an aqueous solution containing 12% sulfuric acid and 4% oxalic acid was prepared. The valves were immersed in the solution which was maintained at a temperature of 30% F. and while vigorously agitating the bath the valves were subjected to a voltage of approximately 90 volts and a current density of about 60 amps/sq. ft. for about 30 minutes. The valves were then removed and rinsed in cold water and upon inspection were found to have an an-

odized coating having a thickness between about 0.003 and 0.0035 inch uniformly over the entire surface of the valves. These valves were tested in a V-8 engine of standard specifications with the exception that the inlet manifold used four Stromberg model 97 two-throat carburetors with adjustable main jets on each of the eight venturis. The engine was a Dodge V–8 using a Dodge D500 cylinder head, a specially ground cam shaft with 270° duration and 0.432 inch lift on both inlet and exhaust. The engine employed hydraulic lifters and the spring load was 175 pounds valve open load on the inlet and 240 pounds valve open load on the exhaust. The valves were inserted in the engine which was run at 5000 r.p.m. and a 13.5:1 air-fuel ratio, which simulates the most severe conditions normally encountered for inlet valves in passenger automobile engines. Under these conditions, the engine produced about 200 H.P. observed. The valves failed by fatigue in the lower surface of the valve head, the first failure occurring after about six hours.

A second set of valves comparable in all respects except that the under surface of the head portion of the valve between the inner surface of the valve face and approximately the middle portion of the fillet which connects the valve stem to that under surface was masked during the anodizing treatment and received no anodizing surface coating. This set of valves was run in the same engine under the same conditions and the fatigue life of the valves was found to be increased to 15 hours or to approximately two and one-half times the fatigue life of the first set of valves, measured to the first failure in both cases. The seven valves out of this second set of eight valves which had not failed after fifteen hours in the test engine were then run for one hour at 2000 r.p.m. and an additional hour at 3000 r.p.m., in both cases employing an 0.06 inch lash, 13.5:1 air-fuel ratio, and at the end of this high lash running condition the valves were withdrawn and inspected and found to be unchanged. None of the valve faces were grooved and the valve stems were free of cracks and breakage in the anodized coating and no corrosion was detected.

The test conditions employed in this test engine are extremely severe relative to conditions normally encountered in ordinary automobile engines in that the temperature is higher than is normally present. The temperature on the inlet valves was approximately 600° F. when the engine was operating at 5000 r.p.m. and thus these tests represent rigorous limiting conditions.

As an indication of the severity of this test, a separate set of eight valves was prepared in accordance with the conditions described for the second set, above described, that is, anodized on all of the surface except the under head surface portion. This set of valves was run in the Dodge V–8 engine at 4000 r.p.m., 13.5:1 air-fuel ratio full throttle, and no failure of the valves was encountered until the end of twenty-six hours, at which time an inspection showed that three of the valves had failed by valve face grooving.

A further modification of the fabrication procedure of valves made from the sintered aluminum powder alloy material was made, and in this case the valve stems were hot forged and the valve heads were forged at room temperature. With comparable anodizing of the surface, these valves were found to successfully withstand forty hours of engine testing at 4000 r.p.m., full throttle, 13.5:1 air-fuel ratio.

Example II

A set of eight valves were fabricated to the shape shown in FIG. 1, having a head diameter of 1.66 inches, from an aluminum alloy material having the following composition: 3.5–4.5% copper, 0.4–1.0% manganese, 0.2–0.8% magnesium, 0.8% maximum silica, 1% maximum iron, 0.25% maximum chromium, 0.1% maximum zinc, 0.15% maximum of other impurities, balance aluminum. The alloy used is commerically designated 2017T4.

These valves were tested in a 1954 Dodge V–8 engine, 240 cubic inches, which was built to standard factory specifications with the exception that the inlet manifold was specially fabricated to use eight single-throat carburetors.

The valves were placed in the engine which was operated at 2500 r.p.m., full throttle, and 13.3:1 air-fuel ratio, using Indolene 30 test fuel. Under these conditions, the engine output was about 100 H.P. The valves were run for eighteen hours and upon inspection one of the valves was found to have a scuffed stem. The valves were replaced in the engine and the test continued and at the end of forty-five hours another inspection showed that all eight valves had stem scuffing, seven valve stem ends were badly worn, and all eight of the valves were grooved on the valve face.

A second set of valves were made to the same dimensions and form and thereafter were subjected to an anodizing treatment on the entire surface of the valve of the same type and using the same conditions as above specified in Example I and upon withdrawal from the anodizing bath, an inspection showed that the anodized layer coating had a thickness between about 0.003 and 0.0035 inch. This anodized set of valves was then placed in the same engine and run at 2500 r.p.m., full throttle, 13.3:1 air-fuel ratio, and at the end of eighteen hours no change in the valves could be detected. At the end of forty-five hours one valve was found to have a scuffed stem, three valve faces were grooved and two of the valve stem ends were worn.

Another set of twelve valves were made from the same alloy material and were modified to include steel caps on the end, of the type shown in FIG. 1, and they were anodized on all of the surface of the valve except the lower surface of the valve head extending from the valve face through approximately one-fourth of the extent of the fillet, which joins the lower surface of the valve head to the valve stem, in the direction of the valve stem from the valve head portion. These valves were then inserted in the same test engine and operated at 2500 r.p.m., full throttle, and 13.3:1 air-fuel ratio with the same fuel. After 40 hours, one valve had slight seat grooving and one had slight stem scuffing. After 57 hours, one valve had the anodizing chipped. No valve failures were noted until the end of 113 hours, at which time one valve head broke from fatigue. A number of the other valves were continued in that test and 400 hours of satisfactory operation was accumulated on them. An inspection of the valves at end of this time showed that the anodized coating was thin in certain areas and that there was some slight seat grooving but the valves were considered to be in fair operating condition.

Example III

A set of eight valves was formed from a wrought aluminum alloy composition having alloying ingredients in the following percentages: 3.8–4.9% copper, 0.3–0.9% manganese, 1.2–1.8% magnesium, 0.5% maximum silicon, 0.5% maximum iron, 0.25% maximum chromium, 0.10% zinc, 0.15% maximum other impurities and the balance aluminum. The alloy used is commercially designated 2024T4. The set of these valves was run under the slow speed endurance testing conditions of 2500 r.p.m. in the 1954 Dodge V–8 engine used in Example II and after 45 hours the condition of the valves was observed to be comparable to that observed in connection with the set of eight non-anodized valves described above in Example II.

A second set of valves of similar composition was anodized with the under surface of the head portion of the valve masked and upon testing these valves in the same V–8 engine operating at 2500 r.p.m., full throttle, and 13.3:1 air-fuel ratio, comparable results were observed

to those obtained with the anodized valves of Example II.

Example IV

A further test was made of another specific wrought aluminum alloy composition by forming a set of valves of similar dimension and shape from the following specific composition: 1.2–2.0% copper, 0.1–0.3% manganese, 2.1–2.9% magnesium, 0.7% maximum iron, 0.5% maximum silicon, 0.15–0.4% chromium, 5.1–6% zinc, 0.2% maximum titanium, 0.15% maximum other impurities and the balance aluminum. This alloy is commercially available under the designation 7075T6 from the Aluminum Company of America. Sets of valves of this composition were tested in an uncoated condition, in a completely anodized surface coated condition and in a condition of anodizing in which the lower surface portion of the head was masked so that the anodized layer covered all of the surface except that masked portion. When tested in the same engine operating at the low speed of 2500 r.p.m., as above described, similar results were obtained for each set as those set forth for the wrought aluminum compositions described in Examples II and III.

Each of the aluminum compositions specified in Examples II, III and IV were fabricated into additional sets of valves and the surfaces of each set were subjected to a hard chromium coating process as follows: the valves were first dipped in an aqueous solution of nitric acid containing 50% nitric acid by volume for a few seconds at room temperature, withdrawn, water rinsed and then rinsed in an aqueous hydrofluoric acid bath containing 5% hydrofluoric acid by volume, removed and water rinsed. The valves were then immersed in a solution containing 525 grams per liter sodium hydroxide, 100 grams per liter zinc oxide and maintained therein for thirty to sixty seconds while the bath was being agitated and maintained at a temperature between 70° F. and 80° F. and withdrawn. After water rinsing the valves were then covered with a hard chromium plate by immersing them in a solution containing 52 ounces per gallon chromic acid, 0.5 ounce per gallon sulfuric acid, balance water and electrodepositing chromium on the surfaces of the valves at a current density of 200–225 amps per sq. ft., 6–8 volts, at a temperature of 65° F. to 70° F. and for a time sufficient to deposit a coating having a thickness of about 0.001–0.003 inch. When these valves were tested in the V–8 engine at 2500 r.p.m., full throttle, 13.3:1 air-fuel ratio, substantially comparable results were obtained to those obtained with the corresponding alloy compositions which had been anodized in accordance with the above described procedure.

What is claimed is:

1. An aluminum valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to be stressed substantially uniformly throughout by pressures resulting from combustion loading, and a corrosion-resisting, compression and creep-resistant coating on the surface of said valve stem, valve face and valve head other than the lower surface portion of said valve head.

2. An aluminum valve for an internal combustion engine having a head portion, a beveled valve face on said head portion, and a stem portion, the lower surface of said head portion having a planar portion adjacent to the inner surface of said valve face, a fillet portion integral with said valve stem and smoothly joining the said planar portion to said stem, said valve having a corrosion-resisting, compression and creep-resistant coating covering the surface thereof other than the lower surface of said head portion extending from a point adjacent to the inner surface of said valve face across said planar portion and towards said stem for a distance of at least one-fourth of the length of the arcuate portion connecting said stem and said planar portion.

3. An aluminum valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, the lower surface of said head portion having a planar portion adjacent to the inner surface of said valve face, a fillet portion integral with said valve stem and smoothly joining the said planar portion to said stem, said valve having an anodized layer having a thickness in the range of about 0.0015–0.007 inch covering its surface other than the lower surface of said head portion extending from a point adjacent to the inner surface of said valve face across said planar portion and toward said stem for a distance of at least one-fourth of the length of the arcuate portion connecting said stem and said planar portion.

4. An aluminum valve for internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, the lower surface of said head portion having a planar portion adjacent to the inner surface of said valve face, a fillet portion integral with said valve stem and smoothly joining the said planar portion to said stem, said valve having a hard chromium layer having a thickness in the range of about 0.002–0.04 inch covering its surface other than the lower surface of said head portion extending from a point adjacent to the inner surface of said valve face, across said planar portion and toward said stem for a distance of at least one-fourth of the length of the arcuate portion connecting said stem and said planar portion.

5. A poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to have substantially uniform stress throughout as the result of pressure-loading during combustion, said valve being formed from an aluminum alloy consisting of 3.5%–4.5% copper, 0.4%–1% manganese, 0.2%–0.8% magnesium, 0.8% maximum silicon, 1% maximum iron, 0.25% maximum chromium, 0.10% maximum zinc, 0.15% maximum of other impurities and the balance aluminum.

6. A poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to have substantially uniform stress throughout as the result of pressure-loading during combustion, said valve being formed from an aluminum alloy consisting of 3.8%–4.9% copper, 0.3%–0.9% manganese, 1.2%–1.8% magnesium, 0.5% maximum silicon, 0.5% maximum iron, 0.25% maximum chromium, 0.1% maximum zinc, 0.15% maximum other impurities and the balance aluminum.

7. A poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to have substantially uniform stress throughout as a result of pressure-loading during combustion, said valve being formed from an aluminum alloy consisting of 1.2%–2.0% copper, 0.1%–0.3% manganese, 2.1%–2.9% magnesium, 5.1%–6.0% zinc, 0.5% maximum silicon, 0.7% maximum iron, 0.15%–0.4% chromium, 0.2% maximum titanium, 0.15% other impurities and the balance aluminum.

8. A poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to have substantially uniform stress throughout as the result of pressure-loading during combustion, said valve being fabricated from an aluminum powder metallurgy alloy consisting essentially of about 1% to about 20%, by weight, of aluminum oxide and the balance substantially aluminum.

9. In an aluminum valve for an internal combustion engine having a head portion and a stem portion, the improvement comprising providing means on the outer

end of said stem portion for receiving and supporting a wear-resistant cap member, and a wear-resistant cap member mounted on and secured to said supporting means, the diameter of the largest portion of said supporting means being at least one-third of the diameter of said cap member.

10. In an aluminum valve for an internal combustion engine having a head portion and a stem portion, the improvement comprising providing means on the outer end of said stem portion for receiving and supporting a wear-resistant cap member, and a wear-resistant cap member mounted on and secured to said supporting means, the diameter of the largest portion of said supporting means being in the range of one-third to about one-half of the diameter of said cap member.

11. An aluminum valve in accordance with claim 10 wherein said cap member is hardened steel.

12. In an aluminum valve for an internal combustion engine having a head portion and a stem portion, the improvement comprising providing means on the outer end of said stem portion for receiving and supporting a wear-resistant cap member and a wear-resistant cap member mounted on and secured to said supporting means, said supporting means consisting of a centrally disposed slot in the outer end of said stem, said cap having a nail portion and a head portion and said nail portion being disposed in and filling the said slot, the diameter of said nail portion being at least one-third of the diameter of said head portion.

13. In an aluminum valve for an internal combustion engine having a head portion and a stem portion, the improvement comprising providing means on the outer end of said stem portion for receiving and supporting a wear-resistant cap member, and a wear-resistant cap member mounted on and secured to said supporting means, said supporting means consisting of a centrally disposed projection on the outer end of said stem, said cap having a centrally disposed slot therein adapted to fit over and mate with the said projection, the diameter of said projection being at least one-third the diameter of the said cap.

14. A poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to have substantially uniform stress throughout as the result of pressure-loading during combustion, said valve being fabricated from an aluminum alloy containing 1.2%–4.9% copper, 0.1%–1% manganese, 0.2%–2.9% magnesium, and a maximum of 1.4% of impurity elements including iron, chromium, titanium and zinc, and the balance substantially all aluminum.

15. An aluminum-base alloy poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, said head portion being shaped so as to have substantially uniform stress throughout as the result of pressure loading during combustion and including a planar portion connecting said stem and said valve face, and a corrosion-resisting, compression and creep-resistant coating on portions of the surface of said valve other than on said planar portion of said head.

16. An aluminum-base alloy poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion, and a stem portion, the lower surface of said head portion having a planar portion adjacent to the inner surface of said valve face, a fillet portion integral with said valve stem and smoothly joining the said planar portion to said stem, said valve having a corrosion-resisting, compression and creep-resistant coating covering the surface thereof other than the lower surface of said head portion extending from a point adjacent to the inner surface of said valve face across said planar portion and towards said stem for a distance of at least one-fourth of the length of the arcuate portion connecting said stem and said planar portion.

17. An aluminum-base alloy poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, the lower surface of said head portion having a planar portion adjacent to the inner surface of said valve face, a fillet portion integral with said valve stem and smoothly joining the said planar portion to said stem, said valve having an anodized layer having a thickness in the range of about 0.0015–0.007 inch covering its surface other than the lower surface of said head portion extending from a point adjacent to the inner surface of said valve face across said planar portion toward said stem for a distance of at least one-fourth of the length of the arcuate portion connecting said stem and said planar portion.

18. An aluminum-base alloy poppet valve for an internal combustion engine having a head portion, a beveled valve face on said head portion and a stem portion, the lower surface of said head portion having a planar portion adjacent to the inner surface of said valve face, a fillet portion integral with said valve stem and smoothly joining the said planar portion to said stem, said valve having a hard chromium layer having a thickness in the range of about 0.002–0.04 inch covering its surface other than the lower surface of said head portion extending from a point adjacent to the inner surface of said valve face, across said planar portion and toward said stem for a distance of at least one-fourth of the length of the arcuate portion connecting said stem and said planar portion.

19. A reciprocating poppet valve for an internal combustion engine formed of an aluminum alloy, said valve including a head portion and a stem portion, and hard surfacing, corrosion resistant means formed on an outer surface of said stem portion and said head portion whereby said valve will reciprocate at high frequency in the engine due to the low inertia mass of the aluminum alloy material and be highly resistant to corrosion and friction wear.

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