

# Understanding High-Performance Valves, Guides and Seats for Racing

BY FERNANDO CURELLO

As many of our AERA members are approaching the right time to begin working on their high-performance or racing engines for next season, we thought that we could review concepts (that I'm sure you all know, but may be useful to emphasize), regarding the best ways to get the maximum performance from some of the critical parts we are going to put inside them — like the valves for “valving”, the seats where they will “seat”, and the guides that will “guide” them!

Even though the above phrase sounds like a joke, those are exactly the basic functions that we must assure for a good valve life and trouble-free running in a race, several races, or a full season.

First of all, I'd like to talk about the main differences between the life of a “street valve” and a “race valve”, so we can understand why some simple things that we can “accept” in a street valve, seat, or guide, shouldn't be allowed for a high-performance or pure racing engine.

We know that these three parts will be subjected to the maximum stresses, the highest temperatures, the biggest impact loads, and even sometimes substantial abuse from the very first minute the engine is turned on, to the checkered flag!

So, what I'm saying is that usually a street engine would never see such a punishment in its whole life, even though the O.E. engine designers had considered the maximum conditions for the design, calculations, stress analysis and final testing. Only a small percentage of the predicted/intended engine life will these three parts face such punishment, and so are designed based on statistical concepts of time usage at maximum power, maximum rpm, etc.

This makes a big difference in the way we must approach them because any minor detail in the valve head, stem, tip, grooves (and mating parts as valve retainers, locks, lash caps, rocker arms), or insert seats surface, and ID guides surface, could lead to engine failures like seized valves, worn out guides and seats, broken or burnt valves. Perhaps in a very short time or few laps, no need to wait thousands of miles or months, it will begin showing a problem.

Our high-performance or racing engines are anything but patient with our mistakes or oversights! Even worse, with the mistakes and oversights of other people, like shop colleagues, or the ones that shipped the parts to our shop, or who received them, or assembled them, or even before, who manufactured them, or packaged them... I like to say that a good and successful race engine builder always watches everything, checks everything, measures everything, hears everything, and many times... smells everything! LOL!

We should never forget that when we're machining or assembling an engine, the conditions we have like a comfortable room temperature (or A/C), clean environment, steady or idle state,

have nothing to do with the real conditions these parts will have to work in a race — especially with these three engine components, in reference to the high temperatures and cycling per second.

We always give the example of a 4-cycle engine valve, opening and closing 50 times per second at 6,000 rpm, or 75 times at 9,000 rpm, and only in a small portion of these 0.02 or 0.133 seconds is seated against its seat! And that minimum fraction is the only time it has to dissipate the heat received from the exhaust gases and combustion chamber.

At the same time, the dynamic forces created by the cam profile accelerations may put from 500 to a 1,000 g's on them, (1g is the normal acceleration gravity). So, when hitting the seats, the valves' weight is in fact 500 to 1,000 times heavier... So, for instance a 120 grams valve, depending on the camshaft profile and rpm, when hitting the seat could be in fact a 120- to 250-pound hammer!

Talking about the temperatures, mainly for the exhaust valves, we have shown many times that could reach to 1400/1600°F (760-870° C) in a gasoline naturally aspirated engine, in the zone around the center of the head, and more than that in a turbo engine where the exhaust gases could hit the valve at above 1900°F (1038°C). The intakes, which are not surrounded by the hot exhaust gases and receive the fresh inlet charge or fresh air, usually work around 750 to 1025°F (400-550°C). But in the area near the valve seat surface, the temperatures drop drastically (if the seat contact is correct and properly machined) approximately to 550/800°F (300-425°C) in the intakes, or 900/1100°F (480-600°C) in the exhaust valve seats, because the seat surface is the area where the valve dissipates most of the heat, let's say approximately 75-76%. The other 20% goes through the guide to the head and water jacket, and the remaining 4% is dissipated in the air through the locks, retainers and valve springs.

These percentages are average and change with the kind of engine, head material (cast iron, aluminum), seats and guides materials, and of course, are different with hollow stem valves or hollow head valves, because they conduct more heat to the stem, reducing the valve head temperatures. (This is a large enough subject to discuss in another article...)

Please refer to Figure 1 for typical heat flows, and Figure 2 for typical working temperatures on exhaust valves from naturally aspirated gasoline engines.

The temperature profiles on typical diesel (or compression ignition engines) are lower than the profiles on gasoline engines (or spark ignition engines). The temperature distribution for the exhaust valves is particularly dependent on the temperature of the exhaust gases, which depend on the fuel/air ratio and compression ratio.

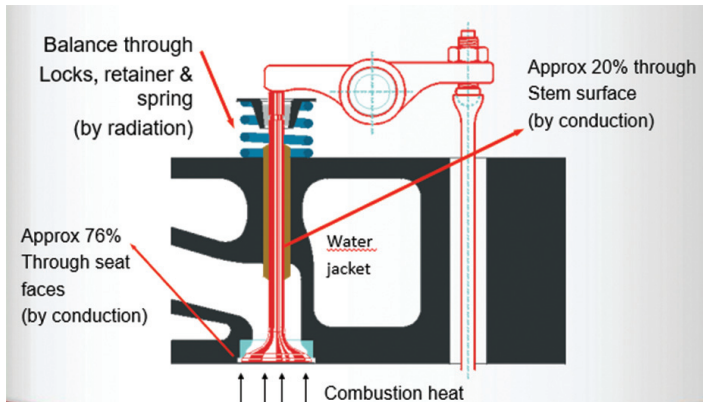


Figure 1: Heat flow from valves.

It's clear in the temperatures' graph that the maximum temperature values are reached close to the center of the valve head, and where the projection of the seat line hits the stem, (Area "A"), before the stem gets inside the guide. Then drops getting closer to the seat surface, and along the stem in contact with the guide. The higher temperatures concentrated in the "A" area, are particularly important mainly in racing exhaust valves, because all the valve materials reduce their tensile strength with the increasing working temperatures, so any bending forces (for instance due to a lack of coaxiality between guide and seat), of a light impact with a piston on an accidental overrevving could easily lead to a fatigue breakage or a sudden breakage in this area, which is usually the zone where we see these types of failures.

For the intakes, the temperatures are more even along the head surface, as in fact is constantly cycling from combustion chamber peak temperatures when closed, and fresh inlet charge when opening.

So, if a valve is not properly seated, with the right concentricity between guide and insert seat, or stem and seat surface, or too wide stem clearance, or too low tip lash, the consequences will be that the valve won't be able to transfer the right amount of heat to the seat or guide, overheating the head and stem, with the final act of this theater play... burning the valve or breaking the head, or scuffed stem inside the guide to the point of not moving and sometimes even hitting the piston.

As we mentioned in other articles, the higher temperatures in the stems make them grow due to thermal expansion, and that's a physical law, there is no way a valve stem would keep the proper clearance with the guide if working at higher temperatures than designed, because the steels or whatever material we're using, (Titanium, Inconel for instance) "needs" to expand linearly with the stem temperatures. That's because so many times the root cause for a broken head in an exhaust valve is the stem sticking in the guide. (For those interested in reading about valve materials and coatings, please refer to my article in the Oct-Dec 2021 issue of Engine Professional magazine.)

The above-mentioned temperatures and heat flow explain the huge importance of the valve and cylinder head seat area, and the emphasis we'll put from now on about how to keep the best machining practices, measuring and checking to assure the best contact between the valve and the seat insert, and going up to the guide also. If guides and seats are not carefully installed, machined and measured, the valves simply cannot dissipate the heat and a failure will soon appear, usually on the exhaust ones, but sometimes intake valves also show similar problems if heat conduction is too bad on them either.

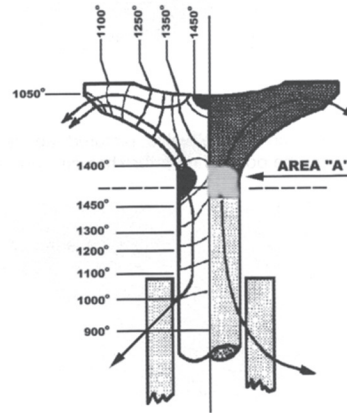


Figure 2: Typical exhaust valve heat flow lines and temperatures (in degrees Fahrenheit).

We will not extend on typical failures or their analysis as they have been covered many times in very good articles and books, our intention today is to talk about how to avoid them if possible, going step-by-step on the mating components of this chain, from the valve to the seat, guide, head, etc.

## High-Performance/Racing Valves

Talking about valves, there are several areas where we must concentrate:

### Valve Seat Concentricity or Runout With The Stem

We can't take for granted that a new or used race-intended valve is correct just by appearance, we need to measure it. The best is the lowest Total Indicator Reading (T.I.R.) we can get. Usually O.E. valves accept from .0015" to .0020" (0.0038-0.0050 mm) maximum runout, but for a race valve the ideal would be less than that, if possible .0010" (0.025 mm) or less. As I said, the lowest is the best...

It'd be important for the gauge indicator resolution to be .0001" (0.0025 mm) or less, if not the measuring error could be in the same range we need to measure.

It's also important to consider that when we check the runout through the Total Indicator Reading, we see a combination of shape form error (out of roundness for instance) and concentricity, to give a predicted performance when the valve is rotated about its stem centerline (or the "datum" axis).



Figure 3: Measuring valve seat surface runout.

The valve seat surface must be carefully inspected for scratches, dimples, high roughness, discoloration (that could indicate

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overheating in a previous race or testing), etc.

It's important to remember that a valve failure today could have originated on something that went wrong one or more races ago... like overrevving, overheating, detonation, wrong air/fuel ratio, wrong ignition timing, inadequate fuel, too small piston-to-valve clearance, too weak springs, etc., etc.

## Valve Seat Roundness

Even though there is no way to measure how well the seat is machined in regard to the perfect roundness, unless you have very special and expensive roundness measuring equipment (please refer to Figure 4), we can check it by bluing with Prussian blue the contact area all around the seat, at least to verify if there is an even contact width and centered in the valve seat surface, with no chatter marks, absence of no-contact zones, etc. We'll talk more about this under the cylinder head insert seat machining section.



Figure 4: Valve seat roundness measuring equipment

## Valve Stems

In order to obtain the best working conditions inside the guide, we need to check stem straightness, stem diameter, surface roughness, lack of scratches, lost Chromium (or other coatings) layer in certain areas. And again, if we see discoloration or dark color going up the stem that is an indication of valve working too high in temperature or too big a guide clearance that avoids good heat conduction to the guide and cylinder head.

Typical value for stem straightness is .00040" (0.010 mm) maximum; typical O.E. stem diameter tolerances are usually  $\pm 0.00040$ " ( $\pm 0.010$  mm), but for a race

valve we need to have less than that in order to reduce the guide clearance range from maximum to minimum, (which engineers call the "stack up" tolerances) when matching the biggest I.D. guide with the minimum O.D. stem, and the other way around. If we can select the valves within  $\pm 0.00020$ " ( $\pm 0.005$  mm) that will be a great condition to match with our guides... Of course, we will talk later about guides, not so easy on them either...

## Valve Tip Perpendicularity To The Stem

This is an important feature many times disregarded, mainly when valves have been adjusted in length. A lack of perpendicularity creates side loads on the stem, pushing it against the guide and stressing the grooves area for the lateral bending loads... This could lead to stem breakage inside the grooves or accelerated I.D. guide wear and highly likely stem galling. If you can measure it, try to keep your valves within .00060" (0.015 mm) maximum. It is also advisable to keep the tip surface finish as smooth as possible, mainly when titanium valves and lash caps are being used. I know that not everybody can have a Profilometer at the Shop, but if you do have one, measure the tip surface and try to keep it below 0.40 Ra (16 microinches Ra).

## Valve Locks and Retainers

I know that I'm not telling you anything new, but when talking about racing valves, must be emphasized that the match between locks and valve grooves it is of great importance. With multiple grooves always check that they are not worn out, deformed or cracked. Even if they are in good state, never mix them with a different retainer, or mix the two halves between the other locks. This could lead to bad angle matching with the retainers, and if you see that the valves grooves are worn out, check everything, valves, locks and retainers... You might need to change them all...

With these multiple groove collets, always consider that they were designed to allow valve rotation inside them, as they touch each other and don't touch the inner grooves diameter. So, usually the valves are heat treated in the grooves area to avoid excessive wear. But in the case of using Titanium valves, they can't be hardened as steel, so always use single grooves with them, mainly if you cut a stem and turn a groove when machining blanks or adapting valves to a different usage.

With single groove valves, maybe the regular 3/8", 11/32" square ones, or the 8 mm (and less, 7.0, 6.0, 5.5, 5.0, 4.5,

4.0 mm) radiused, always check them for internal cracks; usually at high rpm and massive spring loads they tend to shear the tab; the fit in these cases must be tight, no retainer tilting or excess movement between valve, locks and retainers. Be sure that the tabs are not touching the inner groove diameter, the locks must fit on the stem O.D. not pressing the inner groove I.D. because that could lead to a tip breakage due to a complex stress condition if side loads are present.

The retainers are the only guys "married for life" nowadays... (not a common practice, LOL!) with the locks, and before they become couples be sure the taper angle is the same, and after the races never mix retainers with other locks, these "infidelities" are usually more expensive than the ones you are thinking about! And the smaller the stem, the more important to keep this practice!

As mentioned above, they must fit perfectly well without tilting or showing movement with the locks and valve. The tighter the fit, the longer the durability of the set... And these single groove designs should be used for any racing valvetrain application. If not feasible, then please extreme the precautions any time the engine is disassemble for inspection.

## Valve Seat Inserts for Racing

Let's talk about the valve seat inserts that are the mating parts for the valves. The importance of having the right partner to allow all the heat from the valve seat surface to be conducted to the cylinder head and water jacket, as we saw in Figure 1, is paramount. They have three main functions:

1 – To offer an adequate surface for the valves support on the head, sealing the combustion chamber and minimizing the wear along the engine life.

2 – To transfer the heat from the Intake and Exhaust valves to the cylinder head and water jacket, allowing the valves to cool down at acceptable running temperatures for the different valve materials and applications.

3 – To help getting good airflow and fuel charging dynamics in conjunction with the valves and throat section of the runners.

There are several materials being used to achieve these requirements, and each one is intended for specific applications, like street engines with different fuels and totally different engine designs, from naturally aspirated to supercharged or

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Figure 5: Beryllium Copper and Aluminum Bronze seats in a race head.



Figure 6: High Chromium Steel and Bronze Alloys for racing seats.

turbocharged, light-duty to heavy-duty usage, offroad, etc. but since we're talking about high-performance/racing applications, we can reduce the range to the following seat alloys that find their places in the racing world:

- **Ductile Iron (or Nodular Iron) Alloy** is perhaps the most popular alloy for many racing applications in the USA, due to its good friction coefficient with the steel valves, an acceptable heat conductivity, and easy machining. It can match both cast iron heads and aluminum heads regarding thermal expansion, but it doesn't offer a high heat transfer to aluminum heads when high-power outputs or titanium valves are present.

- **Powder Metal or Sintered Steel Alloys** are the most popular alloys present in O.E. passenger car heads today, mainly for the lower cost to manufacture big volumes, and their characteristics are like the ductile iron alloys, being harder to machine due to their "interrupted cut" (microscopic internal porosity) and higher alloyed than Ductile Iron or Nodular Iron alloys. There are hundreds of different alloys being used today, according to the engine application, and many of these alloys have Copper infiltrated inside in order to improve the heat transfer, with good results.

- **Highly Alloyed Cast Steels like the High Chromium Steels** are beginning to replace the Ductile Iron in some racing and high-performance applications nowadays, mainly because they have the same machinability, similar heat conductivity but a better strength and durability due to their heat treated microstructure with a fine net of tempered martensite that substantially increase the tensile and compressive strength, (important to withstand the valve closing impact at high speeds), and so reducing the seat wear at the valve contact area.

- **Bronze Alloys** are also very popular in racing, like Aluminum Bronze, or Nickel Aluminum Bronze (that are harder than other Bronze alloys), but with a good improvement in the heat conductivity, allowing to increase the heat flow from the valves to the cylinder head, and are a good choice, mainly in the intake position for many aluminum cylinder heads and high speed applications like four cylinders, ATVs, motorcycles, etc. that due to their high rpm and high specific power (HP per cubic inch displacement) required to withdraw the heat faster. But, when the exhaust gases are too hot, or if turbo or supercharging is present, they are not recommended for the exhaust side, and we need to go

to other alloys with higher thermal conductivity, like the Beryllium Copper alloys, or recently developed Copper-Chrome-Nickel-Silicon alloys.

- **Beryllium Copper** seat alloys are only used in race applications when we combine high rpm usage, high power density (HP per cubic inch displacement), and specially needed with Titanium exhaust valves. There are basically two alloys being used, one with approx. 2% Beryllium that has lower thermal conductivity but higher hardness and strength, and the other one with approx. 0.5% Beryllium and almost double thermal conductivity but lower hardness. These alloys are expensive when compared to the other seats alloys mentioned before, and this is another reason for its only race engines application, or when Titanium valves are used in high output racing engines.

Titanium has a different failure mode than Stainless Steel when reaching the highest exhaust temperatures (not stretching or cupping before breaking). So, it is important to reduce the valve head working temperatures by improving the heat flow from the valve to the seat and water jacket. In Figure 5, we can see a high-output race head with Beryllium Copper seats in the exhaust and Nickel Aluminum Bronze in the intakes.

In recent years, a problem of possible carcinogenic risk with grinding dust inhaled from these Beryllium Copper alloys was discovered, so some Copper alloys manufacturers developed alloys with somewhat similar characteristics, but without this risk.

- **Copper-Chromium-Nickel Silicon Alloys** are the ones mentioned above, and they contain approximately 90% Copper, plus variable percentages of Chromium, Nickel and Silicon depending on the manufacturers. These alloys can be used in replacement of the Beryllium Copper alloys, some with higher thermal conductivity but lower hardness, so its usage and application (intake or exhaust sides) must be carefully discussed with the technical advisors of each material manufacturer. Again, due to their high cost they're only used in racing or ultra high-performance engines.

The most important things regarding valve seats for racing heads is how we install and machine them to assure perfect contact with the head bore and minimizing seat surface runout with the guide centerline. In this article, we're not going deeper into all the head and seat machining methods... you all know about them, and there are very good articles and presentations on the subject.

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Here are some recommendations made by Chuck Lynch, AERA's Director of Technical Service, from a past presentation called "Machining Powder Metal Valve Seats" that can be applied to all the above-mentioned seat materials:

To produce accurate valve seats, you must keep the guide processing under control, if the reference point for the seat is subpar, the seat quality will suffer. Some indications of seat issues that are originated in guide causes are:

- 1) Random seat runout measurements
- 2) Chatter
- 3) Different results when you re-grind or re-cut a seat
- 4) Poor or varying vacuum tests results

From these recommendations we see that one thing is again emphasized – the importance of measuring our results. Sometimes we're asked about the vacuum test replacing seat runout measurement. This is not acceptable, mainly if we are machining heads for high-performance/racing applications. We must do both because in fact they are checking different issues, the vacuum (or sometimes pressure) test does not assure good concentricity between valve and seat, but verifies possible scratches, chatter and undulance problems at the head seat insert surface, or nicks and debris. Measuring runout can't find these problems but assures how well-centered the valve will seat, avoiding head flexing or stem bending every time it seats down. We could get a good vacuum test result even though when the valve is out of concentricity with the guide because the valve materials are elastic, meaning that due the vacuum force the valve head is pushed against the seat, flexing and sealing, but it's going to be forced back and forth every time it opens and closes in the running engine, with a very likely stem fatigue breaking and head falling inside...

Now, we get to the point where you ask, "How much is good enough on valve seat runout?" Valve seat runout tolerances will vary based on stem size, head diameter, seating angles, etc. As we said with the valves, in racing engine tolerances, the least is the best, but as .0010-.0015" (0.025-0.038 mm) is usually the maximum values for nowadays O.E. cylinder heads, we'd recommend, if possible, to carefully work to get no more than .0010" (0.025 mm), and you'll see the results in lower guide wear, longer seat face durability and less wear, better sealing, etc., and the most important feature in a race valve... increasing its fatigue life avoiding bending



Figure 7: Typical valve seat concentricity gauge.

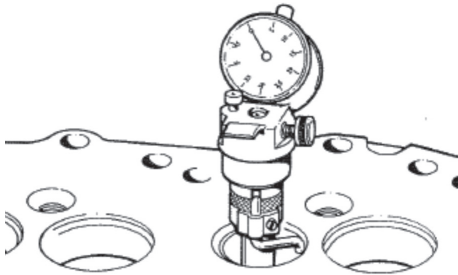


Figure 8: Measuring valve seat runout.

the stem due to excessive eccentricity at the closing point.

To get the best results in concentricity between the guide and the machined seat, I'd like to repeat what we said at the beginning... The guide ID finishing and final clearance with the valve stem must be right, if too much, the valve will struggle to hit the seat in a repeatable manner as the geometry or angle at which the valve is traveling at the seat can vary. The greater the clearance, the greater the variation.

And something related to the seat cutting tool, if you're using a form tool, or multiangle cutter, be gentle with the feed, as the surface being cut is big compared to a single angle cut or single point profile generation; the forces that pushes the tool back are also big as to reject it and you could get not a good roundness, undulations or even chatter marks.

Another subject that has been discussed along the years mainly for racing applications, is the seat width to leave in the intake and exhaust seat inserts. There are three components in the equation that we should consider:

1 – The mechanical stresses that a valve imposes on the seat while closing in a high-speed engine are very important, so if we leave too thin seating surfaces, these areas will suffer high surface stresses (called Hertzian stresses) due to the mechanical contact, and will wear out at a fast rate, sometimes even during a race, changing the inlet flow, damaging the sealing and could affect the engine power also, if not producing a premature valve failure.

2 – As we said before, the thinner the seat the less heat can be conducted through it. You know the consequences, exhaust valves working at higher temperatures with the risks already discussed.

3 – As the opposite argument, we should not put too wide a seat surface because it will affect the intake flow figures, and in the exhaust side carbon soot or debris could deposit and become extremely hard, impairing good valve sealing and cooling.

So, what we'd like to recommend is to work with intake seat widths between .040-.050" (1.00-1.30 mm) depending on valve head sizes, and for exhaust seats between .060-.070" (1.50-1.80 mm). This is an approximate guide only for naturally aspirated water-cooled engines, because when we deal with turbo or supercharged ones, or air-cooled engines, the heat flow is higher, and the valves need bigger surfaces to transfer the heat to the seats and cylinder head.

Finally, I'd like to mention something that has been written and shown in presentations for many years, but due to its importance in valve seating mechanics, we need not forget that it's the location of the valve to seat contact width. It must be centered in the valve seat face, using 2/3 of the valve seat, and should not lead to bottom line contact. If we have the contact area in the runner side of the seat, leaving a crevice at the valve O.D., hard carbon deposits will build up in the combustion chamber side, with the risk of preignition. Figure 9 shows this recommendation.

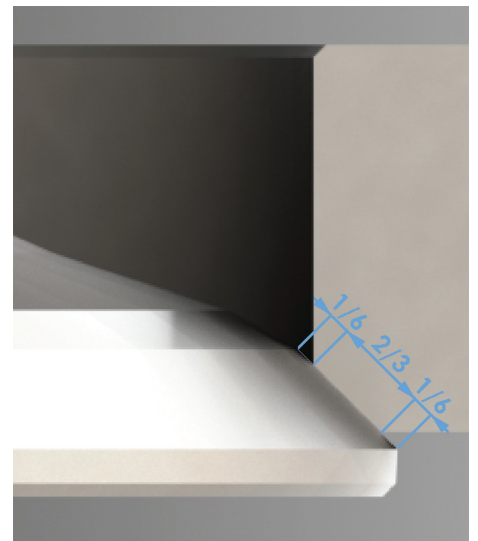


Figure 9: Valve to seat recommended contact surface.

(continued)

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## Valve Guides for Racing

As in any engine, the guides have two important functions, but for our high performance/racing engines each one of them has a paramount importance, not only for its own durability and low wear but also for the moving parts inside, that if broken we'll never forget... the valves. So, these main functions are:

- It's a bushing for the valve stem, in order to maintain the coaxiality between the valve stem and the seat insert for optimal sealing.
- Offers a heat conduction wall all around the stem, conducting the heat from the valve to the cylinder head and to the cooling system.

The lack of coaxiality, or as we usually say a big seat runoff, leads to accelerated and high wear rates for both valves and seat inserts, but there are other important consequences:

1 – The valve stem is not contacting evenly the inner surface of the guide, so the heat flow from the stem is much less than it needs to be, and the valve will work at a higher temperature, expanding the stem more than it was designed and reducing the clearance, with consequences as scuffing, galling, or even sticking inside and braking the valve (piston impact), or anything else in the valvetrain like rocker arms or bending pushrods, etc.

2 – The valve head is pushed to seat “out of concentricity”, generating lateral forces that will initiate a bending fatigue behavior, flexing the head back and forth, and this movement can only lead to a fatigue breakage eventually, usually at the point where the fillet radius meets the stem.

## Valve Guide Materials for High-Performance/Racing Applications

Even though most of the guides for O.E. passenger cars nowadays are manufactured from powder metal alloys, or sintered steels, and for many racing classes they are kept that way and only reamed and/or honed for the proper valve clearance and I.D. surface roughness, there are many other alloys for different applications, like in the race purpose-built heads, higher rpm engines and mainly higher specific power outputs (HP per cubic inch of engine displacement).

As we mentioned earlier for the valve seat alloys, the O.E. sintered guides come in a wide range of steel alloys and mechanical properties, so we'll concentrate on the special guides offered for Racing purposes.

The old and well-known cast iron guides are not adequate for high rpm's, mainly due to the low heat thermal conductivity, so they should be replaced with the so called “bronze guides” in different alloys that have higher thermal conductivity and lower friction with the valve stems, especially with aluminum heads. In the case of using Titanium valves the bronze alloys are strongly recommended, mainly for high output engines.

In fact, the best guide materials regarding thermal conductivity are not really “bronze”, but “brass” alloys. The bronze alloys are a solid solution of tin in copper, and brass is a solid solution of zinc in copper, plus other chemical elements in the case of valve guides.

For many years, the bronze alloy to use in racing guide applications was the phosphorus bronze, a copper-tin alloy with approx. 0.25-0.5% phosphorus. It has good friction properties,

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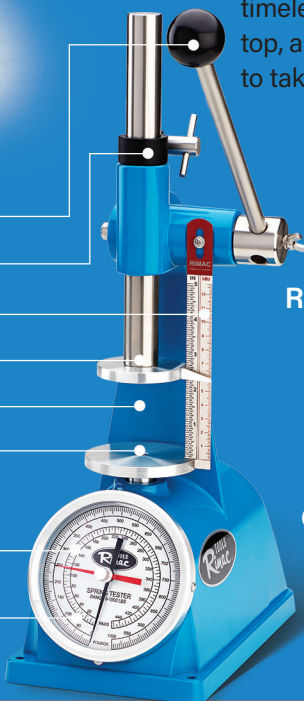
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and strength as the addition of phosphorous increases the wear resistance and stiffness of the copper-tin alloys. But not so good durability at high temperatures because the thermal conductivity is not so high. There is still an ongoing discussion in many race forums about which is the best guide alloy to use, and we must say that finally depends on the engine application, but from the point of view of best balance in thermal conductivity, hardness, tensile strength and low friction characteristics against valve stems, the Manganese Bronze gets the most followers nowadays.

The alloy that has the best compromise between thermal conductivity and hardness of all copper based alloys for mechanical usage is in fact the beryllium copper that we mentioned before for the valve seats; but due to its very high price it is only justified for guides when extremely high temperatures and rpm are present; if not the manganese bronze alloys are the best we can use. This is harder than a regular brass, with approximately 2-3% manganese, and almost no nickel and low aluminum content. The addition of these two elements in small percentages increases the hardness and strength of the alloy but at the same time decreases the thermal conductivity, so the final choice depends on the engine application, fuels being used and expected durability.

These other alloys are known as nickel aluminum bronzes, or aluminum bronzes and their thermal conductivity is substantially less than in the manganese bronze alloys, so for the big majority of naturally aspirated gasoline engines and high rpm, or even turbo boosted or supercharged – manganese bronze is a great choice. Always ask your guide supplier about the recommendation for your specific application and fuels usage.



Figure 10: Typical Manganese Bronze Racing Valve Guides

A question that usually arises in tech meetings and presentations is how much interference fit a bronze guide should be installed with. We will provide approximate values, but as the range of cylinder heads and race engine applications is so huge, please take them as a reference only and always talk with your guide supplier for your specific usage.

- **Cast Iron Heads with Bronze/Brass Alloys:** .0006" to .0010" (0.015 to 0.025 mm) interference, depending on the guide O.D.
- **Aluminum Heads with Bronze/Brass Alloys:** .0010" to .0020" (0.025 to 0.050 mm) interference, depending on guide O.D.

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# VALVES, GUIDES AND SEATS FOR RACING

BY FERNANDO CURELLO

(The reason to increase the interference fit with aluminum heads is due to the much higher expansion rate with running temperatures on aluminum heads vs. cast iron heads. In addition, the shrinkage effect which happens compressing the guide with interference, is more noticeable with cast iron than with Aluminum).

After installation of a new guide, and reaming plus honing, as we mentioned before we must measure the I.D. to check not only the inside diameter but also the taper and roundness, as the only way to assure the correct clearance with valve stem all along and around the guide. Each guide needs to be measured at three heights (top, middle and bottom), and at 90 degrees to verify all these values. In Figures 11 and 12, we see typical guide bore gauges with a split ball device to measure the guide I.D.

So, our recommendation is that the installed and finished guide I.D. tolerance and taper would not exceed .0005" (0.013 mm).

And finally, we're getting to the result of all this valve and guide work, which is the valve stem to guide clearance as cold, or as said in engineering specifications, at "room temperature" (R.T.). I'd like to say that this way, because the running temperatures and consequent expansion of the stem and also the cylinder head and guide, will end in totally different "hot clearances", reducing the oil film to really small values, but still crucial to keep the stem lubricated and reducing the metal to metal contact, that anyway sometimes will happen (and



Figure 11: Valve guide I.D. bore gauge with split ball system. Photo courtesy Goodson.



Figure 12: Sunnen dial bore gauge. Photo courtesy Goodson and Sunnen.



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# VALVES, GUIDES AND SEATS FOR RACING

BY FERNANDO CURELLO

Approximate Valve Clearance Values for water-cooled, naturally aspirated gas racing engines working with steel valves and ductile iron, high chromium steels or bronze alloys seats, and bronze alloys guides.

VALVE STEM SIZE	INTAKE VALVE	EXHAUST VALVE
.200" to .275" (5.0 to 7.0 mm)	.0010" to .0014" (0.025-0.035 mm)	.0015" to .0020" (0.038-0.050 mm)
.312" to .371" (7.92 to 9.42 mm)	.0015"-.0020" (0.038-0.050 mm)	.0025"-.0030" (0.063-0.076 mm)

that's because the normal wear in stems and guides), but if reduced for bad initial clearances or engine overheating will show scuff, galling and the problems mentioned before.

Again, the huge range of valve and guide materials, head materials, specific power outputs, rpm, fuels, etc. make it almost impossible to predict the best valve clearance for each application. I like to give a reference to work with, but always check with the rebuilders' experience and manufacturers recommendation for each case.

In addition, the O.E. specs for many popular engines (more than 12,000 today) are easily found in AERA's Prosis Pro, so members who subscribe can easily check

the specs in Prosis Pro or members can call or email the AERA tech team.

So, the approximate values for water-cooled, naturally aspirated gas racing engines working with steel valves and ductile iron, high chromium steels or bronze alloys seats, and bronze alloys guides, and depending on each application are shown in the chart above.

In conclusion, as we said at the beginning, the valve guide in a high-performance/racing engine is many times overlooked, and its importance for the result of a properly machined seat and correct valve working is outstanding. It is never a waste of time to manage it carefully, check as many times you need, take notes and verify these values at disassembly...

Good luck never comes without hard work, and that's especially true for our beloved racing engines! ■



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## ENGINE REBUILDING EQUIPMENT

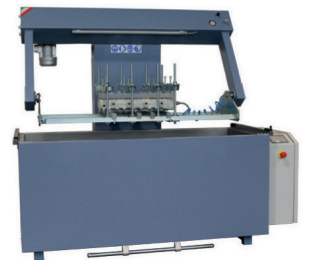
### BGV260

Guide and valve workstation



### RV516

Valve refacer



### VPT190

Pressure tester



### RP1400.CNC

Resurfacing machine



### ACF200.CNC

Block boring/mill