

VARIABLE VALVE TRAINS



THE EVOLVING
ENGINE



Pierburg GmbH
Alfred-Pierburg-Straße 1
41460 Neuss
Germany

www.kspg.com

“WE’RE WORKING ON TOMORROW’S AUTOMOBILE ENGINE.”

**Dr. Dirk Hunkel, Director Business Unit
Variable Valve Train Systems, Pierburg GmbH**

Gasoline or diesel? For years, these arch-rivals have charged ahead along their independent respective development paths, each chiding the other with its own technical advances. Each system has its strengths, but also its weaknesses. The stoichiometric gasoline engine features a highly efficient and cost effective after-treatment system thanks to its three-way catalytic converter. But the fuel consumption has to be improved. Diesel engines, on the other hand, have already reached a very high efficiency. However, controlling their emissions is more challenging and mostly comes at the cost of reduced efficiency. The strategy here involves limiting the production of pollutants

inside the combustion chamber while keeping the impact on the fuel consumption to a minimum. The fact that variability in the air handling system provides advantages for both engines is undisputed. But variable valve trains offer even more potential. Keywords are displacement on demand, scavenging and engine braking.

We’d like to show you what variable valve train systems can do. And we’d like to assist you with your decision, design concept and right on through to SOP. We offer two different variable valve train systems, which we explain in the following.

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DOUBLY COMPLEMENTARY



UNIVALVE: MAKING YOUR ENGINE FITTER FOR THE FUTURE.

Until now, the gas exchange of gasoline engines has always been associated with pumping losses. The reason is that the throttle body has to be closed for part load operation.

UniValve fulfils engine designers' longstanding goal of achieving adjustment of cylinder filling to meet changing operating conditions by means of variable valve timing.

UniValve has a compact, straightforward design. The uncompromising use of roller contacts throughout the system offers a high speed capability with low mechanical losses. Reduced parasitic

losses and pumping work lead to favorable fuel consumption.

An electrical actuator provides precise and quick valve control from full valve lift down to zero valve lift. UniValve delivers outstanding fuel economy, dynamics and power.

UniValve provides the following advantages for gasoline engines:

- high speed capability
- favourable frictional behaviour
- good response
- inherent cylinder deactivation
- up to 12 % improvement in fuel economy



FLEXVALVE: THE VALVE TRAIN UPGRADE FOR DIESEL AND HEAVY-DUTY ENGINES.



FlexValve is a compact, robust and efficient mechanical valve train system. It permits continuous variability of valve lift over a broad range, even allowing secondary opening of the valves, if desired. This gives a lot of flexibility to influence the gas exchange process and engine out exhaust gas temperature.

In addition, FlexValve is modular, offering various modules to change the function of the valve train system without having to change the cylinder head design and manufacture. This makes FlexValve an ideal solution for diesel engines,

including those for commercial vehicles, which are sold in markets with differing emission standards.

FlexValve offers the following advantages for diesel engines:

- faster warm up and improved after-treatment efficiency
- improved transient EGR control and/or faster T/C response thanks to secondary valve opening
- variable effective compression ratio
- adjustment of load and temperature for optimized combustion control
- Compression release engine braking

UNIVALVE: PRECISION FOR HIGH RPM

Design and Function

UniValve features two mechanical cam mechanisms in series. The UniValve rocker assembly is the heart of the system. The camshaft keeps it moving in an oscillating motion and the assembly subsequently transfers its movement to the roller finger follower. Position and orientation of the UniValve rocker are changed to give the desired family of continuously variable valve lifts.

UniValve can also completely deactivate individual valves, fully shutting down their respective cylinders. Now, that's downsizing on demand.

Strong on every side

Even greater potential is available with the use of UniValve on both the intake and exhaust sides, particularly with turbo engines.



How UniValve works

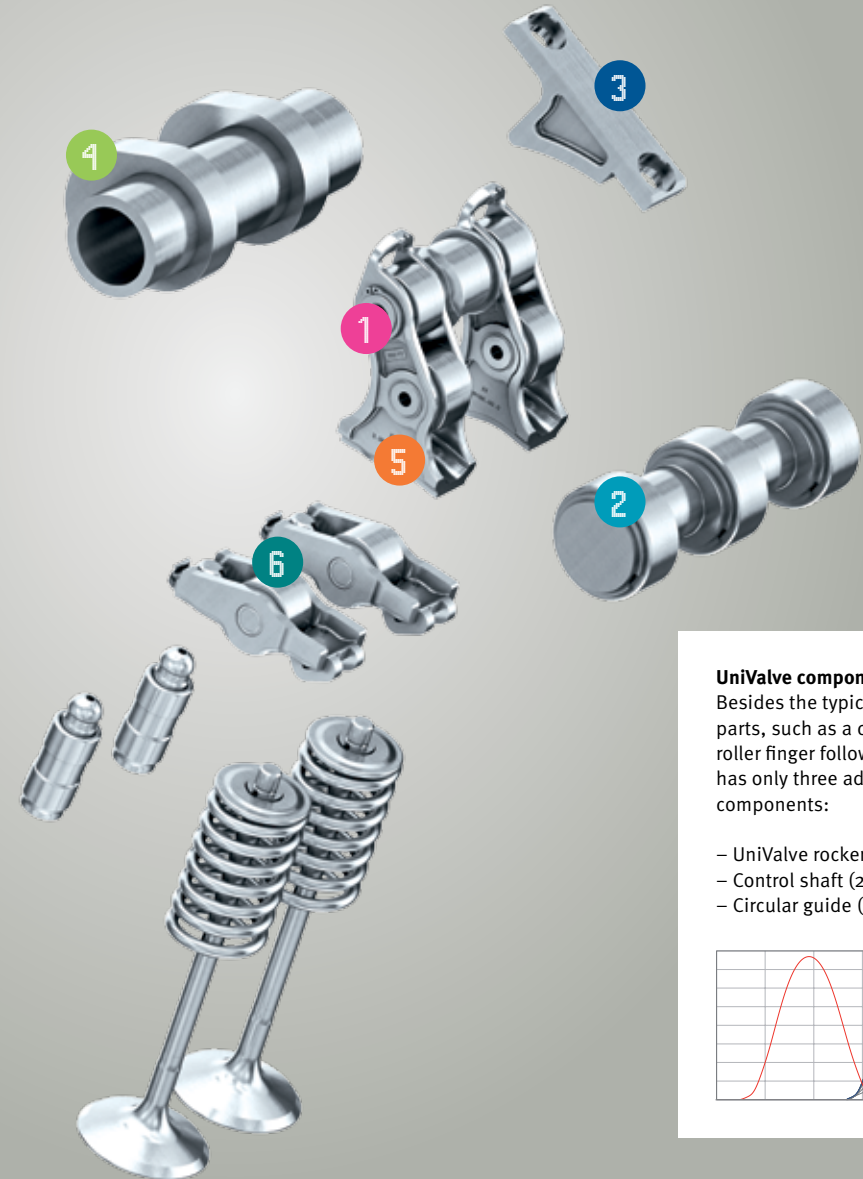
The UniValve rocker (1), which rests on the control shaft (2), is guided by the circular guide (3), and is set in an oscillating motion by the camshaft (4).

The UniValve rocker has a profile (5), which is in contact to the roller finger follower (6). The profile includes a base circle and a lifting curve which together form a "swinging cam."

The control shaft (2) is shaped in a way, that its rotation controls the movement of the UniValve rocker. This varies the relative lengths of the base circle and the lifting curve used.

An electrical actuator steplessly turns the control shaft, rapidly and precisely to provide continuously variable position-control of the shaft and hence the valve lift.

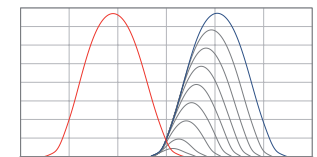
All contact points are fitted with roller bearings to minimise friction.



UniValve components

Besides the typical valve train parts, such as a camshaft (4) and a roller finger follower (6), UniValve has only three additional components:

- UniValve rocker (1)
- Control shaft (2)
- Circular guide (3)



Contact:

Dr. Michael Breuer
michael.breuer@de.kspg.com

FLEXVALVE: BOTH ROBUST AND VERSATILE

Design and Function

FlexValve is based on DuoCam, a twin cam camshaft as the name indicates. An actuator, similar to a cam phaser, changes the angular relationship of the shaft and tube and hence their associated cam lobes, which are in contact with the FlexValve rocker. The FlexValve rocker “adds together” the two cam profiles. Thus, altering the angle between shaft and tube allows the valve lift to be varied.

The FlexValve system comprises a single lobe (1), pinned to the inner shaft (2) of the DuoCam shaft. The two outer cam lobes (4) are fixed to the tube (3). The phasing between the lobes (1) and (4) may be varied via an actuator, (not shown for clarity).

The rollers of the FlexValve rocker (5) follow both cam profiles. This rocker pivots on a shaft (6), which connects it to both finger followers. The return spring (7) keeps all the parts in contact when the valves are closed.



Depending on the shapes and relative angular positions of both cam groups, the FlexValve rocker either rotates about the pivot shaft (6) or generates a valve movement. Different cam contours are possible and through their design can produce multiple valve openings. The figures show two of the potential lift curve families.

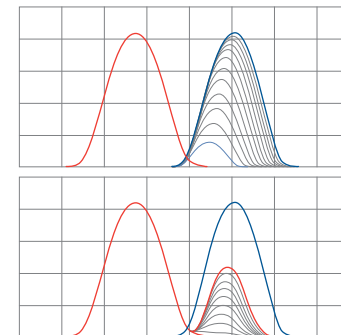
FlexValve is modular. This allows the engine to be built to different specifications without cylinder head design changes. This provides the freedom to implement conventional valve timing, a DuoCam version with variable valve timing of two groups of cam lobes, or the full FlexValve system.



FlexValve components

FlexValve employs a DuoCam to replace the conventional camshaft and two other parts in addition to the conventional valve train system components:

- FlexValve upper rocker assembly (5)
- Return spring (7)



Contact:

Dr. Tim Lancefield
tim.lancefield@uk.kspg.com

715/2007/EC

This European Parliament regulation calls for the reduction of the average fleet consumption and the cutting of carbon emissions produced by European automobile manufacturers to 95 g/km by 2020.

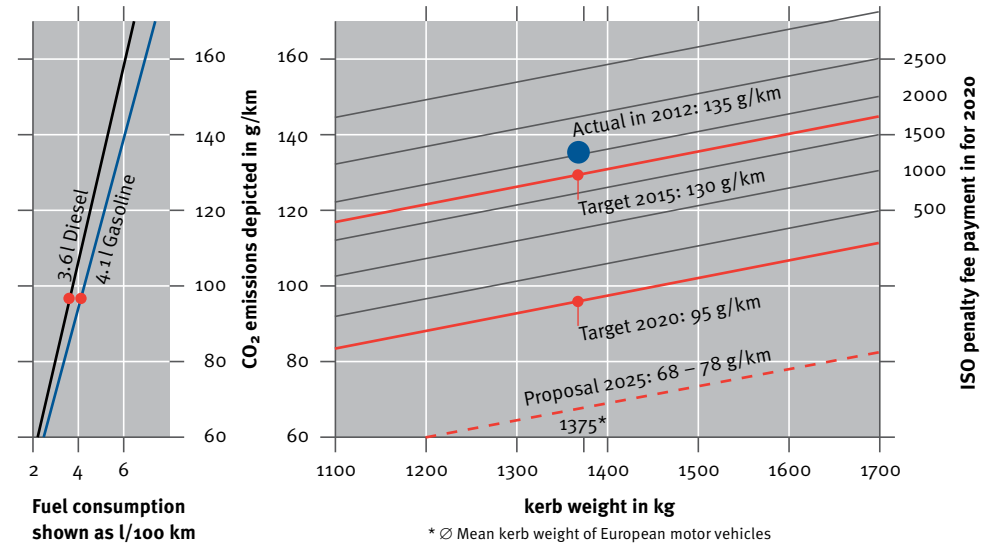
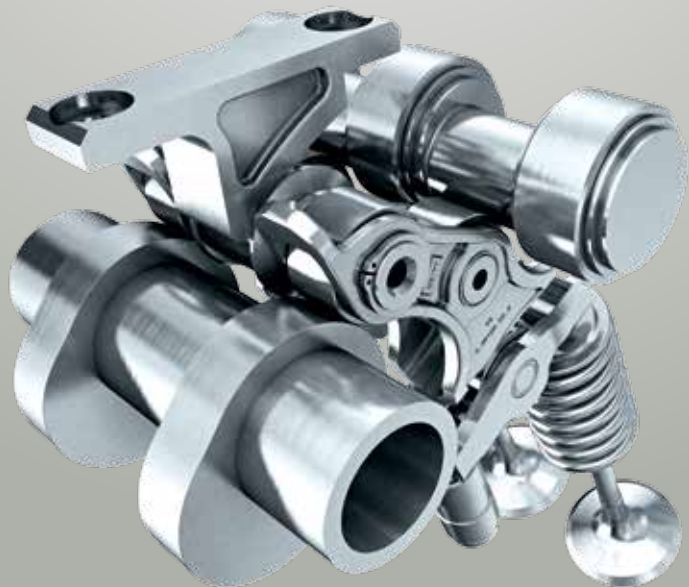
This chart shows the targeted values for 2015 and 2020, as well as values that are in discussion for 2025. You'll also find

the penalty fees that will apply as of 2020 and the European fleet average for 2012.

Our own surveys indicate up to 12 % fuel reduction in the mapping area with the same or even improved full load and emissions performance

12%

Up to 12 % fuel consumption reduction



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EU TARGETS FOR 2020



95 g/km



4.1 l/100 km average fleet consumption



3.6 l/100 km average fleet consumption



THE EVOLUTION OF YOUR ENGINE

We work with you to produce a bespoke design for the future.

A component can perform to its full potential only if it integrates perfectly into its technical environment, which is why we wouldn't sell you an off-the-shelf valve train system.

No, we design your valve train system to meet your specific requirements. That's only possible if we work closely with you. In the following, you'll learn what we mean.



INITIAL DISCUSSION

In this phase we ask many questions, because we desire to know exactly how you envisage your variable valve train system. And of course, we're interested in learning about what you expect from your work with us. Together, we lay the groundwork for the engineering of your system, defining the technical objectives, cost and timing.

COOPERATIVE ENGINEERING

During the design phase, our engineers work closely with your engineers. Thanks to this cooperation it is possible to provide you with a tailor-made solution for your engine. We meet regularly with your engineers to discuss projects and their status, including comparing current mechanical designs and variants. And, together with you, we check to make sure our work is in line with your expectations.

PROTOTYPE BUILDING

As soon as all your product specifications are clear, your expectations understood and the first variable valve train models have been designed for your engine, we begin with the building of a prototype. This way, you can become familiar with how our system functions and what you can expect from our system during your engine's service life. Together, we then determine which enhancements or changes are necessary to the valve train.

MANUFACTURING

Not until all parties are convinced that the variable valve train meets all of your requirements, do we begin regular manufacturing operations, on our premises. Here is where we manufacture, assemble, test and inspect your variable valve train system. You profit from our decades of experience in the manufacture of mechatronic components. Following a final quality inspection, we ship our fully variable valve train product directly to your production line. There, too, our engineers are onsite to assist you with getting the final details straightened out and getting your operations up and running as you expect.

“VARIABLE VALVE TRAIN SYSTEMS ARE NOT SOMETHING YOU GET OFF THE SHELF.”



Heinrich Dismon speaks about variable valve train systems and the future of motor vehicle engineering.



KSPG Automotive CTO



Mr. Dismon, how long have you been working on variable valve train systems?

In 2007, I was the senior director of advanced engineering at Pierburg. Back then, we carefully considered which products we would have in our portfolio today, which are suitable for the future and which new products would be a good fit for Pierburg. The variable valve train system was one of these.

And you believe that variable valve train systems are a technology for the future?

Absolutely. We're taught at university that variable valve train technology is a very effective means of reducing fuel consumption in gasoline engines.

Then, the technology isn't completely new?

No. There exists an often-quoted patent from Louis Renault from 1908, when he received patent rights for his variable valve train technology. Over a hundred years ago, people had good ideas! They just didn't pursue them to their realisation. Today, it's very current, because we have everything we need

to put the technology to work for us – improved materials, improved manufacturing processes and particularly advanced control technology.

Are there other technologies besides mechanical systems?

Yes there are various hydraulic and electrical systems. We have considered all of them extensively. After our review of technical options we chose mechanical systems with advanced electronic controls.

Why did you decide on mechanical systems with electronic controls?

An enormous advantage is the operational robustness: even in adverse conditions, such as cold starts or low battery voltage. Mechanical systems are also more durable. And their similarity to the conventional valve train systems helps keep the costs within reason, because we can use familiar, established vendors and processes, while requiring only slight modifications to the engine layout. That is a major advantage.

Eventually, you decided to go with two systems: UniValve and FlexValve. Why?

We began with UniValve – our preferred system for all gasoline engines. But it soon became clear to us that there was also demand for an alternative system. So we decided to invest in FlexValve. For the past year, we've worked simultaneously on both systems. Since both systems have specific functional differences, there is no danger of them competing directly against each other.

You have different products for different target groups?

We do. FlexValve is more for diesel engines whereas UniValve is clearly designed for gasoline passenger vehicles. The reasons for using variable valve train technology in diesel and gasoline engines are distinctly different. Its application in gasoline engines is desirable as a means of cutting fuel consumption in order to comply with the carbon emission limits for fleets. And for diesel engines, it helps meet toxic emissions legislation requirements, without negatively affecting fuel economy. Exhaust gas temperature management is the buzz-word. That's FlexValve's objective. In addition, FlexValve is very modular, providing the choice between either non-variability or maximum variability. The variability expands in three different steps and doesn't require significant modification to the engines.

With both systems, you work closely with your customers. Why?

Variable valve train systems are not the kind of components you pull off the shelf and say, "install it." Rather it is necessary to adapt or design them for their specific application.

How long does the joint engineering of a new product typically require?

Well, we're operating in OEM territory here. We have to be very integrated in our work with the OEMs. Usually, it takes several years before regular production can begin.

Integrated means your engineers work on-location with the customer's engineering department?

Yes, frequently. Our engineers are often on site. Why? Because variable valve train systems aren't like other KSPG parts. You can't just bolt them somewhere onto the engine. Moreover, the cylinder head is a highly sensitive area. For this reason, we have to work very closely with the OEMs.

Is working so closely with customers something new for Pierburg?

By no means. Although, we can say that this is the first time we're working "in" and not just "on" engines. That is certainly special for Pierburg.

In the past, it was significantly harder to justify investing in fuel economy, however, with the new EU regulations things have changed. Have things gotten easier for you?

No, not really. The market is still highly competitive.

Competitive in terms of price?

Chiefly. Nobody does anything anymore just for the love of technology. Every effort has to be justified by a benefit. The rules of the game have changed significantly. European legislators have set a limit and determined that those who don't remain under the limit will be hit with penalty fees. The fees are naturally drastically higher than the cost of technological development, assuming you can keep pace. The current European fleet limit of 95 grams is already a challenge. And the 68 to 75 they're currently discussing for 2025 is even more ambitious.

Are such standards realistic?

You should never say "never" in technology.

Currently, America is discovering natural gas as a fuel for motor vehicles and in Europe people are increasingly showing interest in alternative fuels. How certain is variable valve train technology's future?

Oh, I'm very upbeat. I believe the internal combustion engine will be with us for quite a while. By the way, natural gas engines benefit from variable valve train technology, too. Although electro and hybrid vehicles may gain momentum, they surely won't find use everywhere.

What is the future's ideal variable valve train system like?

The ideal variable valve train system of the future will be versatile and adaptable. That means it has to be a freely configurable system that accommodates every imaginable timing scenario. And then it will have to be controllable cylinder- or even cycle- wise. Our current systems represent a step in the right direction. And we have further ideas in development, too.



FOR CLARITY: WHAT KSPG DOES.

In a nutshell, KSPG designs and manufactures engine parts and provides all the associated services. But there's more. We are amongst the world's 100 largest Tier 1 suppliers to the automotive industry. And we play a key role in shaping the engine's future.

over 12,000 people across the globe. KSPG's Hardparts, Mechatronics and Motorservice divisions together produce a total turnover of 2.4 billion euro.

The KSPG Group belongs to the Rheinmetall Group and employs



Divisions	Hardparts	Mechatronics	Motorservice
Core brands	KOLBENSCHMIDT	PIERBURG	MOTORSERVICE
Business segments	KOLBENSCHMIDT ALUMINIUM TECHNOLOGIE GLEITLAGER	PIERBURG PIERBURG PUMP TECHNOLOGY	MOTORSERVICE

Hardparts: Whether engine block, plain bearing, large or small bore pistons, this KSPG division designs, manufactures and sells custom solutions for internal combustion engines used by passenger cars, commercial vehicles, ships and stationary machinery.

When it comes to details, we're your specialists, because we never lose sight of the whole picture. Our project teams usually comprise of specialists from every division, which is the only way to produce components and technologies to produce clean and efficient power for our transportation in the future.

Mechatronics: As an engineering partner to the automobile industry, the Pierburg unit designs the technologies and products that enable tomorrow's engines. EGR systems, valves, actuators and pumps are Pierburg's forte.

Motorservice: This division is KSPG's sales organisation and handles all the global after-market activities, while providing wholesalers, engine service businesses and service garages with parts.

