

The customer magazine of BorgWarner Turbo Systems

## Insignia of power

New bi-turbo diesel is the driving force behind the Opel Insignia



BorgWarner introduces world's first cold test bed for turbochargers

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## Dear readers,

Sometimes you have to put yourself on the test bench – and ask yourself just how up-to-date and competitive your own targets, skills, structures and processes really are.

This is a key part of day-to-day business at BorgWarner Turbo Systems, just like defining and then implementing necessary changes. This edition of TurboNews provides some examples of this. In an interview with Tim Richardson, you can learn more about the Global Manufacturing Strategy, with which Turbo Systems is keen to standardize and optimize its processes worldwide for the benefit of its customers. In the article on the cold test bed for turbochargers, we also present a concept for even better quality control that is unparalleled worldwide. And in our report on China, you can discover how BorgWarner is catering to the growing requirements of the automotive industry in China with its new high-tech facilities.

We have also put our customer magazine, TurboNews, on the test bench and made some important changes. With a view to making tried and tested concepts even more effective, in future we will be presenting compact news, interesting articles on engine development projects and granting readers deeper insights into the global activities of BorgWarner Turbo Systems. We believe that we are already on the right path with this edition of TurboNews – and hope you all have fun reading.



Günter Krämer  
Marketing Director  
BorgWarner  
Turbo Systems

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## Comment



Ulli Fröhn, Vice President Sales & Marketing at BorgWarner Turbo Systems.

# The market for turbochargers is changing



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With ever stricter demands being placed on vehicle engines around the globe in terms of emissions and fuel consumption, exhaust gas turbo-

charging is playing an increasingly important role in engine design.

This is nothing new in itself. However, if the internal combustion engine is to remain the number one drive of choice for individual mobility beyond the year 2030, not only must technological challenges be overcome, but also many other tasks such as securing sustainable competitiveness or making adjustments to cater to altered framework conditions in the emerging nations.

Turbocharger manufacturers have, for example, already had to significantly expand their development and production capacities – and not just in their traditional markets. This has led to a large number of new facilities being set up throughout the world over the last 10 years. BorgWarner alone has opened new sites in Hungary, Poland, Korea, China and Mexico to cater to growing OEM requirements. And the need to boost production capacities is far from over, even with these efforts. The expansion of production networks requires new approaches in managing global supply chains, suppliers or production rollouts, to mention just a few of the challenges that must be overcome.

However, this is just one facet of the dynamically changing turbocharger market. New players, new markets, new technological requirements... as a leading supplier of turbocharging systems for passenger and commercial vehicle applications, BorgWarner must also overcome growing challenges in the most diverse of sectors. This is particularly true from a technological perspective, as turbocharging ultimately represents a key technology in the internal combustion engine.

Our turbocharging systems have to be tailored ever more precisely to the specific targets of individual customers and the

framework conditions in which they operate – such as driving cycles. Only with more precisely tailored thermodynamic

solutions can vehicle manufacturers comply with the strict rules and requirements of legislators and the high expectations of consumers buying the vehicles. In addition to this, the number of technical concepts employed is constantly growing. As such, diesel and gasoline engines are no longer the only kinds of drives being boosted. The motor-vehicle industry is, for example, also working on natural gas engines and turbocharged ethanol engines, alongside its efforts to find turbocharger solutions for fuel cells. Added to these are technologies such as titanium aluminide turbine wheels or ball bearings which can further improve turbocharger characteristics – but which

must first be made suitable for use in mass production.

We should also not forget the many different types of multi-stage boosting, such as the use of three turbochargers in BMW's new top diesel engine or electrical turbocharging technology. As the technological leader, we see it as our duty to offer our customers the best solutions in these fields and to compete on a daily basis. We have therefore invested and continue to invest significant funds to establish and expand our research and development capacities across the globe. Our objective is to offer our customers the best available turbocharging technology at all locations, in turn allowing them to achieve their objectives, while providing them with a powerful global production network that they can rely on and which guarantees both maximum efficiency and the best possible quality.

**“Turbocharger manufacturers are having to fulfill ever stricter requirements.”**

**“We are keen to use innovative solutions to prove ourselves as the technological leader.”**

## Brazil remains automotive Mecca

Despite having suffered a slight dip in the first quarter of 2012, the Brazilian automobile market remains in the fast lane. In 2011 alone, a total of 3.6 million vehicles were sold in Brazil. So it comes as little surprise that so many exhibitors and visitors were keen to attend the Automec fair, which was held in São Paulo in April 2012. BorgWarner also took the opportunity to renew contacts with customers and present its spare parts, accessories and services in and around the fields of passenger and commercial vehicles at the southern hemisphere's most important automotive supply trade fair.



Particular highlights on the BorgWarner stand included the Scania Formula Truck of the successful racing driver Roberval Andrade and the new EFR range of turbochargers. EFR stands for "Engineered for Racing" and designates BorgWarner turbochargers that have been specifically tailored to the requirements of motor racing. In terms of turbochargers for passenger vehicles, the primary focus was on the downsizing trend – i.e. reducing engine size while simultaneously increasing power density, which allows improved fuel consumption figures to be achieved with no loss of performance. BorgWarner also presented its latest components for cooling, as well as timing chains, dual clutches, variable valve controls and recirculation valves. With an attractive stand concept and numerous product innovations, BorgWarner's stand at the trade fair once again attracted numerous existing and potential customers, as well as press representatives this year.

## T for two



A better understanding of what customers will need tomorrow: It was with this goal that high-ranking representatives from BorgWarner took part in two workshops at important automotive customers between February 28 and March 1, presenting the latest solutions in and around the field of exhaust gas turbocharging.

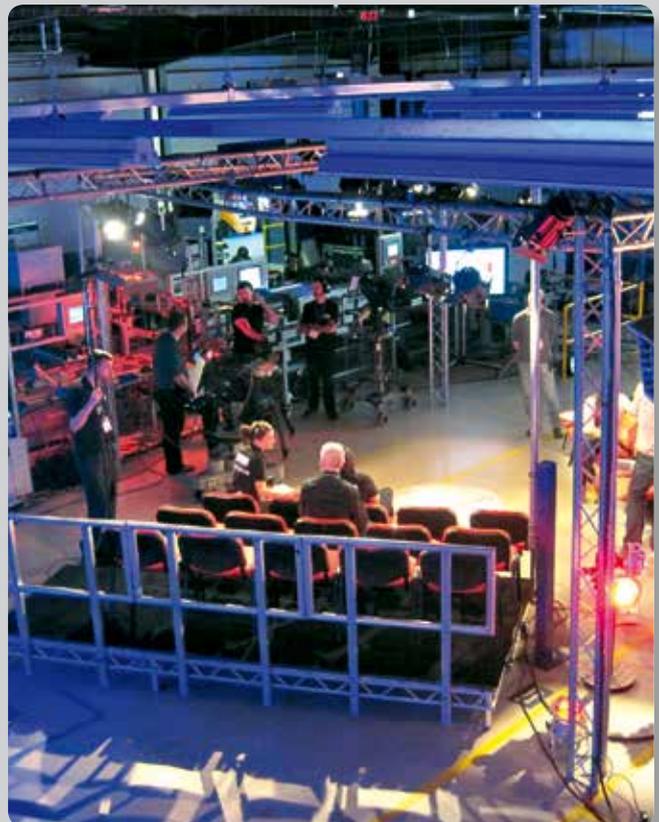
The first workshop was held at MWM International Motores, the second at Mercedes-Benz do Brasil. Both workshops were supported by BorgWarner's Brazilian OEM team, and turbocharger experts from the US, England and Germany were also in attendance. They took the opportunity offered by the event to chat with MWM and Mercedes-Benz about their future requirements, to reinforce existing partnerships and to lay optimum foundations for new development projects.

## BBC visits Bradford

What is the current economic situation like in Great Britain? The BBC is addressing this issue in its "Our Economy" TV series, which each week visits one of the twelve most important economic regions in the country. On March 17 and 18, the BBC team visited BorgWarner Turbo Systems in Bradford to record the show for the Yorkshire region.

When producing the series, the bosses at the BBC look for high-tech companies in the various economic regions. However, the BorgWarner facility in Bradford was also chosen as the host venue because it is one of the largest employers in the region and also a vocational training center.

To record the 40 minute show, which included two MPs as guests, a works hall was converted into a complete television studio with audience seating for two full days. Staff at the facility displayed great commitment in supporting the BBC team when recording the TV debate. The show was broadcast on March 19 together with a brief presentation of BorgWarner as a modern high-tech facility in Bradford.



BBC Look North The Live Debate

## Hyundai invests in R2S

The regulated two-stage turbocharging system from BorgWarner Turbo Systems has long since proven itself in modern commercial vehicle engines in the North American and European market. This R2S technology is now also gaining ground in the Asian commercial vehicle market.

BorgWarner supplies the R2S system for the 5.9 liter (360 cubic inch) inline six-cylinder diesel engine produced by the Hyundai Motor Company (HMC). This diesel unit is thereby the first commercial vehicle engine in Asia to employ two-stage turbocharging. The 260 hp (194 kW) Euro 5 diesel unit is used in medium-weight trucks and city buses in South Korea, including the Hyundai models Aero Town, Green City and Mega Truck. It excels thanks to its low exhaust emissions and fuel consumption figures.

The R2S system from BorgWarner is made up of two turbochargers arranged in series – one B1 high-pressure unit and one B2 low-pressure unit – and employs a compact, brushless servomotor to control the turbine control flap. To protect the units from high thermal loads, the high-pressure impeller is made from milled aluminum. The innovative turbocharging system is designed for high power output and supplies high, constant boost pressure throughout the entire rev band. This helps the Hyundai diesel achieve impressive performance with a maximum torque figure of 981 Nm (723 lb-ft), which is already available to the driver from just 1,400 rpm.



## Renault Supplier Award for Turbo Energy LTD



Securing the highest quality is a key corporate objective for Renault. In this vein, the French auto manufacturer has been presenting its best suppliers with the Renault Quality Awards for seven years. This year saw the addition of awards in the categories of Innovation and Corporate Social Responsibility (CSR) for the first time.

One of the much-coveted awards, which were presented by high-ranking representatives from Renault on June 20, went to Turbo Energy LTD in India. The leading Indian turbocharger specialist, which is a joint venture

of Brakes India Limited, Sundaram Finance Ltd. and BorgWarner Turbo Systems, received a Renault CSR Award for its special commitment in the field of environmental protection. During his speech at the award ceremony, Carlos Tavares, CEO of Renault, stressed the importance of excellent cooperation between Renault and its supply partners, stating: "There is a close relationship of dependency and trust between auto manufacturers and their suppliers, with both sides pursuing the common objective of working together to achieve greater performance."



# Advanced ecology

Mercedes-Benz claims a pioneering role in the development of environmentally friendly drives. The latest example of the vehicle manufacturer's technological ascendancy is the new OM 93x range of Euro 6 engines. BorgWarner provides state-of-the-art turbocharging technology for these high-tech engines.

Having already presented the world's first Euro 6 engine for heavy-duty commercial vehicles in 2011 (see TurboNews 2/2011), Mercedes-Benz presented its new BlueEfficiency Power drives for medium-sized commercial vehicles on March 13, 2012. The modernized range of engines carries the designation OM 93x and rounds off the manufacturer's new commercial vehicle engine portfolio – the first to already comply with the future Euro 6 standard.

#### Powerful, economical, clean

The new engines are offered in various versions, starting with the four-cylinder turbodiesel OM 934 with a displacement of 311 cubic inches (5.1 liters) and

culminating in the six-cylinder turbodiesel OM 936 with a displacement of 469 cubic inches (7.7 liters). The power on offer ranges from 154 hp (115 kW), all the way up to an impressive 349 hp (260 kW). All models offer improved output and particularly low fuel consumption, as well as setting new benchmarks with regard to emissions.

To equip the new units for the strict criteria of Euro 6, the engine developers employed a whole host of technological refinements.

One of the highlights is the adjustable camshaft – something which has never been used before in a diesel engine. The turbocharging technology for

*The new Citaro is among the first commercial vehicles that Mercedes-Benz is offering with environmentally friendly BlueEfficiency Power engines.*

all engine versions comes from BorgWarner Turbo Systems and itself also displays several special characteristics. For example, the latest generation of B-turbochargers is used, employing electrical waste gate adjustment and titanium impellers. In addition to this, parts of the exhaust manifold are integrated into the turbine casings on all models. The top models in the new OM 93x range are also equipped with a two-stage, regulated turbocharging system (R2S) from BorgWarner. An electrical actuator developed by BorgWarner is used for controlling the turbine control flap here. In the R2S system, a compact high-pressure turbocharger is combined with a larger low-pressure turbocharging system, which guarantees dynamic power delivery across the entire rev band starting from extremely low engine speeds, while at the same time offering low fuel consumption and emission values. The fans and fan drives in the new generation of engines are also provided by BorgWarner.

The new OM 93x engine range replaces the previous OM 900 range, which has sold almost one million units to date. The new engines are primarily used in trucks and buses which travel in urban environments. They will therefore contribute to reducing exhaust gas and particle emissions in these densely populated areas, where discussions regarding possible ways of reducing particulate pollution in the air have been running for years. Mercedes-Benz is also planning to introduce the new engines on other continents in a step-by-step approach with other brands and models.

#### **Strict manufacturing requirements**

The importance of the new BlueEfficiency Power range of engines for Mercedes-Benz is underlined by the new, ultra-modern manufacturing

facility at the Mercedes-Benz plant in Mannheim (Germany). The vehicle manufacturer has invested €500 million in a new "synchronous factory" here. With this massive investment, the foundry, machining and assembly areas within production have now been designed as a complete system with continuous production flow. An intelligent production system, top level machinery and a large number of quality checks guarantee both high productivity and quality. For example: The foundry in Mannheim ranks as one of the most modern facilities of its kind in the world with the highest productivity and lowest reject rate.

The requirements that Mercedes-Benz expects its suppliers to meet are equally strict. BorgWarner Turbo Systems therefore not only had to convince this discerning customer of its prowess as a qualified development partner, offering the latest turbocharging technologies. Criteria such as flexibility, delivery reliability and quality also played a key part in the company's decision to go with BorgWarner. Here, the turbocharger specialist certainly benefited from the fact that it has enjoyed excellent cooperation and partnership with Mercedes-Benz for many years – a partnership that has already led to development of many pioneering engines.



Reduced emissions



Better fuel economy



Great performance



*The top model in the OM93x range is equipped with a two-stage, regulated R2S BorgWarner turbocharging system.*



*The new OM 93x series of engines is primarily intended for use in trucks and buses which travel in urban environments.*

## Interview with Tim Richardson, Vice President Global Manufacturing Strategy

# “Our goal is to become the global benchmark.”

BorgWarner Turbo Systems has enjoyed rapid development in the course of the last 13 years. Following the acquisition of Kühnle Kopp & Kausch and Schwitzer by BorgWarner, two former competitors with just a few sites were integrated to create a single global turbocharger specialist with production facilities throughout the world. In an interview, Tim Richardson talks about the efforts being made by BorgWarner to comply with the ever stricter requirements of auto manufacturers in a globalized market, how his military experience helps him master these challenges and what he likes about Germany.

And then there is another team, which is responsible for advanced manufacturing. The primary focus here is on implementation of globally standardized processes. Because our facilities are spread out across the globe, different processes and machines are sometimes used. This is something we are seeking to improve.

### **Mr. Richardson, you are Vice President Global Manufacturing Strategy. What does this position actually involve?**

This is a role which is still relatively new. Following the acquisition of Kühnle Kopp & Kausch and Schwitzer, our passenger vehicles business was initially focused on our Kibo site, with the addition of a satellite facility in Hungary. It is only in the last three to four years that we have added Hungary has grown into a stand-alone facility. In the wake of rapid growth and increasing globalization, we realized that we were not yet structured like an effective global organization. The well-established and proven facility in Kibo had to support all other facilities in setting up efficient manufacturing systems. BorgWarner Turbo Systems, however, is a global company and should therefore act as such. We therefore addressed this issue two years ago by creating the Global Manufacturing Strategy department.

### **What steps have you taken to establish Turbo Systems as a key player on the global stage?**

First of all, we set up a team to focus on our product strategy. There are three Product Line Directors, which look after our product and technology roadmap. They are responsible for making sure that we provide products in line with market requirements and our technological innovations, employing the right production and supply strategy for their manufacture. Another team is responsible for Quality Management – i.e. for program quality and the BorgWarner Quality System. This team addresses the question of how we can launch our products most effectively in the market and how we can provide our manufacturing facilities with the best possible support in this endeavor.

### **From the customer’s perspective, what are the reasons for a global production strategy?**

Our customers expect us to employ the same standards and work to the same uniform processes throughout our company. They do not expect that quality issues long since resolved at one facility occur again at a different facility.

Our productivity is just as important, as we need to offer high quality product at competitive prices. Customers regularly want to audit our consistent utilization of lean processes and Six Sigma tools at our locations. They are looking to discover if we achieve a higher output per machine than at other sites using the same machines. We must be in a position to measure our performance using a common matrix for the various facilities and to drive the improvements in a visible way for our customers.

Another issue involves us aligning our product and technology roadmap more effectively with market trends, and offering innovative technology. Our goal here is to offer the right product at the right time with the necessary supply base and manufacturing capacities available to produce our turbochargers with an optimum cost structure.

### **Are there any current projects you could describe as an example of a global production strategy?**

One important project is in the domain of High Speed Core Balancing. Using this key process, we have been able to determine that we currently achieve markedly different outputs at our various facilities, despite the fact that they are all using the same machines, the same suppliers and the same parts. We are working on localizing

A close-up portrait of a man with short brown hair and a light beard, smiling. He is wearing a dark suit jacket, a light blue dress shirt, and a red tie with white polka dots. The background is a soft, out-of-focus light blue.

the reasons for this, so that we can achieve the best possible results at all locations throughout the world. Although we have already implemented local initiatives in the past to target improvements, we have lacked a global offensive to ensure that we employ best practices at all locations and thereby reach the necessary level. This is quite simply indispensable in light of the growth anticipated over the next few years in the automotive industry, and the turbocharger segment in particular, and our objective of ensuring that our facilities maintain their market shares. Initial analyses have shown that we are capable of achieving improved quality and higher productivity while at the same time minimizing the investments required for this.

**“Many people consider my career rather unusual.”**

**Tim Richardson** spent 12 years in the British Army before joining General Electric and beginning his career in industry. In 2007, he joined BorgWarner Turbo Systems in Kirchheimbolanden (Germany) as Director Program Management and was appointed head of the facility in Oroszlány (Hungary) in 2008. Since 2010, Tim Richardson has been responsible for the global alignment of BorgWarner Turbo Systems as Vice President Global Manufacturing Strategy.

“Why should quality issues that have long since been resolved at one facility occur again at a different facility?”



#### **How successful have you been so far?**

Staying with the example of the High Speed Core Balancing Process, we determined that we require approximately two hours to switch over a machine from processing one part number to another. We have been able to demonstrate that we are able to reduce the time to 45 minutes. When visiting potential new machine suppliers, we have seen that they were able to complete the same job in just 30 minutes. We are now working to revise our processes once again and can now also complete the changeover process in just 30 minutes ourselves. This example shows that we have plenty of potential to increase our production capacity even without new investments. Our objective now is to consistently exploit this potential.

Another example is cleanliness. Turbochargers are key components within the engine oil circuit and also provide the engine with air. For our customers, it is therefore extremely important that we supply clean turbochargers, as soiling caused by metal swarf could damage other components in the engine. When investigating the various methods employed at our facilities, we determined that we are actually exceeding our current specifications and in many cases are already complying with the requirements our customers are looking for. Based on this, we decided to combine the best practices from our various locations as a way of creating global standards. We expect to be able to drive a clear advantage over our competitors in this regard.

#### **What goals are you looking to achieve with a global Turbo Systems organization?**

My goal is for us to be the benchmark in the turbocharger business by 2014 and for our customers to recognize this.

This involves perfect, zero-issue product launches within the specified timeframe, 100% on-time deliveries and zero issues within the first three months following the perspective product launch. There must also be unexpected observations during customer audits. Our employees must examine the facility through the eyes of the customer, be self-critical and understand what customers consider important.

A crucial motto for our global organization is: Local responsibility coupled with global strength. We are keen for our facilities to feel responsible for their own profit/loss and results and operate largely autonomously. With our global strength we also offer them the support they need to achieve the best possible results, leveraging our global footprint with common processes and standards.

In terms of our products, our goal is to be number one when it comes to turbocharger noise reduction, as the current trend is clearly moving towards low-noise engines.

#### **Prior to your career in industry, you spent some time with the British Army. Would you say that your military experience has helped you in your role at BorgWarner?**

Many people consider my career rather unusual. I must thank General Electric for helping me make the switch from the military to the market economy. They targeted former officers in their recruitment operations, as the military instills many values which are also important in industrial and commercial enterprises. For example, you cannot simply do what you want when you want. It is important to have common goals in moving forward. The BorgWarner values of integrity, respect and collaboration are very similar to military values. Collaboration is a particularly important topic in this regard. I learned very early on that you must

surround yourself with the best experts, provide them with the best possible information and – very importantly – listen to what they have to say.

The military also prepares you for handling crises. The economic crisis in 2008 was a dramatic situation for our facility in Hungary, which I was managing at the time. My military experience helped me assess problems from various different perspectives, set priorities and detect the most urgent issues as a way of choosing the right options.

**Was it difficult for you as an Englishman to gain a foothold in Kibo? What is it like working with German colleagues?**

I have spent most of my industrial career working outside Great Britain. I have spent a total of three years in Hungary, eight years in France and am now in Germany. So although I have a British passport and support England in sporting events, I definitely consider myself to be a European. I chose Wiesbaden as my home, as it offers me a cosmopolitan environment. I have friends from all over the world and am also a member of a triathlon club, whose other members are mainly from Germany.

In terms of professional career development, BorgWarner is a global enterprise. As such, our colleagues are very

welcoming to staff from other countries. Although there are definitely cultural differences, this has never really been an issue. Everyone is keen to do their job as well as they can and work in the interests of BorgWarner. I always do my best to balance the issues of the company, the task at hand and the staff involved as effectively as possible. This is also something I learned in the military. There are three intersecting areas of focus that must be balanced: The team, the objective and the individual. When these are well balanced, staff are satisfied, the task at hand is successfully mastered and company goals are met.

**OK, last question: Is there anything you miss from home when living in Germany?**

Actually only baked beans, fish & chips and English beer! But I have now found an English pub in Frankfurt, where I can eat fish & chips, drink English beer while watching German football. So life is good. I have also discovered new and interesting things while living here. For example, I am now a huge fan of asparagus.

**Mr. Richardson, thank you for taking the time to talk to me today.**

**“Our goal is to be the number one in terms of minimizing turbocharger noise emissions.”**



## Porsche's favorite



*From left to right: Uwe-Karsten Städter (Head of Procurement at Porsche), Wolfgang Schneider (Director at BorgWarner Turbo Systems GmbH) and Matthias Müller (CEO at Porsche).*

Everyone at BorgWarner Turbo Systems works hard to set new standards as a high performance automotive supplier. Thanks to its global production strategy, the turbocharger specialist is making excellent progress in this regard. These efforts do not go unnoticed, as underlined by BorgWarner recently winning first prize at the Porsche Supplier Award 2012. Porsche thereby confirmed the role of BorgWarner as an innovative supply partner in the field of exhaust gas turbocharging and honored the company's successful efforts in continually improving both its quality and supply performance. Beside BorgWarner, nine other suppliers were presented with Supplier Awards for their exceptional services in the past year.

BorgWarner introduces world's first cold test bed for turbochargers

# Turbo testing as standard



As the famous German expression goes, “trust is good, but control is better”. In keeping with this motto, BorgWarner Turbo Systems is keen to no longer rely solely on quality assurance to avoid faults at its Kirchheimbolanden site. At the end of 2011, the facility therefore introduced the first test benches that will allow every single turbocharger to be subjected to an additional functional test following production.

A failure rate of less than 20 ppm: this is the explicit aim of the turbocharger specialists for their turbocharger production operations. This represents a major challenge for the planners of the manufacturing processes. On the one hand, the methods for process assurance in manual assembly are particularly complex, as this area bears the greatest potential risk of faults. On the other hand, however, experience and ppm figures from the last few years clearly show that the limits of what process assurance is capable of achieving at manual assembly stations have already been reached. As such, a central task of process planners lies

in developing effective measures for preventing or detecting faults. As a key element of the Kibo quality offensive, management at BorgWarner has therefore decided to subject the turbochargers to a final functional check following assembly.

#### Testing key functions

To this end, a cold testing area is used to test the functional characteristics of finished turbochargers, which form the primary basis for zero-defect products. Every single turbocharging system must comply with the following criteria:

- The specified boost pressure is achieved at the operating point
- The boost pressure regulation corresponds to the requisite targets
- Gas and oil tightness is guaranteed
- Operating noises in the vehicle are within specifications
- The requisite service life is achieved

The function of the test beds essentially lies in driving the turbochargers using compressed air. The measurement results recorded here are then evaluated and graphically presented utilizing intelligent software. Although this kind of testing and measuring involves a considerable investment, it is ulti-

mately indispensable if meaningful conclusions are to be drawn regarding potential faults. Beside the dynamic performance test – the cold test – a leakage test and a noise test are also performed. The combination and accuracy of the different testing procedures are what ultimately determine whether this quality control is successful.

### Launch with BMW

The first production areas to utilize this complex final inspection step are the BMW assembly lines for the turbocharger models N47, N57 and N100. These are the low-pressure and high-pressure turbochargers for the R2S two-stage regulated turbocharging system that BorgWarner supplies as individual assemblies to BMW. The renowned vehicle manufacturer then performs final assembly of the complete R2S system at its own facility. Series production on the two lines was launched in July 2011 and the maximum system capacity is 230,000 turbocharger units per year.

The assembly line planning and implementation stages adhered strictly to the rules of the lean production philosophy. The individual assembly steps are planned in detail on the basis of MTM (Methods Time Measurement) and distributed evenly among the individual stations. Great emphasis was placed on securing a consistent processing cycle. A total of 7 different article numbers are produced in constant rotation on the 2 lines. This places great demands on system flexibility.

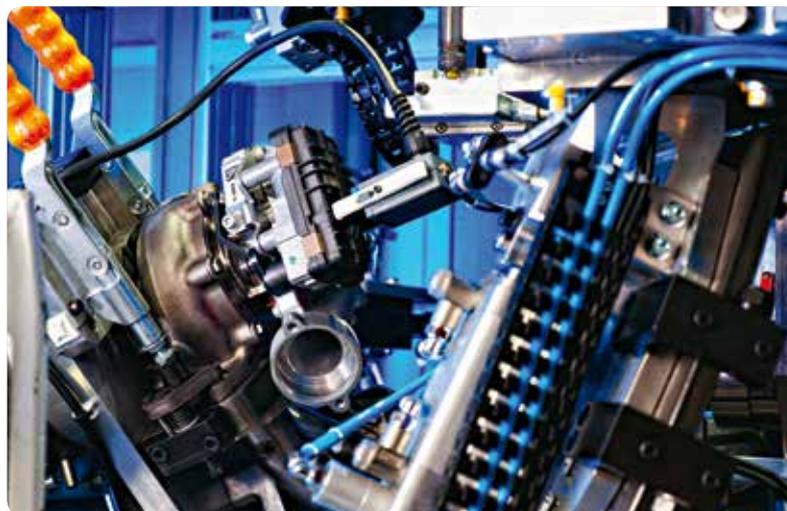
A decision was therefore taken to decouple assembly of the core with the operational balancing process from final assembly. A supermarket with balanced core assemblies creates the necessary flexibility to adjust the systems at short notice and thereby align production volumes to actual customer requirements on a daily basis. In the final assembly area, the tried and tested concept of assembly line production is consistently maintained.

Following a 14-month planning and procurement period, the company took delivery of the first turbocharger cold test beds for connection to the BMW assembly lines in August and September 2011. The system has since been integrated into the assembly lines and commissioned. The low-pressure and high-pressure stages each have their own dedicated test bay. The finished turbochargers remain on the assembly pallet and then move into

the test bay area, where the fully automatic cold test is performed. The pallet holding the tested turbocharger then moves to the unloading bay, where the turbocharging system is removed by the operator, sealed, subjected to a visual inspection in line with a checklist and ultimately packaged with the customer label.

### Pioneering role in cold testing

The cold test beds are the world's first test bays of their kind to be integrated into a serial assembly process and seamlessly subject all finished turbochargers to a final functional check. As such, the Kirchheimbolanden site not only plays a pioneering role within the BorgWarner Group, but also in the general competitive environment. The findings from the new test beds will flow into the development of future projects and help permanently increase both quality and customer satisfaction.



*Following final assembly, every turbocharger must pass a fully automatic cold test.*



Know-how

## Prevention of faults vs. detection of faults

The turbocharger cold testing process is a step for detecting potential defects. It might initially seem to be a less obvious choice than fault prevention, as it takes place right at the end of the added value chain and cannot secure the desired success on its own. However, when embedded in a consistent quality assurance concept, fault detection significantly improves the effectiveness of upstream measures. At BorgWarner, four pillars will therefore determine the success of the quality assurance process in future:

1. Consistent fault prevention through the best possible process assurance for vendor parts, parts manufactured in-house and the assembly process
2. Turbochargers produced in line with manufacturing and assembly stipulations, whose individual parts and assembly processes have been developed in line with Poka-Yoke principles
3. Highly qualified, reliable and attentive employees who are trained to prevent faults
4. Turbocharger cold testing following assembly

# Thunder and light



**With 280 hp, 400 Nm (295 lb-ft) of torque and a 0 to 62 mph time of just 6 seconds – the performance data alone already gives an indication of the power hidden under the hood of the new Opel Astra OPC. The aggressive-looking vehicle also cuts an excellent figure on the race track. This should really come as no surprise, as the sports car fitted with a BorgWarner turbocharger was tested and set up under racing conditions at the Nürburgring.**

The Nordschleife of the Nürburgring enjoys a legendary reputation among fans of motor racing. The track, which is also known as the “Grüne Hölle” or “Green Hell”, is among the most demanding racing circuits in the world. With its hidden corners, treacherous blind crests, severe upward and downward inclines and frequently changing track surface, it is a real test for both vehicle and driver. This is why the engineers at Opel chose this circuit to refine the handling of the new Astra OPC and subject the vehicle to a 6,000-mile endurance test under racing conditions. The loads and forces that the vehicle was subjected to during this testing equate to a dis-

tance of roughly 110,000 miles on standard roads.

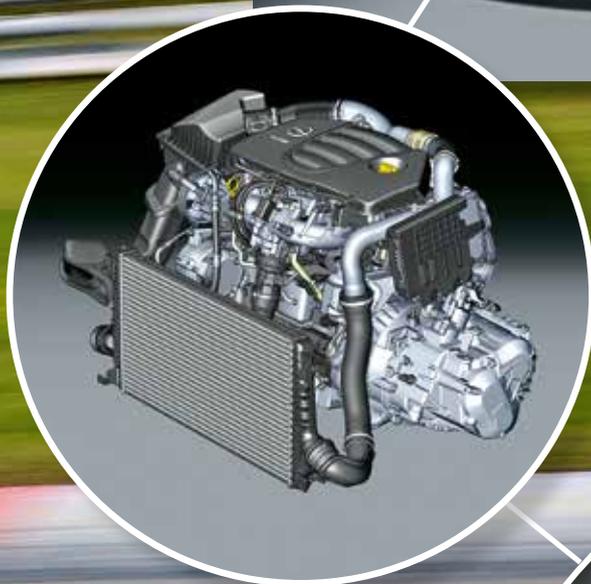
#### **Highest power density thanks to turbo**

The sporty Opel is not designed for the everyday driver. The abbreviation OPC after the model name stands for Opel Performance Center. This designation is traditionally given to Opel models designed for customers seeking the best possible sporting performance, something which the Astra OPC definitely delivers in all driving situations. Boasting 280 hp (206 kW) and just under 200 Nm (150 lb-ft) of torque per liter of displacement, the

2-liter direct injection turbocharged engine used in the Astra is the true king of torque among four-cylinder gasoline engines. With this kind of performance data, it even outperforms competitors from the sports car segment.

The turbocharger plays a key part in the impressive performance offered by the OPC engine. The turbo fitted is a K04 exhaust gas turbocharger from BorgWarner Turbo Systems, which is also already being used in the 250 hp (184 kW) 2-liter gasoline engine in the Opel Insignia. For the sporty OPC version of the engine, however, the engineers at Opel developed a completely new intake system, which provides the turbocharger with an even greater volume of fresh air. The specialists at BorgWarner also optimized the turbocharger, so that it now provides maximum boost pressure of 1.5 bar – some 25% more than the Insignia engine. This pressure starts building

# ning!



up from just 1,400 rpm, with the turbocharger reaching maximum torque at 2,450 rpm. The engine therefore rewards the driver with immediate and impressive response to gas pedal movements.

The sound of the engine in the Astra OPC is also sure to put a smile on the face of ambitious drivers. During the sound engineering process, the developers placed great emphasis on achieving a powerful sound, which is accompanied by a jet-like background noise inside the vehicle.

#### **Maximum performance, minimum consumption**

It is encouraging that attention was not only paid to driving pleasure during the vehicle's development, but also to the environmental impact. The new Astra OPC, which comes as standard with a start-stop system, also sets

benchmarks in the high-performance compact vehicle segment from an ecological perspective with CO<sub>2</sub> emissions of around 300 g/mile and fuel consumption of 29 mpg US (35 mpg UK). Its exhaust emissions and fuel consumption therefore offer 14% and 12% improvements respectively over the values of its predecessor (353 g/mile and 25 mpg US/30 mpg UK).

With the powerful turbocharged engine in the Astra OPC, the engine developers at Opel and BorgWarner have once again impressively underlined the fact that exceptional dynamic driving performance and ambitious ecological goals can indeed be combined with one another thanks to use of the latest exhaust gas turbocharging technology.

*Thanks to its K04 BorgWarner turbocharger, the OPC engine boasts the highest torque output of any four-cylinder gasoline engine currently on the market.*

# All good things come in threes



BMW M Performance – Lovers of exclusive sports automobiles associate BMW's "M" designation with fascinating technology, dynamic driving performance and extreme acceleration; in short: maximum driving pleasure. As a newcomer and genuine highlight in its M engine range, BMW is now presenting the world's most powerful inline six cylinder diesel engine. This new unit is also the first diesel engine ever to use a three-stage turbocharging system.



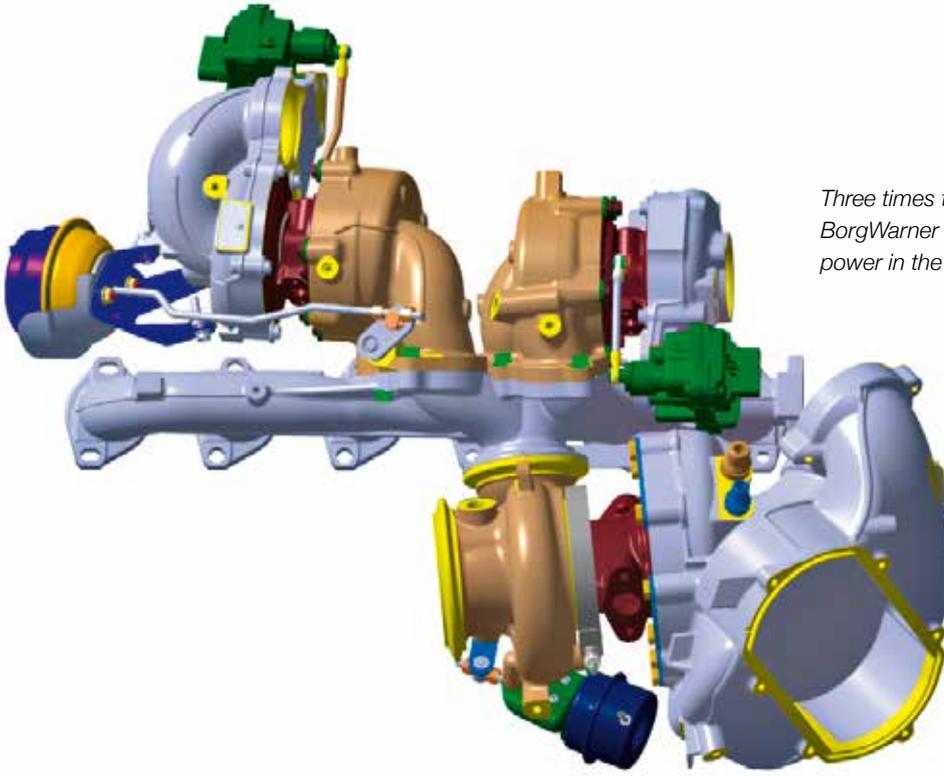
While diesel engines may have been considered an absolute "no-go" in sports and luxury vehicles just a few years ago, they are now gaining popularity among driving enthusiasts thanks to their impressive power and torque characteristics. It was therefore logical that the engineers at BMW would choose this drive concept to develop a diesel drive worthy of the exclusive M Performance badge. The results are thoroughly impressive.

## Incredible torque

The 3.0 liter (183 cubic inch) inline six cylinder unit generates power of 381 hp (280 kW). The most impressive figure, however, is the maximum torque of 740 Nm (545 lb-ft), which is immediately apparent to the driver throughout the entire rev band thanks to its instant and linear power

delivery. Even the most discerning customers that demand the ultimate in dynamic driving performance will be impressed with this immense power. But perhaps even more impressive than the incredible performance figures is the fact that this engine demonstrated average consumption figures of 37 mpg US (45 mpg UK) during standard EU testing in the M550d xDrive model. Of course, the innovative drive also complies in full with the new Euro 6 emissions standard, which will come into effect from 2014.

The developers faced many challenges in achieving the performance figures offered by the new engine. The engineers from BorgWarner Turbo Systems in particular had to use all of their knowledge, experience and expertise, since the new unit is the world's first diesel engine to be equipped with three turbochargers. Although complex, this approach



*Three times the power: Not two, but three BorgWarner turbochargers generate impressive power in the BMW M Turbodiesel.*

allowed the engine builders to achieve immediate response at low revs and a requirements-based increase in boost pressure during higher load driving. This principle has already proven its effectiveness in the regulated, two-stage R2S turbo system, which BorgWarner supplies to BMW for its 535d, X5 xDrive 40d and X6 xDrive 40d models.

#### **First R3S system for a diesel engine**

However, unlike the R2S system, the new M engine employs two comparably small high-pressure turbos with one large, low pressure unit. Integration of the additional high-pressure turbo creates new options for generating the kind of boost pressure required for particularly dynamic power delivery.

The two high-pressure stages are both BV45 turbochargers with variable turbine geometry. One of these two turbos begins its work in the low rev range just above idling speed. Due to its low moment of inertia, it reacts without delay, instantly providing the combustion chambers with compressed air. The exhaust gas stream then reaches the larger B2 turbocharger, which already provides noticeable boost and support for the smaller unit from 1,500 rpm upward. Together with the BV45, it ensures that the maximum torque of 740 Nm (545 lb-ft) is available from 2,000 rpm and maintained into the 3,000 rpm range.

For a further increase in performance, a negative pressure-controlled exhaust flap is then opened at an engine speed of around 2,700 rpm, allowing exhaust gas already driving the high pressure turbocharger to also flow to the second BV45 high-pressure turbocharger, which then provides additional boost pressure almost instantly thanks to its low moment of inertia. This allows the large turbo to deliver its full output, while the second small turbo supplements the

effect of the two booster systems already active as a way of forcing even more compressed air into the combustion chambers.

So that the three systems guarantee efficient boost pressure generation when operated together, the supply of exhaust gas and fresh air to the turbos, as well as the introduction of the compressed air into the combustion chambers is controlled with extremely high precision. A waste gate valve, which is opened via a negative pressure controller, prevents undesirable exhaust back pressure at particularly high engine speeds. The fresh air supply inlets are also controlled and matched to current requirements using pneumatically actuated flaps. So that the three impellers can provide the engine with compressed air at optimum temperature, the R3S system is equipped with an indirect intercooling system. The primary charge-air-cooler, arranged directly before the combustion chambers, and the intercooler, positioned behind the low pressure turbocharger, are supplied via a low-temperature water circuit with dedicated electrical pump.

#### **A delight for passionate drivers**

Boasting 125 hp per liter of displacement, the BMW M Turbodiesel sets a new benchmark in terms of specific output. The R3S system from BorgWarner plays a key part in this. Compared to the BMW 740d, which employs a R2S system provided by the turbocharger specialist, it offers a power increase of almost 25% – while consuming around 8% less diesel fuel. As such, the new engine is certain to enjoy great popularity among BMW's discerning "M" clientele. The new engine will be available in the BMW models M550d xDrive, M550d xDrive Touring, X5 M50d and X6 M50d.

# Insignia of power

Opel's Insignia celebrated its premiere in 2008. Since this time, the company's flagship model has won more than 50 national and international awards, including "Car of the Year 2009". The highly successful vehicle is now being given a further boost with a powerful bi-turbo diesel engine, which employs two BorgWarner turbochargers and an innovative cooling concept to set new standards in the class.

The new 2.0 BiTurbo CDTI is the top of the range diesel engine in the Opel Insignia. The highlights of the four-cylinder common-rail engine include regulated, two-stage turbocharging (R2S) and a sophisticated twin-cooler system with two separate charge coolers. Opel is the first manufacturer to use this system in a passenger vehicle.

## Intelligent turbocharger concept

The turbocharging system in the new engine comes from BorgWarner. A compact KP35 high-pressure turbocharger, which already generates boost pressure at low exhaust gas flow rates, ensures dynamic pick-up without the dreaded "turbo-lag". This turbocharger has a dedicated 2-liter charge cooler, which is water-cooled and fitted directly to the engine above the two turbochargers in such a way that it only has to overcome a short distance to force a low volume of air into the combustion chambers. This ensures fast response times.

In the rev band from 1,500 to 2,500 rpm, the exhaust gas stream is then split and a larger K04 turbocharger works together with the KP35 in series. With this system, the larger K04 low-pressure turbocharger pre-compresses the intake air and the smaller turbo then compresses it further. A bypass valve continuously feeds a portion of the exhaust gases to the larger turbo. From around 2,500 rpm, the large turbocharger then starts to take over the workload and is ultimately responsible for providing the entire boost pressure from 3,000 rpm upward. The temperature of its voluminous air flow

is reduced from around 430°F (220°C) to around 120°F (50°C) in a conventional air-to-air charge cooler.

Both turbochargers are fitted with a waste gate. This limits the volume of driven air and also serves to increase the exhaust gas temperature for regeneration of the particle filter. The precision-milled impellers of the two turbos are made from a lightweight aluminum alloy and operate at temperatures of up to around 356°F (180°). The turbine wheels have a high-temperature-resistant alloy.

## Powerful, economical and clean

The great deal of time and effort that the engineers at Opel and BorgWarner invested in the development of the new BiTurbo really paid off. The new diesel engine generates 195 hp (143 kW) and boasts fast, agile response in all driving situations, as well as impressive power delivery across the entire rev band. It generates an incredible 295 lb-ft (400 Nm) of torque, some 80% of which is already available from just 1,250 rpm. The diesel fuel consumption of 48 mpg US (57 mpg UK) and CO<sub>2</sub> emissions of 206g per mile are extremely impressive in light of these power and torque figures. The Insignia 2.0 BiTurbo CDTI therefore not only ranks among the most powerful, but also the most economical vehicles in its class.



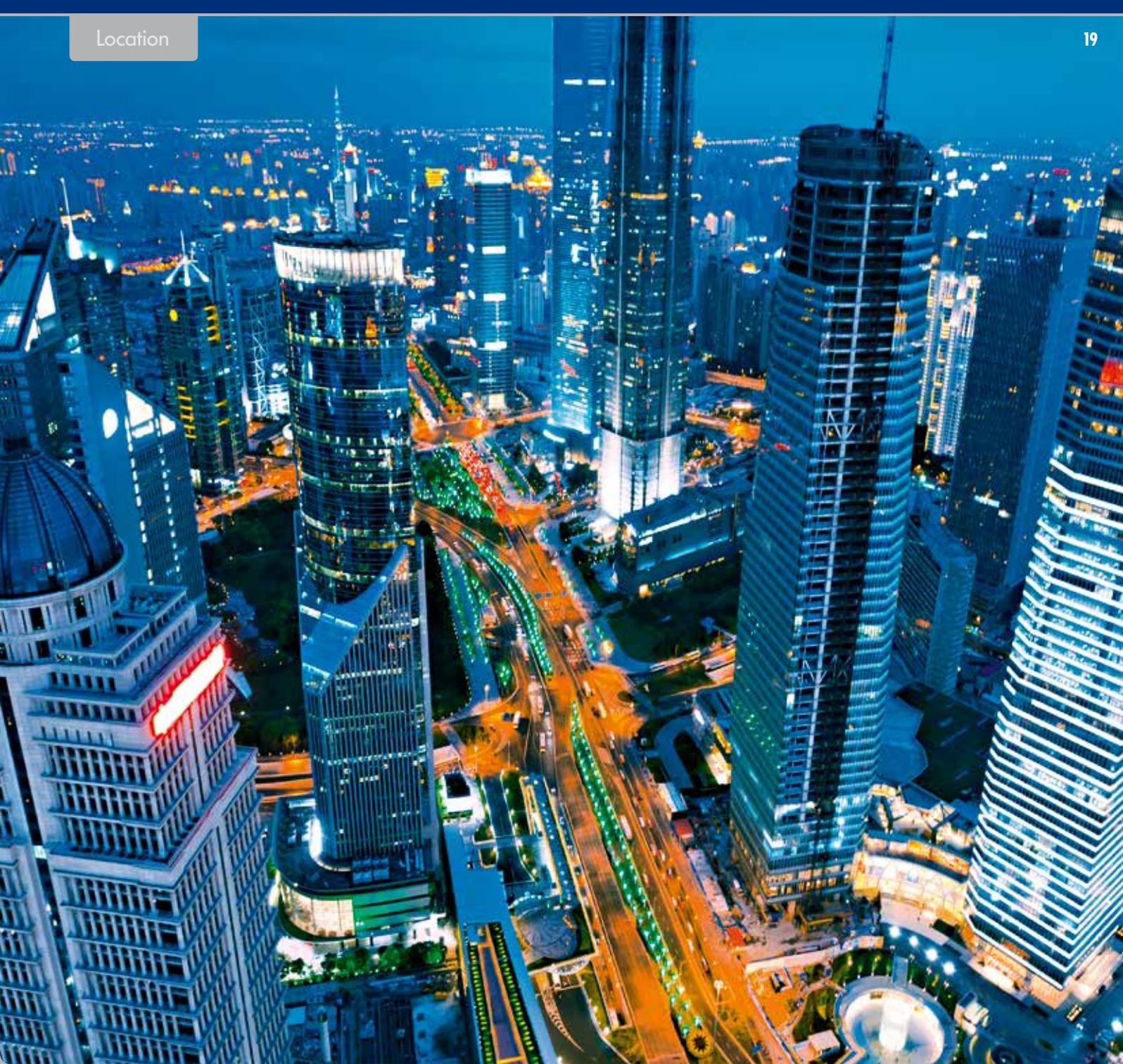
Success model: Opel has already sold almost one million Insignias.



Technical highlight: regulated, two-stage turbocharging (R2S) and a sophisticated twin-cooler system with two separate charge coolers.



More power in tandem: The innovative turbochargers from BorgWarner.



# High-tech made in China

BorgWarner inaugurated its new Ningbo Engineering Center (NEC) in November 2011. With the new facility, the automotive supplier is ideally equipped to supply the Chinese market.

*The Engineering Center in Ningbo*

8,882,456

Vehicle production  
in China 2007\*

The market for passenger vehicles is enjoying massive growth in China. And the market for turbochargers is growing even faster, as energy-efficient and environmentally friendly vehicles are also in great demand in the land of smiles. With a new development and manufacturing center in the coastal city of Ningbo, BorgWarner is reinforcing its excellent market position in the emerging Asian nation.

Turbo Systems shares the new 19,000 square meter Engineering Center with Emissions and Torque Transfer Systems. Morse Tec is set to move into the neighboring building. The new facility enables BorgWarner to develop turbochargers independently at the location and validate the products to the specifications of the Chinese market. Among other things, the site is also home to a dedicated prototype department, as well as two turbocharger and two engine test benches. The building has also been designed to allow further growth and offers sufficient capacities for additional test rigs. This is good news, as BorgWarner is planning to install a further turbo test bench in May 2013.

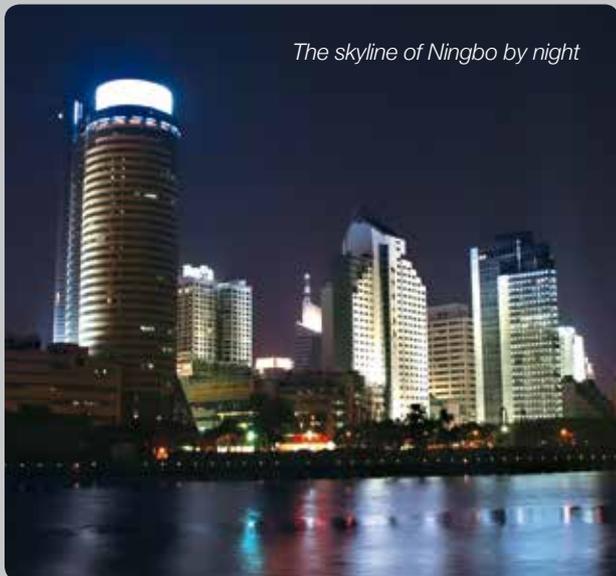
Turbo Systems employs a total of around 500 staff members at the Ningbo location, 52 of whom work in engineering.

The NEC can therefore offer customers a first class local service, ranging from on-site simulations, through concepts and dimensioning, all the way up to application design.

#### A win-win situation

The extensions in Ningbo are a win both for BorgWarner and its customers, as the company can now test and validate turbochargers on site. This allows the automotive supplier to save valuable time and react more quickly to the strict demands of its local customers.

18,

*The skyline of Ningbo by night**Shanghai*

The China Technical Center (CTC) in Shanghai



418,876

Vehicle production  
in China 2011\*

Indeed, some 90 percent of the turbochargers that BorgWarner manufactures in Ningbo go to Chinese vehicle manufacturers. The portfolio produced at the facility ranges from particularly compact turbochargers, such as the KP 31 for small passenger vehicles, all the way up to large turbocharging systems with a turbine wheel diameter of 3.4 inches (87 millimeters), which are used in commercial vehicles. BorgWarner works to the same, uniform quality standards in development and production that have been established at all of the company's other facilities worldwide.

With the Engineering Center in Ningbo, BorgWarner Turbo Systems is strengthening its position as a global player that provides its customers across the globe with local support in the form of comprehensive expertise and the latest technologies.



Shanghai

**Ningbo** lies around 125 miles south of Shanghai in the estuary of the Yangtze. The coastal city with around **5.7 million residents** ranks among China's key industrial locations and its port is one of the country's most important hubs. Ningbo has a subtropical monsoon climate with hot summers and mild winters.



# First GDI from BYD

China's auto manufacturers are focusing more and more on the latest technology to win over demanding customers. The first direct injection gasoline engine ever to have been developed in China is a good example of this. Build Your Dreams Auto (BYD) used the expertise of BorgWarner Turbo Systems to create a high-performance and economical Euro 5 engine.

China's rapid economic growth has resulted in the growth of the Chinese middle class, for whom car ownership is often a top priority. As such, modern engines that combine dynamic driving performance with low fuel consumption and low exhaust emissions are also enjoying increasing demand in the Chinese megacities. When developing a new gasoline engine for its own passenger vehicle models, the Chinese vehicle manufacturer BYD therefore decided to go with direct fuel injection and exhaust gas turbo-charging technology.

The 1.5 liter (91.5 cubic inch) GDI engine from BYD is equipped with a KP39 BorgWarner turbocharger which enables it to achieve the kind of performance figures that could otherwise only be achieved with a 2.4 liter (146.4 cubic inch) normally aspirated engine. The four-cylinder unit generates a power output of 154 hp (113 kW) and maximum torque of 240 Nm (177 lb-ft). The acceleration values remain constant throughout the entire rev band. To ensure that the pneumatically controlled turbocharger can perma-



nently withstand the high exhaust gas temperatures of the turbocharged gasoline engine, the engineers at BorgWarner equipped it with a water-cooled bearing casing.

The high-performance GDI engine complies with the Euro 5 emissions standard and celebrated its premiere in the G6 sedan from BYD, which ranks among the most popular mid-range models in the Chinese automobile market. The fuel-efficient engine is now also available in other models produced by BYD.

# TURBO GOES TO SCHOOL

Who can build the most energy-efficient prototype? On 22 June, fifteen teams of 10<sup>th</sup> grade pupils from the Donnersberg district (Germany) competed with one another to find out. They took up the invitation from BorgWarner in Kirchheimbolanden to build a vehicle that could keep moving for as long as possible.

The aim of the “Turbo goes to school” project was to stimulate interest among young people for the so-called MINT disciplines. These are the subjects of mathematics, IT, natural sciences and technology – fields in which greater numbers of well-trained specialists will be required in future. The objective was to master a practical challenge in connection with theory and a presentation. The pupils were asked to build a vehicle that could travel along a 75 cm high and 150 cm long halfpipe for as long as possible without any on-board drive source.

## Impressive concepts presented by pupils

24 teams with a total of 81 participants registered to take part in the competition, 15 of whom were ultimately invited to present their prototype concepts at the works premises in Kirchheimbolanden. The teams impressed the jury with their sophisticated models and creative solutions for using kinetic energy. Most of the teams selected large wheels, smooth running bearings and minimized frictional losses. One of the teams even equipped its vehicle with an energy storage system in the form of rubber band fitted to the axles which was rolled up and down as the vehicle moved. Beside the total travel time, the originality of the design and the tracking of the vehicles were also factors included in the overall assessment. “The pupils displayed incredible creativity in designing their vehicles and worked intensively on making last-minute modifications on the final day,” reports Arno Schwarz, Vice President Engineering Passenger Car Turbochargers at BorgWarner. The winners in the travel test were a team from the IGS Rockenhausen school, whose total travel time of 152 seconds gave them an impressive lead over the second place team, which managed 68 seconds.

The competition was rounded off with a presentation and a theory test, during which the pupils had to get to grips with the working methods of turbochargers and the associated physical forces. “All the teams were well prepared for the test and scored highly with their knowledge of turbocharging,” confirms Arno Schwarz. The members of the winning team from the IGS Rockenhausen school were delighted to each receive €250 in prize money, which they were encouraged to invest in driving lessons.

*Top of the class: The team from the IGS Rockenhausen school was clearly delighted to win first prize.*

## Competition proves a real hit

Following the competition, the participants were invited to take a tour through the company’s turbo-charger production facilities. This provided the pupils with exciting insights into the work of the 2,000 specialists at BorgWarner in Kirchheimbolanden, the largest private employer in the region. The members of staff, the pupils and the teachers were truly enthusiastic about the “Turbo goes to school” event. Indeed, it was so well received that Arno Schwarz has since announced a follow-up competition for 2013. “I think this competition clearly proved that physics can also be fun. Extracurricular events like this provide an excellent opportunity to get pupils excited about the prospect of a technical career.”

*Test course: The prototypes had to prove themselves in this halfpipe.*



# Innovation reloaded

Six PACE Awards, three PACE Innovation Partnership Awards and one PACE Environmental Award: BorgWarner is one of the most frequently honored companies in the history of this coveted award, with which automotive suppliers are celebrated each year for exceptional innovations and services.

BorgWarner received the last Automotive News PACE Award on April 23 for its turbochargers which have been optimized for low-pressure exhaust gas recirculation systems.

Diesel engine development has already reached a high technological level. As such, the challenge for engine developers to further improve on drives with regard to response, fuel consumption and emission values is greater than ever. BorgWarner therefore continually works on achieving significant advances using exhaust gas turbocharging technology. The company's most recent achievement is a new generation of turbochargers which, thanks to special coatings, can be combined with low-pressure exhaust gas recirculation (LP EGR) for the first time ever – and promptly won a PACE Award.

## LP EGR an important milestone

Exhaust gas recirculation in the combustion chamber is a widespread and effective measure for reducing NOx emissions. Until recently, however, the only EGR systems used were high-pressure units (HP EGR), with which exhaust gas is extracted before the turbine. LP EGR therefore represents an important milestone. With this system, the exhaust gas is not extracted until after the turbine, which provides a larger volume of exhaust gas for the turbocharger. However, the introduction of LP EGR technology necessitates further development of existing turbocharger technologies, as the extreme loads and particles in the exhaust gas can damage individual turbocharger components. To offer protection from extremely high temperatures and acidic exhaust gas components, the engineers at BorgWarner developed a special coating for the impeller wheel and other relevant components. In addition to this, an optimized mixture geometry guarantees precise combination of fresh air and recirculated exhaust gases with an extremely low loss of pressure.



*Dr. Stefan Münz (Director Advanced Engineering), Frederic Lissalde (President and General Manager Global Passenger Car Products), James Verrier (Chief Operating Officer) and Arno Schwarz (Vice President Engineering) at the award ceremony.*

## New technology already in series production

BorgWarner turbochargers which have been designed for LP EGR thereby optimize the combustion process and facilitate higher EGR rates. The result is improved response of the diesel engine, coupled with significantly lower fuel consumption and emission values. This represents an important advancement, which clearly impressed both the jury of the Premier Automotive Suppliers' Contribution to Excellence Awards and the first customers taking delivery of the new systems. Indeed, the BorgWarner technology is already being deployed in series production at several major auto manufacturers.

The PACE Award was presented on April 23, 2012 in Detroit following a process consisting of a detailed written application, a tour of the facility and an assessment by leading personalities from the fields of industry, science and the economy. The award was presented by Automotive News, the corporate consultancy Ernst & Young and the Transportation Research Center Inc. BorgWarner was nominated with three different products at this year's ceremony.