Honeywell

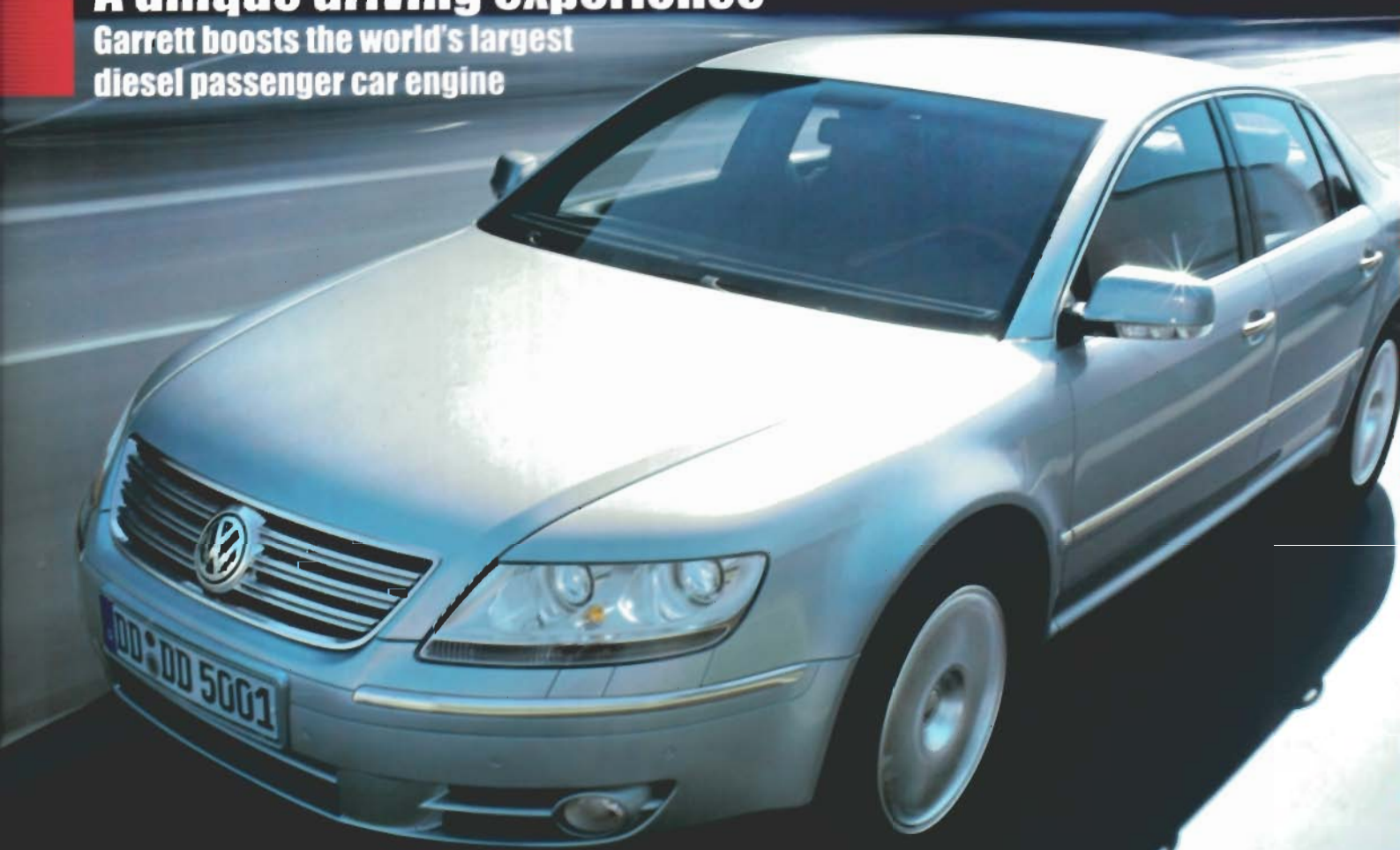
GARRETT

booster

MAGAZINE

March 2003

The Phaeton
A unique driving experience
Garrett boosts the world's largest diesel passenger car engine



Turbocharger Bearing Systems Technology
Challenges and Strategic Developments

Garrett®

On Track

Working in partnership with VW, Garrett has recorded a world 'first' by using CAN-Bus technology to create a dialogue between the engine control unit and the REA of the twin turbochargers in the world's biggest diesel engine production passenger car.

Currently just 2% of passenger cars in the US are powered by diesel engines. Now though, there are signs that a major change in public perception is underway ... and Garrett's European experience looks set to support the trend towards clean diesel technology.

Bucharest is the location for Garrett's latest advanced manufacturing facility, an investment that supports the growing interest among customers in the opportunities presented by Eastern Europe.

Garrett's latest generation VNT™ turbocharger features numerous technological innovations – all of which combine to deliver more power, more efficiency and enhanced reliability.

Twenty five new passenger car models will benefit from Garrett boosting technology in 2003. From Asia to South America and across Europe, manufacturers are equipping both diesel and gasoline engines with Garrett turbochargers that help to improve engine performance, deliver better fuel efficency and meet emissions standards.

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LISTENING AND LEARNING

Dear Readers,

First of all let me thank all our readers, representing our customers, suppliers and employees, for the constructive and positive way we worked together throughout 2002. It wasn't an easy year, but we coped with most of the challenges ... and as we know there were enough for all of us.

Personally, I do believe that after years of almost "unlimited" growth, it made all of us a little humbler and forced us to focus on the right issues to lay the foundation for profitable growth in the future. During the many discussions we've had with our OEM partners in recent months, I think we've all come to recognize the huge volatility of the current business environment and that flexibility and adaptability will be critical in responding to the market place.

In the big economic picture, it looks likely that there will be little good news to hide behind and certainly there is no room for complacency. We believe that adopting a position of realism will ultimately be a strength for our business.

Companies, like Honeywell, with the right focus on costs, productivity and efficiency; whose technology supports the growth of their customers; who employ the best people supported by the best digital systems will cope with the new challenges ahead.

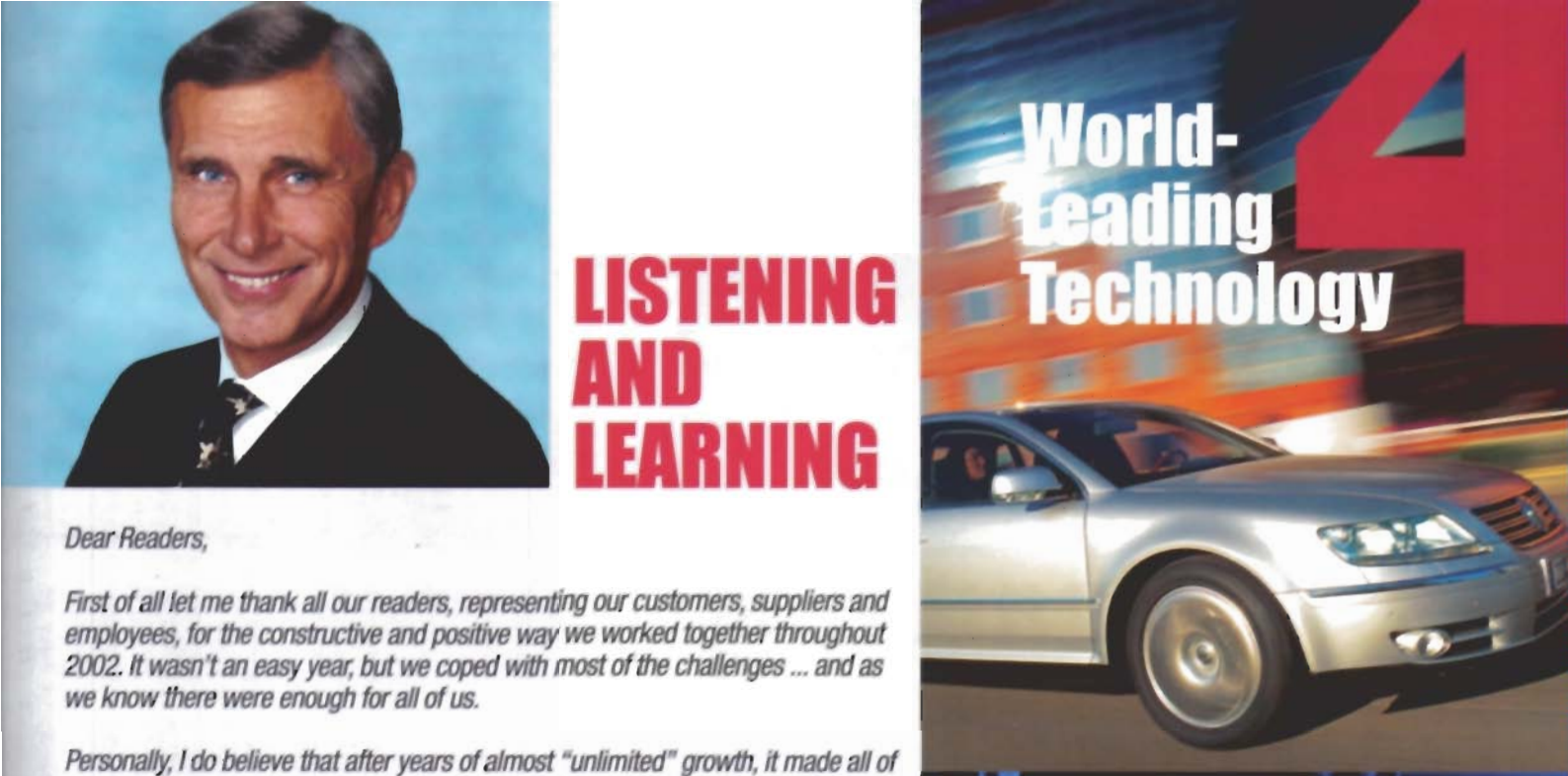
Garrett has proven to be a leading business within Honeywell that partners can rely on, even under adverse conditions. Importantly, we share with our customers and suppliers a winning spirit, a mentality and a behavior that drives a change in mindset, knowing that good is never good enough, because there is always somebody out there who might do better. We have to stay ahead by thinking ahead. By anticipating what our customers need and by organizing to deliver it.

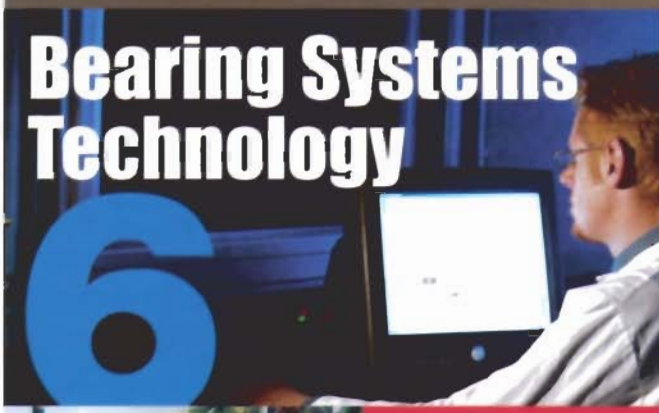
It is against this background that Honeywell's Garrett business has been investing in key technologies, in core competencies and services, in the best people, the best education and training, in the most advanced manufacturing equipment and in the continuous improvement of existing processes. Being critical of our own performance, by benchmarking against the best in class and by listening to the voice of our customers and suppliers.

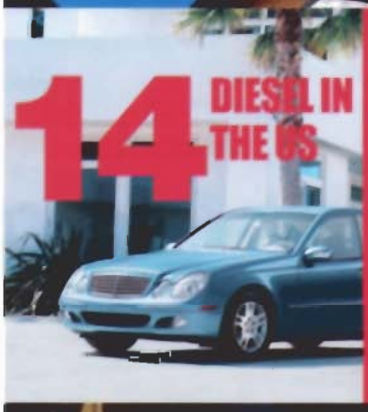
On behalf of the Garrett team, I can say that I am confident that we can face the challenges ahead of us successfully, and I am convinced that we will live up to our customers' expectations. We are definitely committed to our shared future. You can count on us.

We rely on your continuing support, your guidance and your openness when it comes to continuous improvement. In this spirit, 2003 may after all still become another rewarding year for all the right reasons, for all of us !

Bert Snijders
Vice President and General Manager
Europe and Global Accounts







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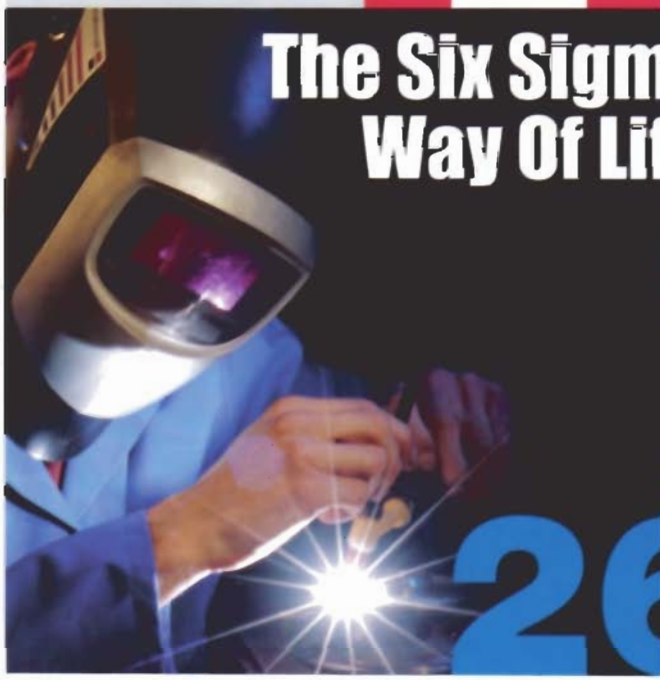
IN VNT™
24



World-Leading Technology For A World Clas

Meeting the VW engin
CAN-Bus first for twin

It's the top performing production diesel passenger vehicle in the world – and it features the most complex turbocharger units ever developed by Garrett. The new VW V10 TDI brings together luxury with extraordinary performance in the shape of the Phaeton, with the 5L engine delivering a top speed in excess of 250 kph and a maximum torque of 750 Nm.

The Phaeton is a unique driving experience – and a unique technological achievement for Volkswagen in partnership with Garrett. What makes the V10 so special from Garrett's point of view is the first-ever application of the CAN-Bus system in turbocharger electronic control strategy. This and the physical design parameters within the engine compartment that had to be accommodated in creating the engine boosting system.

The result is the most complex turbocharger units ever delivered by Garrett – a design so unique that Karim Hassaim, Application Engineer for VW compares the engineering qualities to an artistic creation.

"The V10 uses two GT1852VK turbochargers with rotary electronic actuation (REA) operating at maximum speeds of up to 200,000 rpm in a very complex design configuration," says Karim. "The engineering challenge was considerable, involving the design and machining of many specific parts, including a turbine housing with an integrated inlet pipe – which is the most difficult part ever made in the foundry." The turbocharger bearing housings are bolted directly to the engine block, in a design that minimizes weight and is compatible with the sheet metal exhaust manifolds. But where the project can truly be described as a world 'first' for Garrett is in the use of CAN-Bus to control all the electronic parts of the vehicle – specifically in the dialogue between the engine control unit and the REA of the twin turbochargers.

This allows a very fast and precise control of the variable geometry of the two turbochargers, which gives accurate boost pressure from both turbochargers and allows the same amount of boost between left and right turbos.

Another advantage of the CAN-Bus control is the diagnostics feature, where the REA provides precise diagnostic information to the engine feedback system, so contributing to the wealth of data monitored by the engine management control. Garrett is the first turbocharger manufacturer to offer this diagnostic ability – a feature that is also to be found in the Audi V8 – which demonstrates how the company is supporting its customers in the delivery of new technologies and applications. Garrett's commitment to the V10 started in 1998, and soon the project became a 'fast-track' requirement for VW, particularly in relation to the electronic actuation. Engineers and technicians were co-located at VW and were also actively involved in test programs all around the world to ensure the durability of the systems in extreme conditions. One of the challenges was to optimize the regulation of the turbochargers by minimizing the differences between the left and right side of the engine, particularly with the engine space constraints and the application of the CAN-Bus system. "The result is a true partnership story for VW and for Garrett," says Karim. "By working closely together with VW's engineers we were able to optimize the performance of the turbo within the packaging constraints."

As Klaus Schmidt-Loose from the VW Engine Testing Department explains, the project represents a major success for VW.

"The engine has already won critical acclaim from the media and the partnerships we have established with our suppliers

s Passenger Car

ering challenge urbochargers

The VW V10 is the highest performing diesel engine in the world used in passenger cars. In the VW Phaeton, this power translates to a maximum speed of 250 kph, with a maximum torque of 750 Nm.

have played an important role in the success of the project," says Mr Schmidt-Loose. "We look to our partners to deliver the highest quality levels, to meet delivery dates, and to provide innovative engineering and design solutions as well as on-site support and flexibility. The result of such collaboration is illustrated through the Phaeton - a passenger car that brings together power, technological sophistication, impressive fuel efficiency, remarkable comfort and top level driveability."

Specification:

Engine displacement: 5.0L

Engine block, cylinder head and oil sump are constructed in aluminium to reduce weight.

Injection system: High Pressure Unit Injectors (more than 2000 bar)

High Engine Performance Target: Power 230 kW at 3750 Rpm/ Torque 750 Nm at 2000 Rpm

Emission regulation: Euro 3

Automatic gear box (six gears)

Models: Phaeton and Touareg (SUV)

Turbocharger Bearing Syste

Challenges an

Dr Kostandin Gjika
Garrett's World Leader in Rotordynamics Technologies

Dr Kostandin Gjika is Garrett's Global Bearing Systems Leader and is acknowledged as a world leading specialist in rotordynamics, balancing and vibration control. In his seven years at Garrett, he has led the company's research and development programs in bearing systems – in his view the technology at the heart of the turbocharger.

Dr Gjika holds a Ph.D in Vibration Control/Structural Nonlinear Dynamics - Very Honorable with Congratulations, French MEGA Ph.D School; holds a Ph.D in Rotating Mechanical Structures Dynamics, Tirana Polytechnic University; and is a Graduate Mechanical Engineer, Tirana Polytechnic University.

His expertise in his field has taken him to countries across the world where he has worked on research focusing on a wide range of industrial applications. His many research projects have contributed to numerous technical papers and books and he is also much in demand as a university lecturer. Dr Gjika is fluent in French, English, Italian, Russian and Albanian.

Test cells push the technological boundaries in Rotordynamics

Predictive tools add value to customer partnerships

As engine technologies become ever more advanced, Garrett's engineering community takes up the challenge to create turbocharger solutions that marry innovation with reliability.

The focus on engine downsizing, better fuel efficiency and lower emissions, creates its own technological demands for Garrett ... and means that technical partnerships with customers have never been so important. At the heart of this program is a unique approach to the development of high performance bearing systems.

Dr Kostandin Gjika, Garrett's Global Bearing Systems Leader and Rotordynamics specialist, outlines the challenges – and talks about Garrett's investment in innovative bearing systems technology and performance tools that are proving vital in meeting the needs of customers.

ns Technology

Strategic Developments

What is the role of the Rotor-Bearing System in turbochargers and what are the associated technologies?

The principal role of the turbocharger rotor-bearing system is to transmit turbine wheel energy to the compressor wheel with minimum induced effect. I really think that the bearing system is the heart of a turbocharger. Development of reliable high performance bearing systems is a key requirement for Garrett and is an integral part of our continuous improvement process. The current Garrett bearing systems designs and technologies are: Hydrodynamic bearing technology (fig. 1) and Ball bearing technology (fig. 2), but other advanced designs and technologies are under development like oil less bearing technology (fig. 3). The bearing system is a complex design. For example: A traditional hydrodynamic bearing systems integrates the assembly "Shaft - Journal bearing assembly - Thrust bearing assembly - Seals - Center housing" (fig. 4). Its associated dynamic behavior is quite nonlinear and involves several technologies:

- Rotor-Journal Bearing Dynamic Stability, Friction and Oil Flow Technologies for robustness, increased product reliability and high design performance.
- Rotor-Journal Bearing Transmissibility Technology for VSR throughput increase & noise reduction on the car. Attacking noise at its sources is a Six Sigma approach.
- Thrust Bearing Technology for high axial load capacity, low power loss and low oil flow.
- Sealing Technology for better leak control and low power loss.
- Support Balancing as a Core Technology / in product and process view points.
- Benchmarking activities.

Figure 1

A hydrodynamic bearing system

Figure 2

A ball bearing system

Figure 3

An oil less bearing system

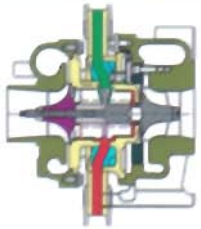
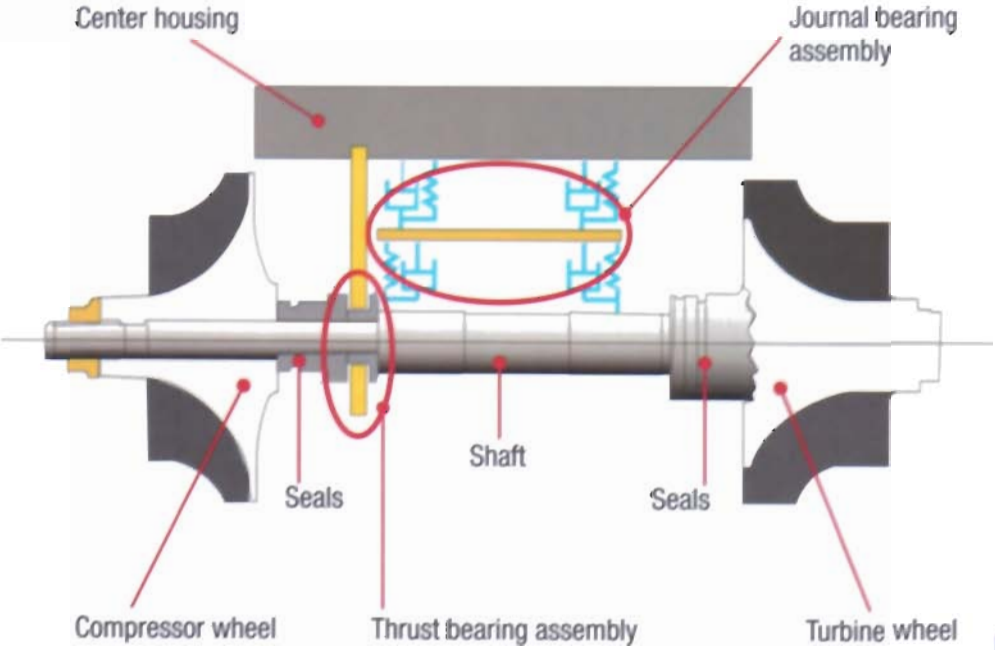
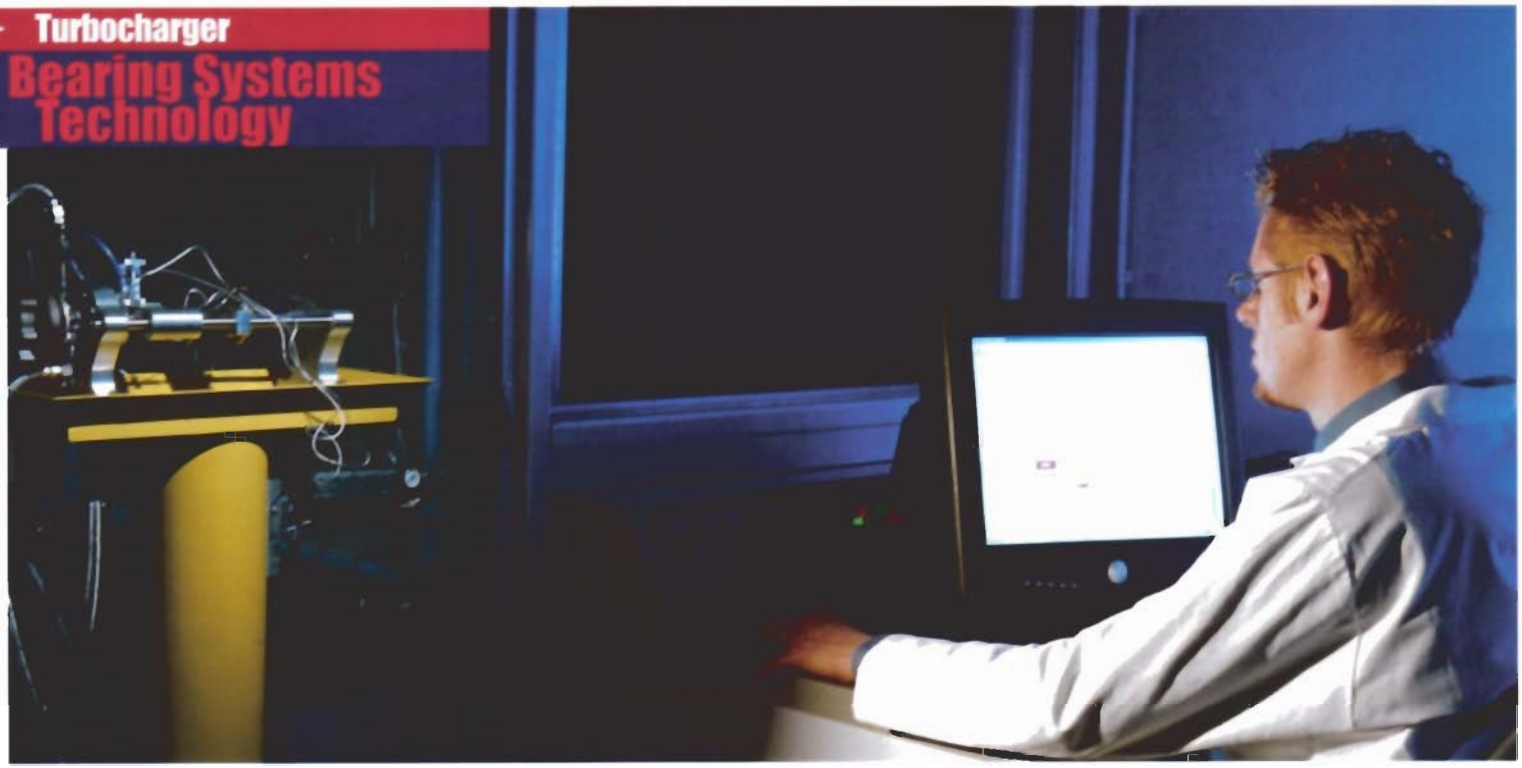


Figure 4

Turbocharger rotor-bearing system
Complex system with nonlinear dynamic behavior



Bearing Systems Technology



What are today's challenges for Garrett bearing systems technology?

In recent years, the desire for increased engine performance has led to technology that increasingly relies on turbocharger robustness and reliability.

Bearing systems are running under extreme conditions: low viscosity oil (e.g. 0W30 or 0W20 oil), high temperatures up to 150°C, low HTHS (high temperature high shear) value and low oil pressure, while the demand for maximum turbocharger speed and variable geometry technology continues to increase.

At 150°C the oil viscosity is close to water viscosity; the small passenger vehicle turbochargers are running with a maximum speed rating higher than 300,000 Rpm and a journal diameter of 6.0 mm; the axial thrust load is higher on variable geometry turbochargers; rotordynamics instability and thrust bearing failures are concerns to be addressed. An optimum bearing systems selection is becoming difficult and more and more critical.

How is the Garrett global bearing systems team facing these challenges?

Greater level of product complexity and a more sophisticated engine environment requires strong and detailed bearing systems behavior understanding.

New and advanced experimental tools and approaches for better understanding of the bearing systems behavior physics are under development. New predictive tools are being explored with outside universities that will allow the optimizing of the design solution at its development stage.

Greater complexity needs an intensive level of simulation and testing prior to validation. The development of new and more realistic qualification criteria and procedures are in progress with the strong cooperation of customers in partnership with Garrett's global bearing systems team, product engineering, application engineering and aerodynamics experts.

A rotordynamics technology test cell is being developed in Thaon-les-Vosges, France. Can you explain the concept?

The idea for a test cell emerged in 2001 as an approach to strengthen research and development into all aspects of bearing systems and rotordynamics technology. The development of reliable bearing systems predictive capability is dependent upon the calibration of analytical tools i.e. a partnership between numerical and empirical methods. This test cell should allow Garrett to establish an empirical data base critical to the development/enhancement of bearing systems technology, to reduce bearing systems development cycle time, and to achieve the Six Sigma level for the bearing designs. It should enable the identification and provision of rapid solutions and recommendations to emerging customer feedback, field issues, manufacturing cost reduction proposals etc.

Five rigs for different functions are planned. The Thrust Bearing Rig is designed to capture static and dynamic characteristics that also interface with radial vibration. The Journal Bearing Rig will be used to find dynamic characteristics as well as stability cards. The Bearing Dynamometer is focused on measurement of power losses at different speeds. The Rotordynamics Rig can be an effective tool for studying instabilities of rotor-bearing systems and shaft motion prediction code validation. The Seal Rig will serve as an instrument to define static and dynamic characteristics for new seal designs.

The Rotordynamics Technology Test Cell is located in Thaon-les-Vosges Engineering area and is now operational. It is a "product" of strong cooperation among the Global Bearing Systems team, engineering laboratory and the plant.

One year ago we had only bearing systems qualification tools; now we have a powerful dedicated facility for research and development activities.

The Thrust Bearing rig is up and running. Very useful empirical data for PV and CV thrust bearings are being obtained. New and alternative thrust bearing designs for increased axial load capacity and reduced losses are tested.

The Bearing Dynamometer is close to being completed and the concepts of other test rigs are under development.

The Test Cell will be completed by mid-2004.

Figure 5

Shaft motion concept and analysis

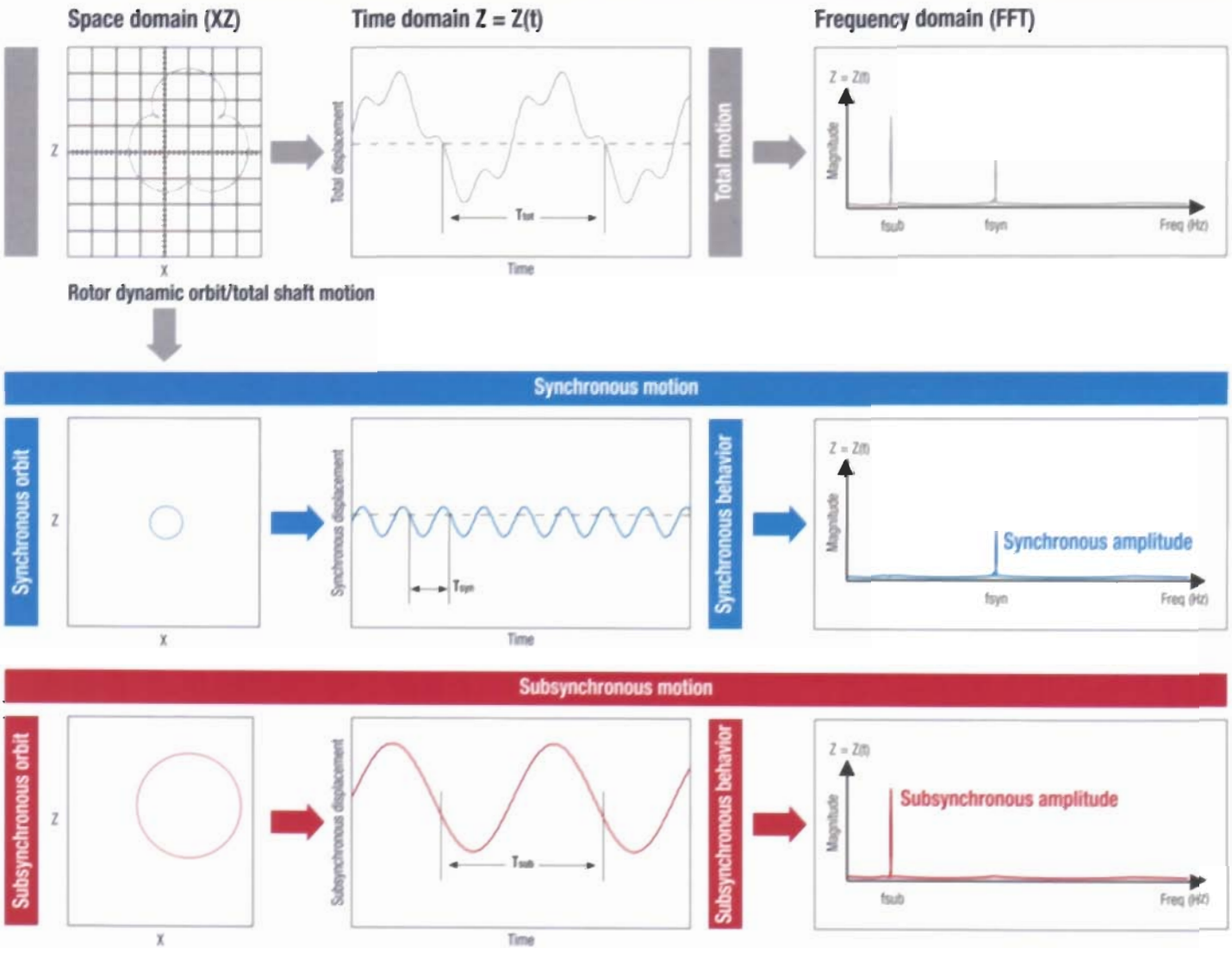


Figure 6

Predicted vs measured unbalance response (synchronous motion)

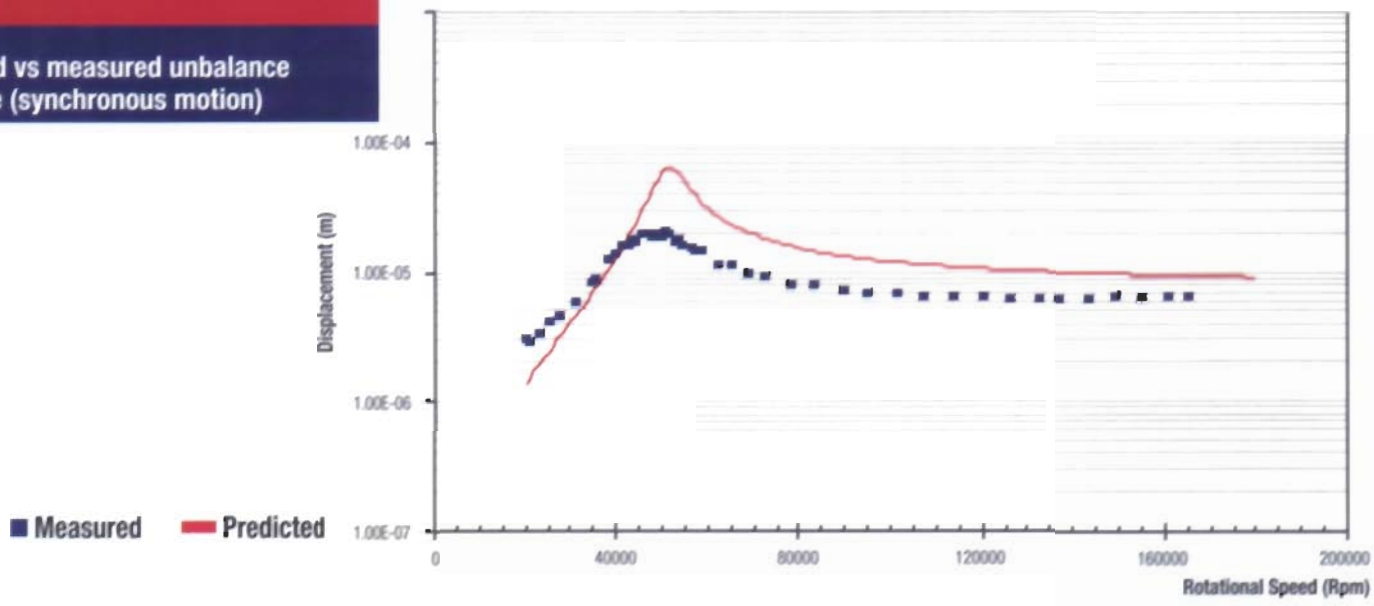
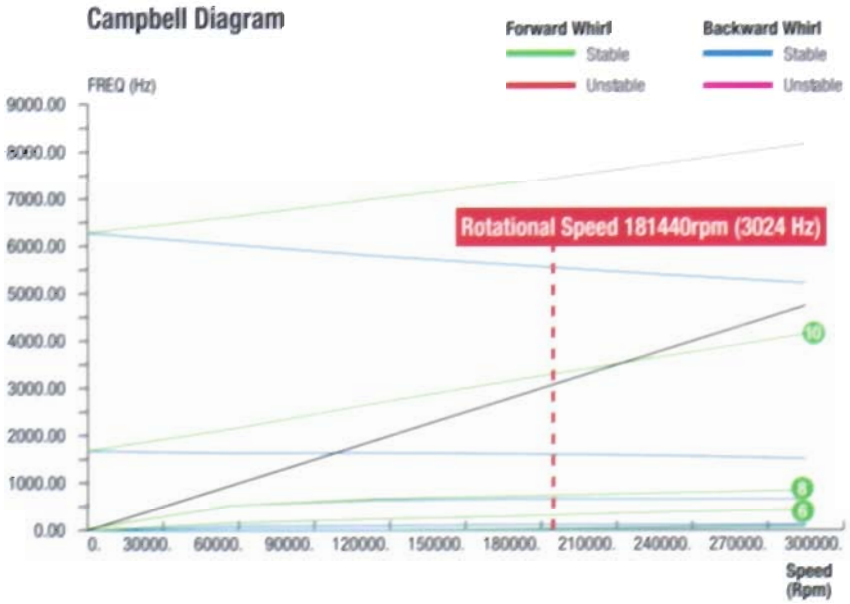
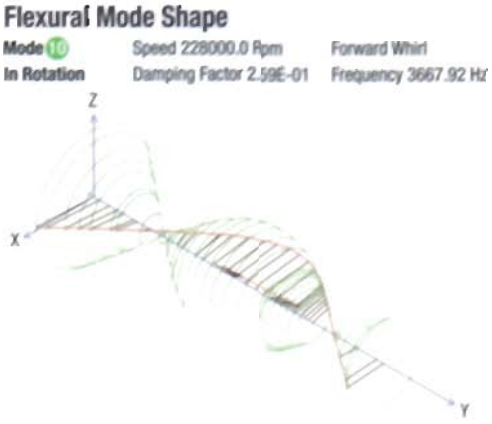
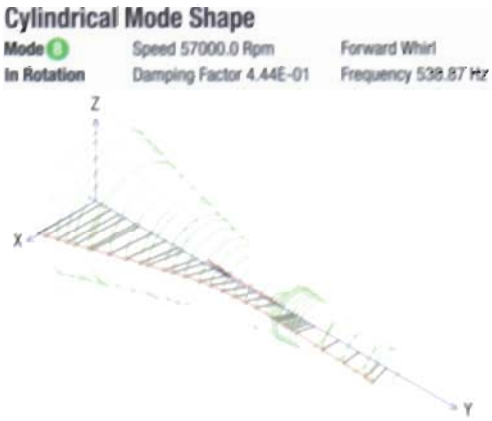


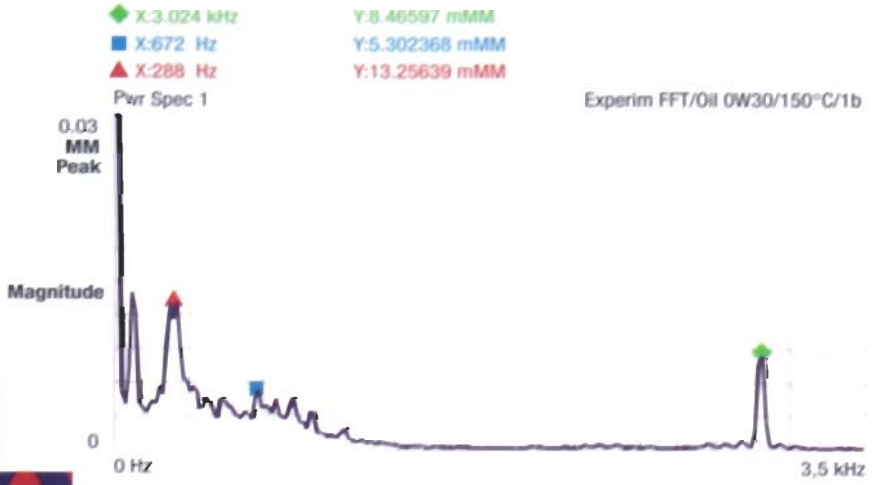
Figure 7

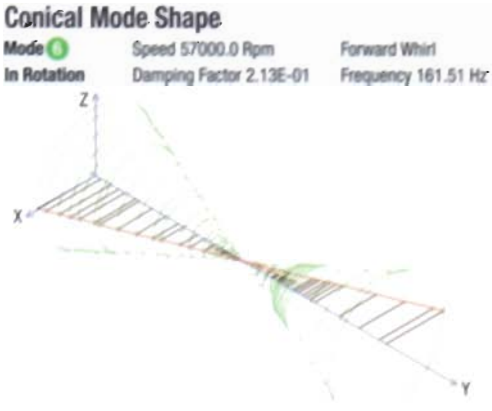
Predicted synchronous and subsynchronous frequencies











Do you believe that Garrett can achieve high performance bearing systems with increased reliability using predictive tools?

Yes, absolutely. Our goal is "Get it Right the First Time" and predictive product design tools will certainly help in this regard. This is a significant challenge for the Garrett Global Bearing Systems team but we are working hard and in strong cooperation with outside universities to build robust and validated software. Predictive tools to help to eliminate shaft motion journal bearing system failures are well advanced. Figure 5 (see page 9) shows nonlinear and the high complexity of bearing systems' dynamic behavior, including synchronous, subsynchronous and super-synchronous components.

We can predict reasonably well the synchronous behavior (motion) (fig.6) and subsynchronous frequencies (fig.7). First tentative steps to predict total shaft motion show encouraging results (fig. 8) and we continue to work on improved analytical models. The current process map relies heavily on iterative testing to develop and qualify a new bearing system; the new process will analytically predict the shaft motion. Development of robust analytical tools to predict the performance of the thrust bearing system is another challenge. To date significant experimental work and analytical development have been completed. The figure 9 shows predicted thrust bearing oil-film pressure field. Discrepancy occurs between predicted and measured load capacity (fig.10) and improved theoretical models are under development.

The development of bearing systems and rotor-dynamics technology performance tools is a serious commitment to achieve the Six Sigma level for the bearing system designs, develop rotor-bearing systems advanced technology and to meet customer satisfaction and benchmarking activity.

What is the customer reaction to the development of Bearing Systems & Rotor-dynamics technology performance tools?

True partnerships are founded on sharing knowledge and know-how. At Garrett, this translates into anticipating the needs of customers and developing the right strategies to meet their needs ... based on programs that will advance boosting technology.

Our work to date has provided considerable experimental and predictive data which, when shared with customers, has produced very positive reactions. Such an approach – augmented by customer objectives and suggestions - is adding value both to the technology and the relationships with customers.

Figure 8

Waterfall of predicted shaft motion

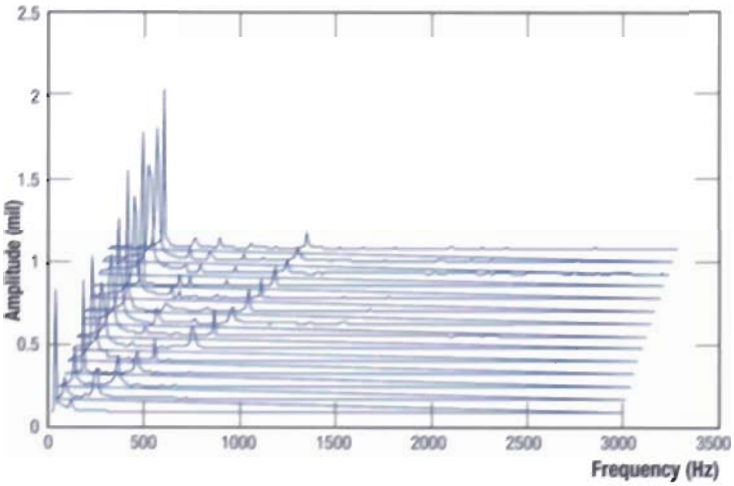


Figure 9

Predicted thrust bearing oil-film pressure field

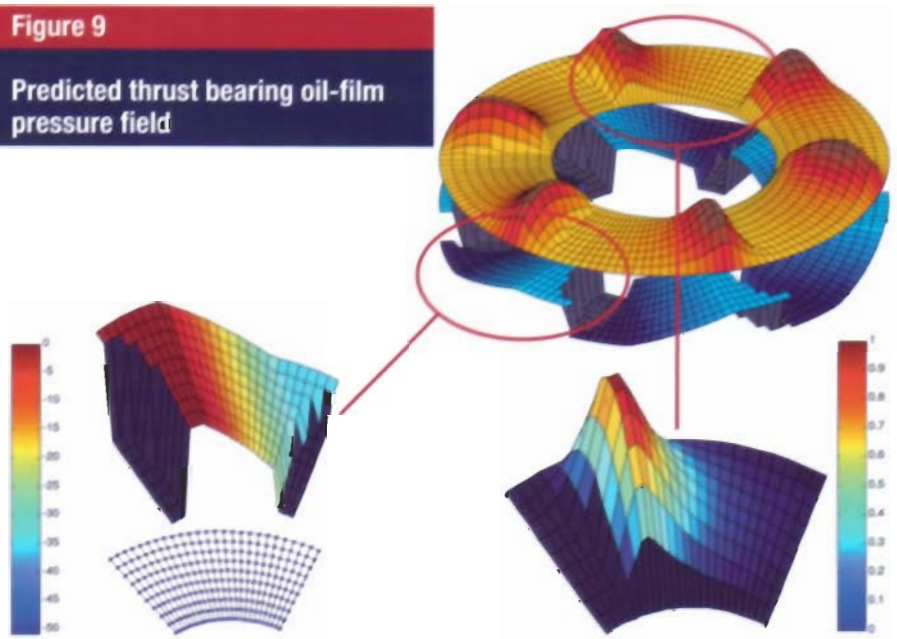
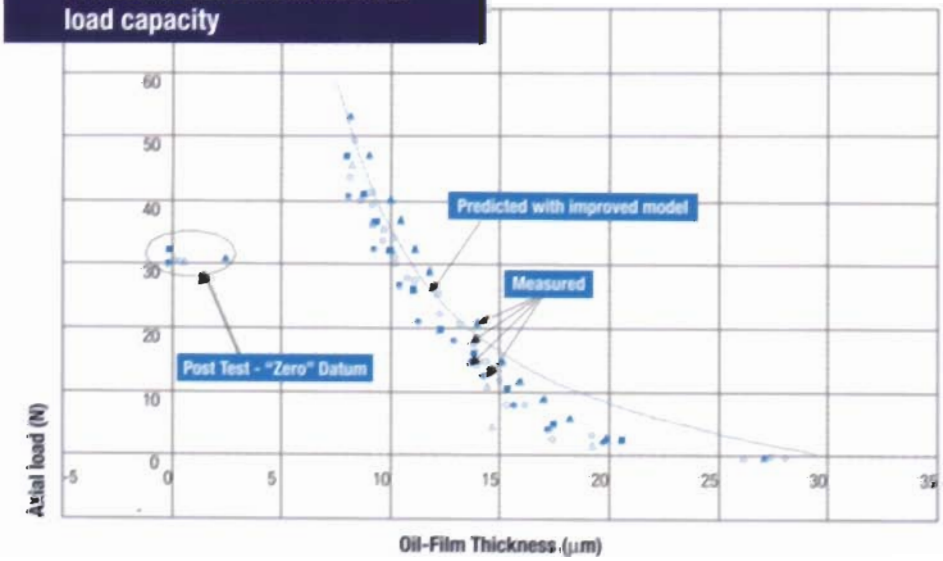


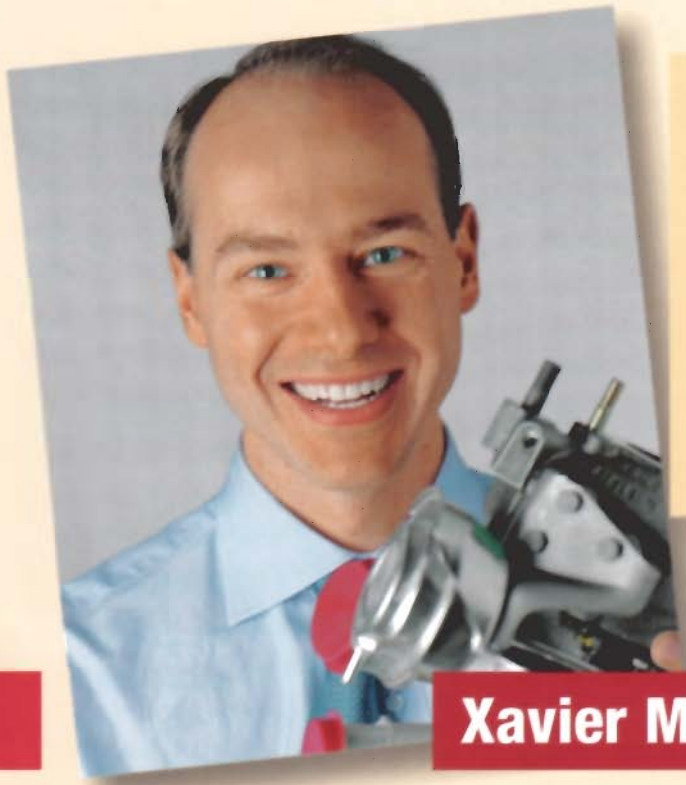
Figure 10

Predicted and measured axial load capacity



Connecting

■ Making the difference through a common visio
■ Shared valu



Enthusiasm, commitment, innovation ... three attributes at the heart of the Honeywell business culture. Fine words. But travel to any of Garrett's worldwide facilities and there you will find people who demonstrate what makes the business special.

Xavier Mathevet

Xavier Mathevet is passionate about innovation, technology ... and cultural diversity. So when the opportunity arose to join Garrett, he jumped at the chance. A graduate of the Engine School of France, Xavier spent the first four years of his working life at Renault working on diesel engines. With Garrett he saw an opening in an international environment that would take him closer to the customer.

Xavier, 33, is based at Thaon-les-Voges, where he is supporting projects with Toyota and Isuzu. For him, working with the customer is about much more than boosting technology – it's about developing partnerships and seeking new ways of providing the competitive advantage that they seek. What also excites him is the cultural diversity he experiences.

"It's a fantastic business to be in. We share the expectations and aspirations of our customers, we use our technological know-how to contribute to their success ... and we do this by always pushing the boundaries through innovation and technical excellence."

"What's great about Garrett is the support I receive in pushing projects forward, in being given the responsibility to take decisions that make a tangible difference to customers. I think of it as a spiral of success...always moving upwards and ever closer."

Anton

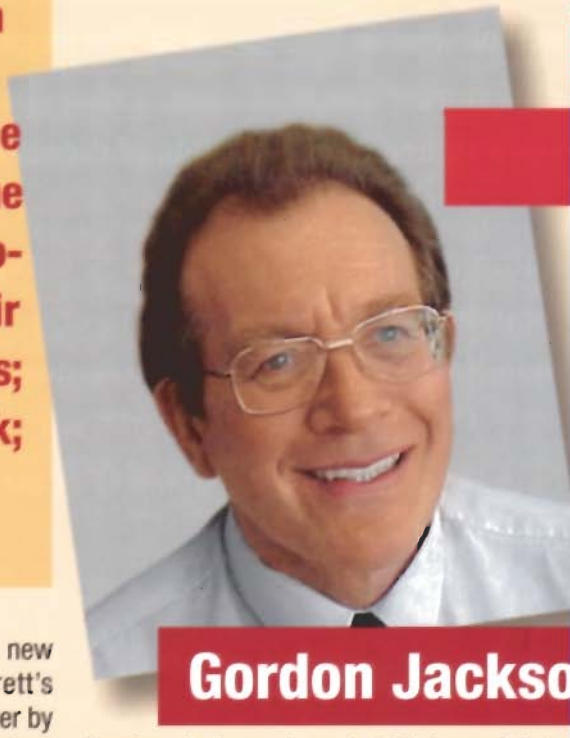
Enthusias

Commitm

Cultures

rooted in customer partnerships

It is these shared values that will this year form the platform of a new corporate advertising campaign that acknowledges that it's people who make the difference. People whose combined skills make the company what it is and who define the nature of the partnerships built with customers, suppliers and co-workers. Here, three Garrett people reflect on their experiences - each at different stages in their careers; each individual in the skills they bring to their work; but together part of a network that places the customer at the heart of everything that is done.



Gordon Jackso

Antonio Falchi personifies the spirit of Honeywell. Antonio joined Garrett 11 years ago, following in the footsteps of his father who worked with Garrett for 15 years.

At first his time at Thaon-les-Voges was spent in the workshop, learning his trade in the machining area and assembly line, but then his manager spotted that Antonio had the essential qualities that define the Honeywell culture – enthusiasm, commitment and motivation. At his suggestion, Antonio started out on a major change in career direction.

Falchi

With the full support of Garrett, he went back to college for two years, splitting his time studying for a business degree and working with the Garrett VW customer team.

"Garrett identified that I had potential – but ultimately it was down to me to respond to the challenge and to demonstrate that I could add value to the company by taking on new responsibilities," says Antonio. Garrett's investment was returned many times over by Antonio, who gained his degree and then joined the company's Purchasing Department as a Buyer.

But in many ways, that was just the beginning. Now 30-year-old Antonio is going still further with Garrett's support. He's studying for a Masters degree in Purchasing ... and also spending every Monday improving his English language skills.

"I feel that I am living a real dream with Garrett – and it's the same for everyone in the company who demonstrates a real determination to progress. But what I really enjoy about the work is the human relationships we form with customers and suppliers – the fact that I can speak with people in Italy, France, England, Germany and the US all in one day. It is this diversity that makes Garrett so special."

Gordon Jackson, based at Skelmersdale in the UK, is as enthusiastic today about Garrett and boosting technology as he was when he joined the company 30 years ago.

What stands out above all else for Gordon is Garrett's commitment to investing in the best – the best technology, the best equipment and the best people.

"My work with Garrett has taken me far and wide... but wherever in the world you meet Garrett people you share a sense of a common purpose founded on enthusiasm for the technology and commitment to the customer."

"Even now, after 30 years, I still get the same buzz out of my work – tackling technological challenges, working with customers to find shared solutions to problems."

nt Innovation

Boosting
The Public Percepti

Three years ago, Garrett became a founding member of the Diesel Technology Forum (DTF), established in the United States to counter the misinformation that existed over the environmental credentials of diesel engines.

Automotive manufacturing and component industries, diesel fuel refiners and manufacturers of emission treatment systems joined forces to create the DTF with a mission to present the positive aspects of clean diesel technology.

In particular the DTF focuses on: championing environmental stewardship; supporting scientific inquiry and discussion; and sustaining worldwide economic growth by demonstrating advanced diesel technology.

Allen Schaeffer, Executive Director of the DTF, spoke to Garrett Booster Magazine about the considerable impact that the DTF is having on attitudes over the adoption of diesel technology – in particular in campaigning on the 'clean diesel' proposition.

1. What drove the formation of the Diesel Technology Forum?

In 1999, there was a growing concern about the persistent and worsening reputation of the diesel engine. This was based largely on a steady drumbeat of misinformed, outwardly biased and negative media coverage about diesel engines, without a countervailing voice from the diesel industry.

2. How does the DTF seek to address this misinformation?

The primary activities are to educate policymakers (elected officials, regulatory officials) and the media about the value of diesel technology, how much progress has been made in improving the technology. We reach out to potential allies – users of diesel products and others, to educate them about the value of diesel – and conduct major meetings involving elected officials, policy-makers and industry to discuss policy and technical issues as they relate to diesel. We conduct a "24/7" news monitoring service that identifies media coverage on any diesel issue around the country, affording us an opportunity to respond rapidly to developing stories. We also support symposia and forums where diesel issues can be discussed, and conduct public opinion research regarding public attitudes on diesel. We promote a greater role for states to target diesel trucks and buses that are gross emitters – improperly operated or tampered with, that emit excessive black smoke. Here, we have developed model legislation and a host of information on our website.

3. The take-up of clean diesel technology in passenger cars in the US seems to lag a long way behind Europe, why is this?

Several reasons. First, the US has evolved into a gasoline-driven economy, with gasoline as the predominant transportation fuel for personal transport. The tax structure in the US also does not make an economic case to favor diesel over gasoline (as are the structures in Europe). Also, US consumers have no familiarity with diesel as an option for personal transportation use, so they have very limited understanding of the advantages of a diesel and

Clean diesel campaign targets media and policy-makers

Turbocharging acknowledged as a technology of the future

n Of Diesel In The US

the tremendous advance in clean diesel technology overall. But we're hoping that is going to change shortly.

4. Are there cultural differences between US and Europe that affect diesel take-up?

Europeans are more conservation-oriented in overall terms of their consumption. They have cars that consume less fuel, have lower impact on global warming and keep them for several years. In the US, there is a greater trend toward short term investment in personal transportation – fueled by shorter leasing and financing terms, and no real connection with global warming concerns. Also, there has not been a culture or climate of anti-diesel sentiment in Europe as in the US, where environmental and other public interest groups have used fear and misinformation to attack diesel technology in the media and before policy makers.

5. What are likely to be the key drivers in the US that will encourage greater adoption of clean diesel technology?

A significant rise in prices for gasoline, instability in the Middle East and an increased interest in reducing US consumption of foreign oil are all major drivers towards US policies that encourage fuel conservation. The US continues to have a significant focus on light trucks and sport utility vehicles, which are very suitable for the use of clean diesel products. In addition, the role of manufacturers in communicating the value and attributes of diesel products and in demonstrating that they are high-performance machines that are fun to drive will be vital.

6. What is DTF doing to support diesel take-up?

Getting out the facts on clean diesel technology is job #1. To do that, we use a number of tactics. We've created a tremendous information portal at www.dieselforum.org to provide fact-based information about clean diesel technology. We have also initiated research to fill the information gaps about the economic importance of diesel technology, its continuous improvement toward lower emissions, and its prospects for use in light duty diesel applications, in a paper called "Demand for Diesel: The European Experience." We have held technology demonstrations – otherwise known as 'ride-n-drives' to allow key policymakers, elected officials and the media the opportunity to experience modern clean diesel technology first hand. We have also spent a tremendous amount of time educating reporters and journalists because this audience has the ability to reach out to their readers and viewers and communicate the key messages about clean diesel technology.

7. What specifically needs to be done to promote diesel technology in the US?

Policymakers and the public must be educated about the benefits and value of modern clean diesel technology. At this time, while the next phase of engine emission standards for diesels appear very challenging, there is not a move to challenge the regulations – there is a strong view that the diesel should compete on equal footing with gasoline engines, and having the equivalent standards is one way of doing that. There very likely needs to be a supply of cleaner diesel fuel (lower

Boosting

The Public Perception Of Diesel In The US

in sulfur content) available on a widespread basis prior to the introduction of advanced clean diesel technologies. This is now a federal rule that will become effective in the fall of 2006 and require 80% of all diesel fuel sold in the US to have sulfur levels that do not exceed 15 ppm. The lower sulfur fuel enables the use of after-treatment technolo-gies that will likely be needed for the diesels to meet the very low emission standards for nitrogen oxides and particulates.

8. How will the situation have changed by the year 2010?

By 2010, thanks to cleaner diesel fuel being available for over three years, it is our expectation that there will be a dramatic increase in consu-mer vehicle choices for clean diesel technology in cars, trucks and SUVs. We anticipate that there will be a dramatic shift in public knowledge towards this advanced technology.

9. What indicators exist now of a change in public perception?

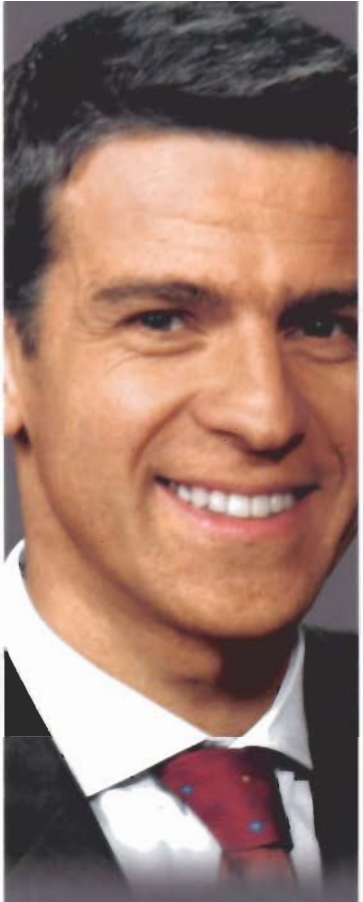
Good progress has been made in last three years. A recent survey showed that 26% had recently heard the phrase 'clean diesel'. People are beginning to listen to the arguments and understand that this is a clean technology. In addition, we have seen a 42% increase in the number of stories written in the media about clean diesel and these now number several hundred every year.

10. How is turbocharging technology viewed among consumers?

Engine boosting technology is a critical element in enhancing the perception of diesel engines among the general public. There is no doubt that turbochargers are currently viewed primarily for their performance enhancing qualities, for adding to the fun of driving, and there is more to do to communicate the greater contribution that the technology can deliver in terms of fuel economy and environmental emissions. The DTF will increasingly promote engine boosting as a key technology of the future.

11. What support is Garrett giving to the Forum and the debate on clean diesel technology?

Garrett is a key supporter for the DTF, both in the information the company provides about the benefits of engine boosting systems in diesel engines and in offering access to some of the leading thinkers and opinion leaders in this key area of activity. Garrett is very supportive when it comes to lobbying for clean diesel in the US. Its expertise is invaluable as we go about building our campaign messages on a foundation of fact.



Paolo Carmassi is Vice President, Strategy and Product Management for Garrett Worldwide.

"There is strong indication that clean diesel technology has a promising future in America"

Indu

Diesel penetration of passenger cars is around 2% in the US, which equates to 370,000 vehicles each year out of a total US market of 17 million.

But change is underway – America is showing a renewed interest in the clean diesel technology European auto manufacturers have adopted.

"The reasons for the growing support for clean diesel technology are the same in the US as in Europe - the drive for improved performance, better fuel economy and reduced emissions," says Paolo Carmassi, Vice-President, Strategy and Product Management of Garrett.

There is increasing pressure in the US to improve fuel efficiency as a way to reduce America's dependence on foreign oil. As oil prices keep rising, SUV drivers begin to complain about what they have to pay at the gas pump. "This is pushing government regulators, auto makers and suppliers to seek new technologies that do not

stry Insight

Focus on diesel boosting in the US

require trade-off between fuel efficiency and performance," says Paolo Carmassi, "and diesel is increasingly seen as a viable solution to reducing fuel consumption significantly in the US."

Developing turbochargers for the US market and increasing boosting penetration have been a major goal for Garrett, which is encouraged by the recent favorable attitude toward clean diesel technology in the US. "By managing customers on a global basis" says Mr Carmassi, "Garrett enjoys a unique advantage in serving major global auto makers who have witnessed major consolidation in recent years."

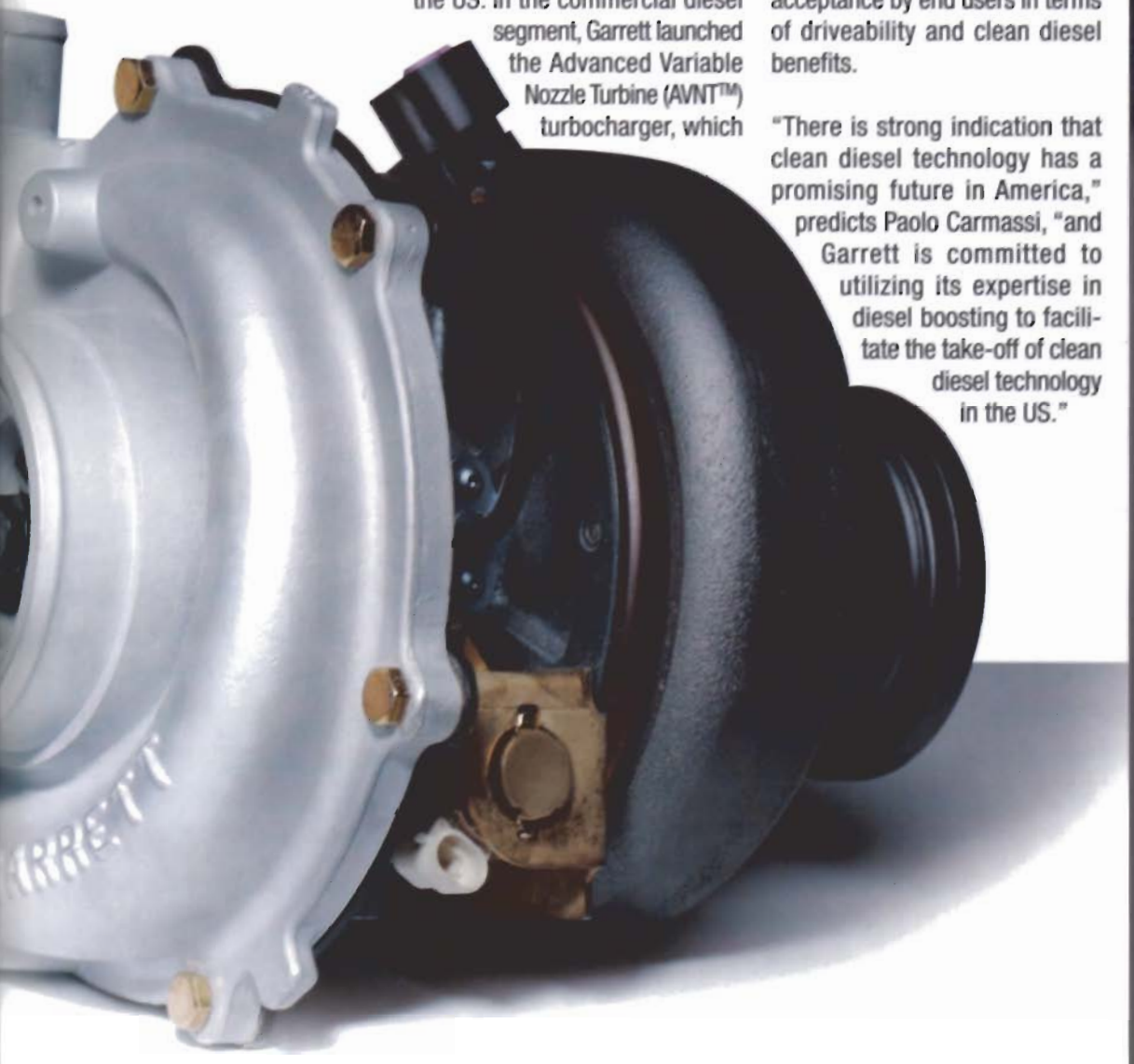
As Alexandre Ismail, Vice President, Sales and Customer Management for Garrett, explains, the company is maximizing the competitive advantage gained in Europe. "Garrett's expertise in diesel turbocharger technology, gained through its European experience, is a strong asset for the company," says Mr Ismail. "The European market has embraced this technology in response to consumer-led demand for diesel engines that are more fuel efficient, perform better and meet stringent environmental standards."

The Garrett experience in Europe directly benefits its activities in the US. In the commercial diesel segment, Garrett launched the Advanced Variable Nozzle Turbine (AVNT™) turbocharger, which successfully adapted Garrett's VNT™ technology for passenger cars to medium and heavy-duty trucks.

As for passenger cars and light trucks, in the coming months, Garrett will be hosting 'ride-n-drive' events for the automakers, US press, regulators and environmental groups with a fleet of both diesel and gasoline turbocharged vehicles to communicate the benefits of turbocharging.

Looking ahead, for US to embrace the clean diesel technology, three major conditions have to be met: better emissions control, availability of clean diesel and the acceptance by end users in terms of driveability and clean diesel benefits.

"There is strong indication that clean diesel technology has a promising future in America," predicts Paolo Carmassi, "and Garrett is committed to utilizing its expertise in diesel boosting to facilitate the take-off of clean diesel technology in the US."



Alexandre Ismail is Vice President, Sales and Customer Management for Garrett Europe.

"Garrett's expertise in diesel turbocharger technology, gained through its European experience, is a strong asset for the company"

Turbine housing machining

For

A World

A highly successful Taiwanese company is developing a global partnership with Honeywell's Garrett business as a result of a forward-looking investment program in China.

Mei Ta Industrial Co Ltd established New Wei San (NWS) to build and run one of Asia's most advanced foundries - and now the China facility is supplying high quality products, including Garrett turbine housings, to a customer base that spans the world.

ging wide Partnership

Turbine housing inspection by CMM

■ World Class foundry supplies Garrett world-wide
■ Continuous investment in people, plant and processes

Mei Ta, which also owns a foundry and machine center in Taiwan, looked to China after plans to expand in Taiwan were thwarted by labor shortages. This also created the opportunity to build a much bigger facility in China – with three automatic molding lines and an output capacity of 4,500 tons per month - which, in turn, would enable the company to maximize its export potential, notably to Europe. The foundry, employing 400 people, is a world class facility which became operational in March 1998. Three years later the partnership with Garrett began, initially through Shanghai and then with Garrett in the US, Japan and Australia. NWS invested heavily in machining equipment to deliver the Garrett contract and soon was also supplying Garrett in France, the UK and Italy, manufacturing turbine housings for a number of projects. In 2003 NWS will deliver 850,000 units to the company. The modern facilities, the company's strength in material development and control, its quality ethos and its continuous investment in new machinery all go to make NWS a key partner for Garrett. Indeed, it is the first foundry in China capable of producing Garrett Ni-resistant castings.

"As a young company, we are quick in learning better ways of doing things and we constantly focus on the quality of the products, our processes and the skills of our people," says Ben Chen, Vice-General Manager of NWS. "The potential for growth, the high quality output, the commitment to our customers and the competitive advantage of China as a location – these are the most valuable things that we offer to customers such as Garrett."

Automative molding line with autopouring equipment

NWS focuses inexorably on customer service and, in the case of Garrett, has organized its internal teams to reflect Garrett's own customer teams. Fast channels of communication have been set up to ensure maximum efficiency between the two organizations. "We share many of the same business principles with Garrett – continuous investment in our people and in plant, advanced manufacturing processes and a focus on customer service," says Mr Chen.

The NWS plans for the future include a multi-million dollar investment program which will shortly double the size of the foundry and will complement a 120 unit machining center, of which one third is given over to Garrett products. It sees China as a vital element in its strategy to supply parts into the diesel market across the world.

Comments Mr Chen: "For NWS and Garrett, this is a 'win-win' partnership founded on trust which delivers significant benefits to both companies."

Eastern

– Bucharest plant benefits from
– Move to eastern Europe heralds

Garrett customers are the focus of a major investment program in eastern Europe that will see the company's Bucharest plant transformed into an advanced turbocharger manufacturing facility. Plans announced recently by Garrett will see manufacturing transferred from Skelmersdale in the UK to Romania in a move that mirrors the strategic direction of many customers.

"'Closer to customers' has long been the concept at the heart of the Garrett way of doing business – whether this be through technological innovation, in a digital environment or in a physical location," says Will Pack, who is leading the Bucharest project for Honeywell's Garrett business.

The multi-million dollar investment plan at the plant in Bucharest will transform the existing component factory into an advanced manufacturing facility capable of delivering some 3,600 turbochargers every day.

Promise

major investment plans closer customer relationships

"The Garrett way of doing business is to take decisions based on benefits to customers," says Mr Pack. " In recent years, there has been a trend among both customers and our supply base towards eastern Europe and we therefore decided to move our manufacturing capacity at Skelmersdale in the UK to our Romanian plant."

Skelmersdale remains a key element in Garrett's world-wide operations, and will continue to work actively with customers and to lead out on key commercial and engineering projects. The decision to invest in Bucharest is a reflection of the company's desire to support the needs of its customers as fully as possible. "Our strategy is to focus on delivering high quality products to customers, with service levels to match, and in Bucharest we believe that we have a facility that hits the mark in every respect."

Honeywell's Garrett business originally bought the Bucharest facility in 1996, since when it has been highly successful as a component supplier to European assembly plants. People at Bucharest share the Honeywell mindset and the Garrett culture of quality and innovation.

Indeed, the Bucharest site already enjoys a reputation for excellence, founded on a highly skilled workforce of engineers and technicians

whose aerospace engine background promotes a culture of excellence. These skills will augment the established Garrett manufacturing processes, quality systems, reporting procedures and customer knowledge that will be cascaded throughout the Bucharest operation.

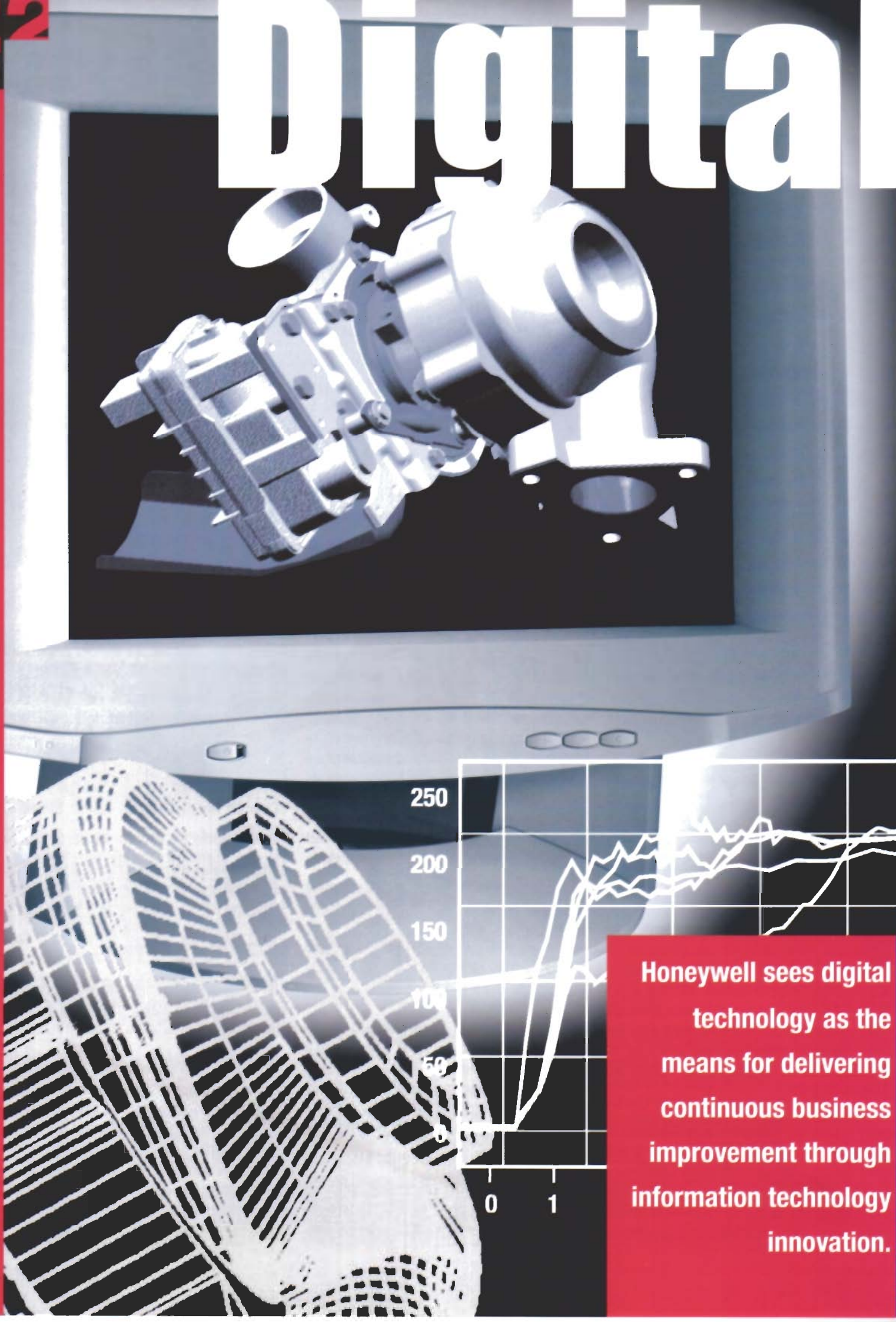
The result will be a seamless transition for customers in the supply of turbochargers – an investment that will bring together the best of Garrett worldwide in an eastern European location.

In operational terms, Bucharest will play a vital role in fulfilling the requirements of customers, supplying 3,000 turbochargers every day to the passenger car market and 600 to commercial vehicle customers.

The local management and workforce are excited by the prospect of playing such an important role in the future of Garrett in Europe.

"Our experience and technical know-how in advanced aerospace technologies creates the perfect foundation for the work that lies ahead", comments Gheorghe Dudau, the Bucharest Plant Manager. "This investment presents an enormous opportunity for our people to contribute to the success of our customers and to their own future... and we are very much looking forward to doing just that."

Digita



Honeywell sees digital technology as the means for delivering continuous business improvement through information technology innovation.

Mock-Up Promises Real Time Benefits

New technologies to improve real time interaction with customers

High speed pathways to share project data

Digital technology increasingly binds businesses together - now Garrett is investing in a new concept that will deliver 'real time' product design benefits to customers.

'Digital Mock-up' brings together all the elements of a customer project in a virtual location and provides the means for partners to modify elements of the masterplan in 'real time.'

This new dimension in sharing data looks set to alter radically the way in which Garrett works on projects with its customers. With 'Digital Mock-up' comes the ability to collaborate in cyberspace in a shared environment ... in real time.

Daniel Geny, who leads Garrett's design technology & productivity, explains:
"Historically, we have built 3D CAD models containing all the ingredients of the boosting technology required by the customer – and this has been sent to customers using conventional low speed telecommunication data transfer. Digital Mock-up changes all of this. It means handling live data. With CAD, the information can quickly become out of date if any of the project parameters are changed. There are no such problems with Digital Mock-up. The customer hosts the entire project digitally and grants partners such as Garrett the ability to access specific areas in real time so that the information held is always completely up-to-date."

Changes to project specification made in consultation with the customer are automatically reflected by the Garrett design community in the Digital Mock-up – and not just in terms of a visual image but in expressing the entire product structure. The major advantage of this concept to customers is the ability to design in real time – and that holds the prospects of significant benefit in the product development cycle because synchronization is immediate. In theory it is possible for several thousand engineers to be working in parallel.

Says Christophe Huerre, Honeywell's Information Technology Director for the Garrett business in Europe: " Automotive manufacturers have been testing the concept of Digital Mock-up internally for some time, but now the speed and security of data transfer makes it possible to increase on line collaboration opportunities with their suppliers.

Accordingly, Garrett is investing heavily in its communications infrastructure and software in keeping with its 'DigitalWorks' program. The company is connected to the European Network Exchange (ENX) and its equivalent in Japan (JNX) as a means of linking its design centers to customers.

"Such investment brings the concept of the 'extended company' one step closer – an environment where businesses are joined seamlessly through digital highways that enable the sharing of appropriate information and skills," says Mr Huerre.

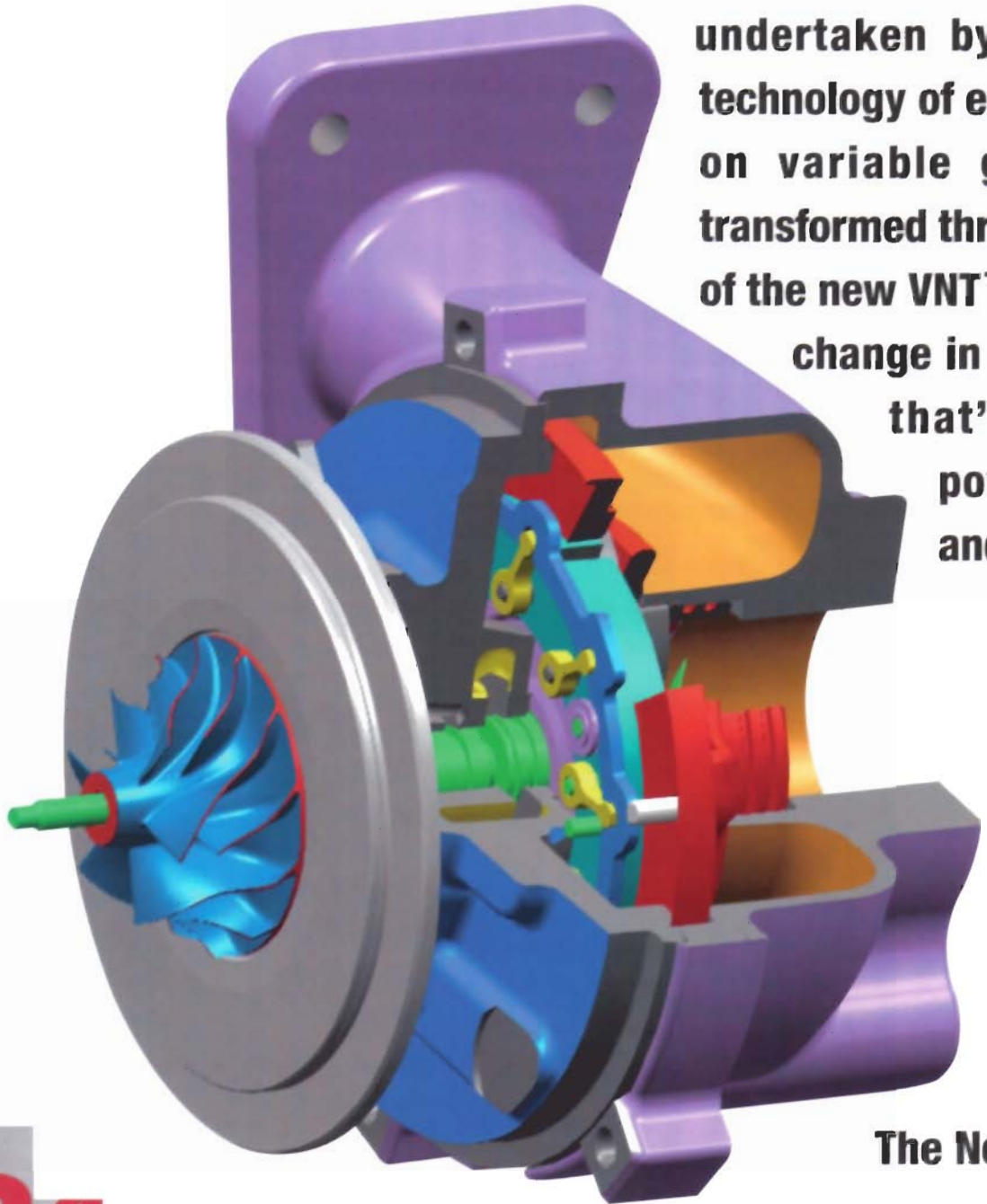
"The goal of such relationships is always the same – to reduce product cycle time, improve quality, enhance knowledge ... and to develop better real time interaction with customers."

As such, it is embracing the concept of becoming truly a digital company through its DigitalWorks program. DigitalWorks is about much more than technology. While hardware and software are clearly important, DigitalWorks is a multi-layered approach to digital integration that places people and their capabilities at its heart. Central to the program is the concept of internal globalization – an ability to share data with thousands of people across the world simultaneously. A prime example of this is the Product Data Management (PDM) initiative, an investment in a huge database of Garrett product specifications that is continuously updated and keeps more than 1,000 engineers and technicians fully up-to-date. The DigitalWorks program is driving process improvement throughout Garrett, whether this be in electronic 'call-off' of product by auto manufacturers; the management of inventory and shipping; the ever increasing automatization level of manufacturing activities or the e-Partnerships established with key suppliers that enable them to gain access to planning and delivery data. Out of such an approach come clear efficiency gains ... and the ability to add value to customers.

Step Chang

- 'Cartridge' design creates new performanc
- Customers play key role in third generatio

Garrett is refining its world-renowned VNT™ technology – with a new generation turbocharger that's delivering the best performance yet for customers. As a result of one of the most intensive testing programs undertaken by the company, the technology of engine boosting based on variable geometry is being transformed through the introduction of the new VNT™ 'cartridge' - a step change in turbocharger design that's delivering more power, more efficiency and enhanced reliability.



VNT™ Step 3:
The New Cartridge Concept

e In VNT™

platform
urbocharger

It was Garrett's introduction of VNT™ turbochargers that created a key industry breakthrough of the 1990s, making it easier for car manufacturers to fully deploy the torque and fuel economy advantages of direct injection diesel engines. The variable geometry technology was an instant success, quickly adopted by many car manufacturers. The system was unique in that it involved the use of a turbine housing that changed its internal configuration to adapt to variations in the engine's air boost requirements.

VNT™ technology enables the turbocharger to supply greater engine boost at lower speeds than a smaller unit, while matching the performance of a larger turbo at higher speeds.

The next stage in VNT™ development was brought about by the introduction of electronic control in line with the newer injection systems that required more dynamic response.

Now the third generation takes a fresh new look at VNT™ – and delivers the best performance and most robust design yet. VNT™ 'cartridge' is ground-breaking in that it attaches the VNT™ mechanism onto the bearing housing through an 'elastic' shroud. This new 'platform' has spawned several high performance innovations - a new vane shape, a new generation turbine wheel and better controllability ... all combining to deliver 130% of second generation VNT™ boost levels at just 90% of back pressure. VNT™ 'cartridge' is the achievement of a project involving thirty people from Europe and the US - designers, engineers, manufacturing specialists and supply base teams all working together on a radical approach to VNT™ progression.

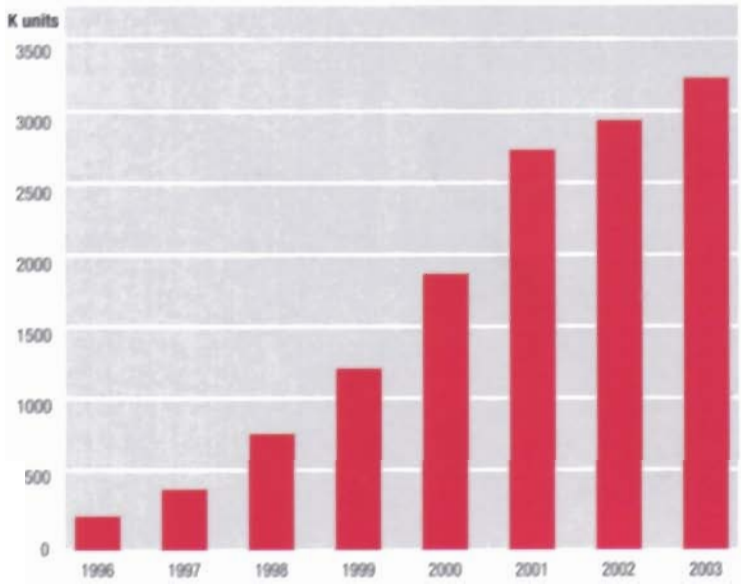
It has been developed specifically to meet the customers' needs coming from the trend towards smaller, cleaner and better performing engines. In addition, because VNT™ 'cartridge' doesn't use the turbine housing as a mechanism holder, this housing can now be made out of sheet metal, which is lighter in weight and provides a faster catalytic light-off.

Extensive testing confirms the higher boost level being achieved through VNT™ 'cartridge'. Based on the success of the 'cartridge' concept, a full range of turbochargers covering all engine ranges from 1 to 3.5 liters displacement is being made available for the first production launch during 2004.

"Customers really like the evolution of VNT™ into the 'cartridge' " says Denis Jeckel Worldwide Product Line Director. "For Garrett and for manufacturers, this project demonsfrates that we are anticipating the engine trends of the future and building on the great success of VNT™. We recognize that the journey is not yet complete ...but together with our customers we aim to exploit fully the potential of this technology which is an integral enabler in meeting stringent emissions regulations."

VNT™ Step 2: Nozzle bolted in the Turbine Housing

The Garrett VNT™ Success Story



The Six Sigma

Taking the holistic approach to quality ■ 'Right fi

A genetic code; the language of quality; a philosophy of excellence...no matter how you describe Six Sigma it boils down to one central business principle – meeting the needs of customers.

Six Sigma is about making every area of an organization better able to respond to the demands of customers, markets, and technologies - with benefits for employees, customers and shareholders. That's why Honeywell is a global advocate for Six Sigma – and constantly reviewing the way it manages its business. In Honeywell, the program was used initially to resolve issues relating to manufacture, primarily through the principles of Define, Measure, Analyze, Improve and Control (DMAIC) and then through the implementation of 'lean' to drive out waste and improve quality. But that was only the beginning. Honeywell recognized that Six Sigma in the manufacturing process could not alone deliver the ultimate objective of the program: the achievement of 3.4 defects per million.

As Russell Stoddart, Garrett's Vice President Six Sigma Plus explains, this will only happen once the program pervades every area of Garrett. Increasingly, this means focusing on the 'front end' through programs such as 'Green Belt for Growth' and 'Design For Six Sigma' (DFSS).

"Green Belt for Growth is critical to the entire Six Sigma ethos, concentrating on the market viability of potential products, assessing whether there is a demand for them before we commit too many resources. Then DFSS ensures that the products taken forward actually meet the needs of the customer – not the needs of Garrett's capabilities."

DFSS helps Garrett get much closer to the customer at the beginning of the product development cycle – to understand their requirements and to factor these in. DFSS introduces innovative diagnostic tools to help engineers gain a better understanding of customer priorities – and sets the entire production process within the framework of mutually agreed objectives.

At the heart of Six Sigma is the commitment of people to make it happen. Key individuals receive intensive training to become experts in specific areas. These are the organization's Black Belts and they learn in-depth the tools and techniques needed to carry through the Six Sigma advantage.

Then there are the five 'masters' who act as worldwide consultants to the entire organization – the in-house 'gurus' who are purely project focused.

Such a quality ethos could not work in isolation and Garrett provides significant hands-on support to key suppliers across Europe to spread the culture of Six Sigma. At the other end of the spectrum, Six Sigma binds the company to many of its customers by defining the language of quality.

"Six Sigma is a total management commitment and philosophy of excellence, customer focus, process improvement and the rule of measurement rather than gut feel," says Russell Stoddart. "Its key strength is that it is an exact science. It defines the standards we must achieve."

Way Of Life

ime' culture defines customer relationships

Garrett's Six Sigma Specialists

Green Belt: Someone trained in Six Sigma tools, often to the same level as a Black Belt, but the Green Belt still has a regular job and serves either as a team member or a part time Six Sigma leader.

Black Belt: This person leads, inspires, manages, delegates, coaches and supports colleagues and becomes expert in tools for assessing problems and fixing or designing processes and products. The Black Belt works alongside a team assigned to a specific Six Sigma project, gets the team started, building their confidence, observing and participating in training, managing team dynamics and keeping the project moving to a successful conclusion.

Master Black Belt: A coach and mentor or consultant to Black Belts working on a variety of projects. This person is a real expert in Six Sigma analytical tools, often with a background in engineering or science. The job is to ensure that the Black Belt and his or her team stay on track, complete their work properly and pass milestones. Provides advice and even hands on help in collecting and analyzing data, designing experiments and communicating with key managers.

Support for the Supply Chain

The goal of Six Sigma is to support people and processes in delivering defect free products and services. Six Sigma recognizes that there is always some potential for improvement, even in the best run processes or best built product. But at 99.9997% performance, Six Sigma sets a performance target where defects become almost non-existent. Part of Garrett's Six Sigma culture involves investing considerable resources in its supply chain – and that includes providing hands-on support to suppliers to create the environment for strategic improvement for their businesses. In one recent example, Garrett worked with a supplier in Europe to introduce elements of Six Sigma into the company's processes. Garrett quality experts helped the supplier to focus on the issues that were affecting performance, including factory lay-out. Improvements followed ... so much so that the business was named Best Performing Supplier of 2002.

Such partnerships with key suppliers create genuine and lasting quality gains, with vital skills for managing such change transferred to in-house staff.

The Benefits of Six Sigma

Every member of the Garrett cross functional team working on the new generation VNT™ turbocharger was trained in Design For Six Sigma. The DFSS tools had an immediate impact, focusing on the customer requirements for higher performance, high exhaust gas temperatures and packaging flexibility. DFSS helped the team to gain a better understanding of the customers' real needs, which were then factored into the project. Many of the key features of the new design resulted from the use of DFSS tools – for example, the elastic shroud holding the nozzle results in a reduction of the nozzle deformation of 50 % and negates vane sticking. Leakage between the cartridge insert, - "the heart of the concept" - and the turbine housing would directly affect the turbine stage efficiency and therefore had to be kept as low as possible. At the same time clearances were required to ensure both mechanical and thermal decoupling of the insert. The use of DFSS tools helped verify the success of this element of the project and contributed fully to the full back disk turbine wheel design and the cambered vanes command mechanism. In summary, improved and optimized solutions were selected and variability reductions achieved, so delivering improved quality and performance to customers.

What Exactly is Six Sigma?

Six Sigma is a business strategy that links together people, processes and products. Six Sigma puts the customer first and uses facts and data to drive better solutions and focuses effort in three main areas:

- Improved customer satisfaction
- Reduced cycle time
- Reduced defects

Three key characteristics separate Six Sigma from Quality programs of the past:

- Six Sigma is customer focused
- Six Sigma projects produce major returns on investment
- Six Sigma changes how management operates (Six Sigma is about putting into practice the notions of working smarter not harder)

Six Sigma plus