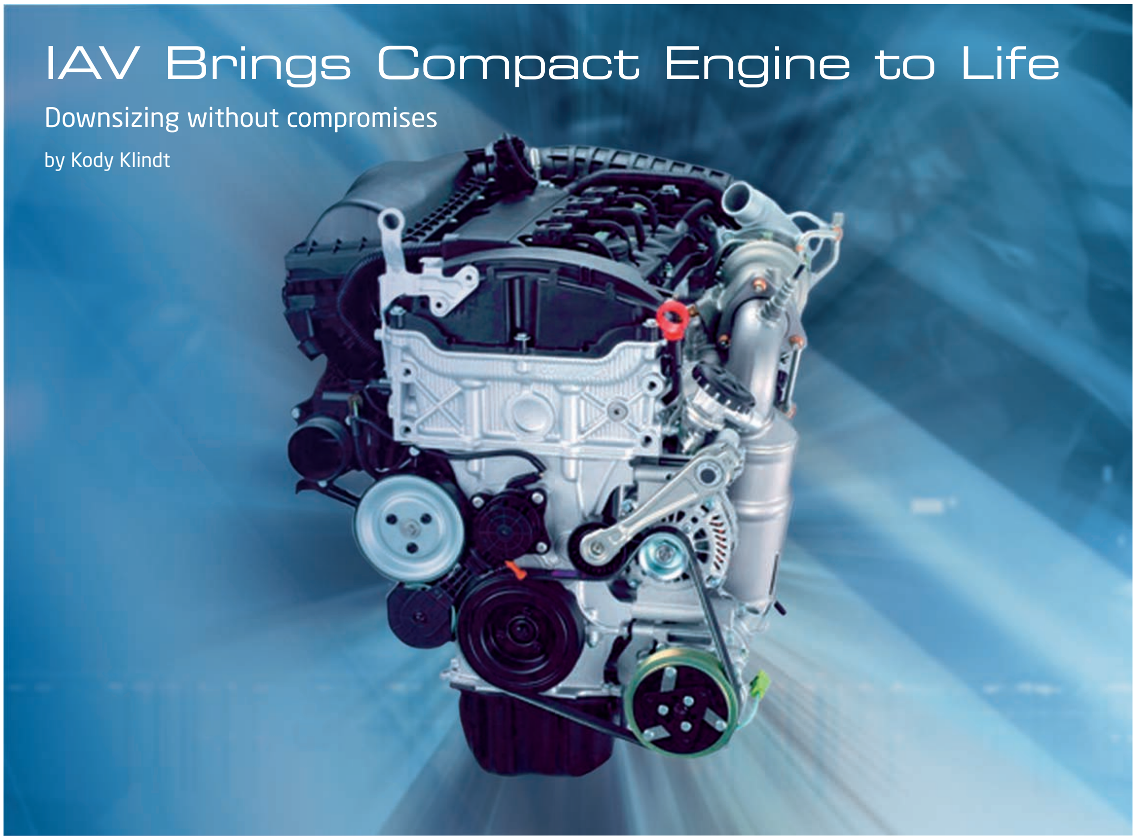
automotion

Excellence in Automotive Research & Development · IAV Customer Newsletter · 02-2009

IAV Brings Compact Engine to Life

Downsizing without compromises

by Kody Klindt



With new regulations being imposed on vehicle manufacturers all over the world, two companies, BMW Group and PSA Peugeot Citroen, have partnered and directed IAV to support them in meeting the requirements with an innovative family of gasoline engines. The new engine family brings together some of the most advanced technologies from both companies.

IAV was tasked to combine each company's strengths and to create two engine variants, each showcasing aspects of the new technology. The two variants provide the bases for a new class of powerful, fuel-efficient units in the small car segment: a normally-aspirated engine with fully variable valve train, and a turbocharged direct-injection engine.

Normally-Aspirated Engine with Fully Variable Valve Train

With a displacement of 1.6 liters, the normally-aspirated engine delivers maximum output of 115 bhp at 5,700 rpm and maximum torque of 118 lb-ft at 4,250 rpm.

Using BMW technology from their latest generation of straight-six gasoline-powered engines, IAV incorporated a fully-variable valve management to control the engine output by adjusting both valve lift and the valve opening duration. The approach significantly lowers engine pumping losses by removing the throttle, which reduces fuel consumption and exhaust emissions and also improves the engine response. The new engine design also includes a new fully-controlled variable displacement oil pump and an on-demand water pump which acts to reduce engine friction – and emissions - by maintaining the engine at its most efficient operating temperature.

High Performance Turbocharged Engine with Direct Injection

With a displacement of 1.6 liters, the direct-injection high-performance gasoline engine combines a turbocharger and an intercooler to produce a maximum output of 143 bhp at 5,500 rpm and a maximum torque of 177 lb-ft from 1,400 rpm to 4,000 rpm.

The new twin-scroll turbocharger provides two separate paths for the exhaust gases to enter the turbocharger turbine and spools up responsively at engine speeds as low as 1,400 rpm.

The new turbocharger, together with the direct-injection common-rail system, are major technological contributions to the new small engine family. They allow the engine to achieve excellent fuel economy, improved emissions and a high specific engine output.

Both engines are very compact and fit easily into many different engine compartments. Weight reduction was also a major consideration and lead to IAV optimizing the design as an all-aluminum architecture.

These key factors together make the small engine family the new benchmark in the compact car class and, not surprisingly, for future engines around the world.

As a leader in advanced engine concepts and design, IAV carried out most design work and mechanical development for both engines and helped the BMW Group and PSA Peugeot Citroen's new small engine family become world class.

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Editorial

Dear Readers,

The first six months of 2009 have been a most difficult test for the automotive industry, almost bringing it to a breaking point. With the bankruptcy of GM and Chrysler, the industry came to a halt and with it came the realization that the approach of the last 10 to 20 years no longer works.

After several weeks, a new Chrysler and GM emerged from bankruptcy - marking a turning point and creating hope for a new start and a better future for the automotive industry. New products have been announced and, from what I have seen so far, confirm predictions that the future models of US carmakers are right on. An important factor is that such new products have regained their own character, a quality which was notably absent in most of the cars built in the eighties and nineties.

Key now is to develop a sustainable approach to ensure that:

- National energy policy supports the purchase of newly developed "green" products required by recent legislation (e.g., by providing a floor on fuel prices)
- OEMs and suppliers work together most effectively in a complementing partnership
- Fuel efficient, yet exciting cars are developed, potentially becoming a part of the entire energy/transportation infrastructure (infotainment systems, smart grid etc.)

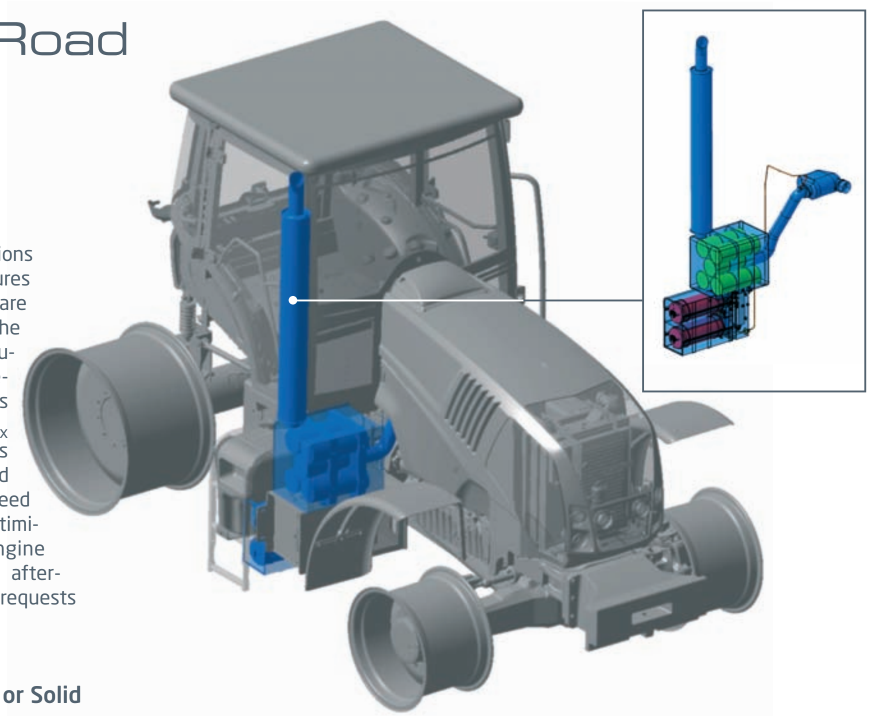
IAV is prepared and ready to assist our customers in ensuring that the US car industry gets back on its feet. It is for exactly this reason that IAV's Technical Center was designed and built. IAV's team is here to work with you on future programs and master any upcoming challenges by providing outstanding engineering expertise, combined with the latest engine development and testing capabilities; please see corresponding articles in this issue of **auto**motion.

Utz-Jens Beister
President of IAV Inc.

SCR Systems for Off-Road Applications

Advanced development methods save time and money

by Peter van Horrick and Yinyan Huang



New emission standards for off-road vehicles and machinery, such as those in agriculture and construction, require the advanced exhaust gas aftertreatment systems necessary to reduce emissions. To reduce NO_x emission from off-road applications, SCR provides an interesting and promising solution - although a number of technical challenges must still be resolved.

In both Europe and the US, legislation in the past 15 years has significantly tightened emissions regulations for both on-highway and off-road engines and vehicles. However, the on-highway market has seen tighter levels introduced at a faster pace with the off-road market following with similar standards after a few years' delay.

Off-Road Emissions Standards

In Europe, Stage 3B (from 2010) and Stage 4 (from 2013) emissions legislation will soon be implemented. In the US, Tier 4i will phase in for most engines during 2011/2012 with final Tier 4 taking effect in 2014. The new standards will significantly reduce the emissions of off-road vehicles and machinery. Currently, off-road emissions certification covers only steady-state engine operations. With Stage 3B or Tier 4, the emissions certification will include transient engine operations. The NRTC test cycle (Non- Road Transient Cycle) was developed with close cooperation between the US Environmental Protection Agency (EPA) and the European authorities. In the future, NO_x emissions will be strictly limited for any engines rated above 56 kW. To meet these NO_x emissions limits, both in-cylinder measures and aftertreatment systems are needed. At the same time, the demand to minimize greenhouse gas (CO_2) emissions becomes important. This creates a trade-off between NO_x reduction, manufacturing costs and operating costs (fuel and urea). Therefore, there is a need to create an economically optimized system comprising engine technology and exhaust-gas aftertreatment to satisfy the two requests simultaneously.

SCR Systems with Liquid or Solid Reducing Agents

For the past several years, SCR systems have been successfully used for reducing nitrogen oxide emissions in European highway trucks. Such systems employ an injector to spray an aqueous urea solution (AdBlue) into the exhaust gas stream. The SCR catalyst is installed downstream of the injector at an adequate distance for the reducing agent to decompose into ammonia and disperse evenly in the flow of exhaust gas. Temperature has a major influence on the rate of decomposition and thus on the efficiency of the SCR system. Additional heating strategies are sometimes necessary in cold start emissions tests in the NRTC or at low-load operation.

One drawback of present SCR systems is that significant space is taken up by the AdBlue tank due to the low specific density of ammonia and the need to carry it in sizeable quantities. In many off-road applications, however, it is very difficult to integrate a large tank into the system. In addition, AdBlue freezes at temperatures below minus eleven degrees Celsius, which means that all AdBlue components must be heated.

The disadvantages of "liquid SCR systems" can be avoided by using new types of solid-substance systems. With the new solid-substance systems, NH_3 is stored in solid forms and released as needed for the SCR catalyst. Gaseous NH_3 is then injected directly into the exhaust gas stream. The solid substance systems also have a higher specific density of ammonia. The potential benefits of the solid substance systems for commercial vehicles are being assessed by IAV's Commercial Vehicle Engineering division as part of an internal development project. The focus of the study includes the ammonia/exhaust gas mixture quality, the metering strategy and the efficiency over liquid SCR systems.

Simulation and Modeling Tools

The test results from the project will be used for refining and validating models applied at the commercial vehicle level. Since simulation and modeling can significantly reduce time and cost-intensive testing, it is particularly beneficial for engine manufacturers with multiple off-road applications. Simulation and modeling make it possible to reduce the effort involved in laying out a large number of possible hardware combinations.

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Employee Spotlight: 10 Years at IAV

Celebrating lasting achievements

by Eileen Lord

Cheryl Boland – Vice President Business Administration, Nadeem Ahmad – Manager, Test Automation and HiL and Craig Assenmacher – Test Facility Manager all have cause for celebration: their 10 year anniversary with IAV takes place in 2009. To celebrate, IAV employees came together for a congratulatory barbeque honoring their lasting contributions over the years. As a company in its eleventh year, these valued employees have been with us since the beginning! Each employee was presented with a certificate to commemorate their time with the company.

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Congratulations to Nadeem (left), Cheryl (center) and Craig (right)

What do you remember about 1983?

The founding of a global enterprise

by Cheryl Boland

Do you remember that Apple launched the first personal computer called the "Apple Lisa"? Perhaps you watched as Björn Borg retired from tennis after winning five consecutive Wimbledon championships? Or maybe you stared in awe as the Space Shuttle Challenger made its maiden voyage into space. Some of us even tasted our first McDonald's Chicken McNuggets while catching the pilot episode of the A Team.

For Some, 1983 Will Always Be Remembered as the Year IAV Was Started

IAV GmbH was founded on September 26, 1983 as a private sector research institute associated with the Berlin University of Technology. The inspiration came from Professor Hermann Appel, head of the university's "Automotive Engineering" faculty, and with support from IAV's first shareholders, including Volkswagen AG, the company provided the necessary link between industry and science.

After hiring initial staff members, many of whom are still with the company today, and establishing the first office space in Hardenbergstrasse, Berlin, the company was ready to begin projects. One such assignment was a large scale research project for the German Federal Ministry of Research and Technology and the Berlin Senate Administration for Science and Research in which IAV developed the concept for a twin-engine bus. The objectives were much the same as they are today: reduce fuel consumption, cut exhaust-gas emissions and keep costs in line. The project was challenging to say the least, but - looking back - its positive outcome can be identified as one of the main factors leading to IAV's later success.

1985 Brings a New Chapter and Some New Buildings

IAV's Gifhorn location began in 1985 when a small group of Berlin employees were sent to work in Volkswagen AG's East Office Center to use the firm's facilities for their research and development work. Soon, however, negotiations began with the mayor of Gifhorn to find IAV a more permanent location. What started as a single small building which once served as a youth hostel has, in fact, now grown into the town's largest employer and IAV's largest development center with over 2,000 staff members.

Soon after the expansion to Gifhorn, it became clear that the Berlin location needed to expand as well. After an intensive search, and careful inspection of all available properties, IAV decided on a dump - a coal dump to be exact! The current site of IAV's headquarters was once the location of coal supplies for the City of West Berlin. Now, of course, it provides office space for 935 employees and includes 16 engine test benches, 1 component test bench and 2 chassis dynamometers - becoming IAV's second largest development center.

After the German reunification of East and West, it became clear to IAV that having a location in Chemnitz would be strategically beneficial - as the city was well known for its engineering talent. Since strong ties were already established between IAV and the Chemnitz-based engine development firm Barkas-Werke, it made sense to employ as many of these engineers as possible. Soon the company IAV GmbH Chemnitz was formed, and would eventually become part of IAV GmbH as the third development center. Today the location employs more than 500 people.

From Germany to the World

Just fifteen short years after IAV GmbH first established itself in Germany, it reached out to the world by establishing IAV Automotive Engineering Inc. in the United States on September 17, 1998. IAV Inc.'s first location in Ann Arbor, Michigan was a tiny two room office in a shared office building on Packard Rd., just enough space for the small ten person staff. But within two years, the company had grown to over 20 employees and needed more room to expand. Another location in Ann Arbor saw the company through to 2008, when the next major expansion occurred. Today, IAV Inc. resides in Northville Township, where over 90 employees perform development work using four state-of-the-art test dynamometers.

With the successful US expansion came the desire to be truly global and the South American market seemed the next plausible step. In 2001, IAV established the subsidiary IAV do Brasil Ltda. in Sao Paulo, Brazil. Here, the focus is on diesel calibration in the commercial vehicle sector. After Brazil, IAV set its sights on the UK with the establishment of IAV U.K. Ltd. located in Basildon, Great Britain, 45 minutes outside of London. The UK team primarily focuses on mass-production calibration of spark ignition and diesel engines, the development of exhaust gas after-treatment systems and design work.

From there, IAV's global expansion continued rapidly, with expansion into Korea in 2003, China in 2005, and Japan, India, Russia and France in 2007.

25+ Years of Excellence, Creativity and Dedication

Today, our company employs over 3,000 people in nine countries at 20 different locations. We are one of the world's leading providers of development services with expertise for the entire vehicle. Our core competencies include perfected, production-ready solutions in all areas of powertrain, electronics and vehicle development. Our philosophy has always been to be exactly where our customers need us and this global approach has been a key factor in our success. But no matter how much we grow, one thing remains the same: IAV is a company shaped by the expertise, creativity and passion of its people!

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"Innovation Remains Crucial Competitive Edge"

IAV Bolsters Advanced Development with New Division

by Dr. Joerg Ross and Curtis Collie

Dr. Jörg Ross, head of IAV's new Advanced Development division

Dr. Jörg Ross was appointed head of the new "Advanced Development" division in January. Previously, he was responsible for developing Formula 1 engines at Ferrari. Below, he describes his new responsibilities and how he envisions the future of automotive development:

Dr. Ross, you are the head of IAV's new Advanced Development division. What exactly does this entail?

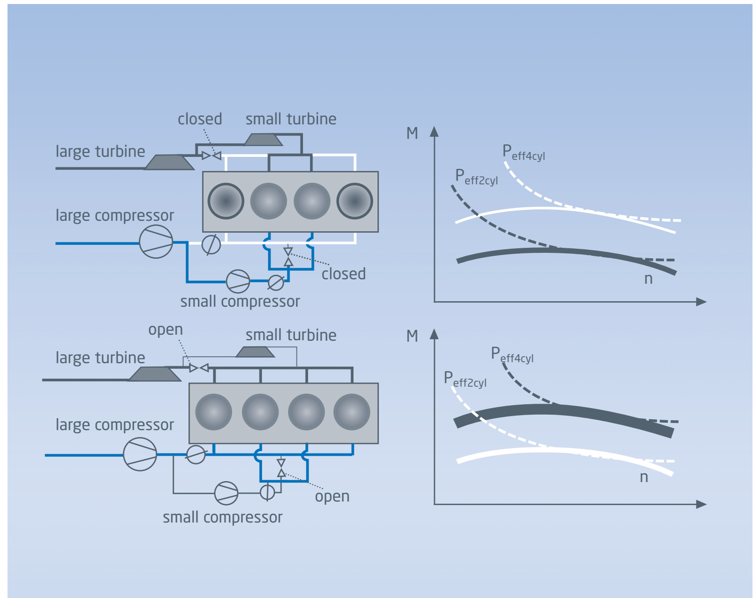
Dr. Ross: In the past, IAV has often been driven by the development projects of its clients. This new division aims to increase IAV's share of concept-related work and, in turn, will help IAV to produce more of its own innovations to offer to clients. I am also particularly keen for these new activities to generate additional business for us – our projects must not only be financed from our own funds, but also through contractual development work. After all, research is not an end in itself and it is IAV's job to push new developments through to mass production.

What time frame do you see for your work?

Dr. Ross: My aim is for the solutions we develop to go into mass production within two to three years. Under no circumstance do we want to embark on activities that might only be relevant in the distant future – if at all. That would hardly be possible either because the new division must focus its attention on projects that promise success.

Question: What aspects do you plan to concentrate on in particular?

Dr. Ross: One of our central goals will be to reduce friction in the engine. Given a better understanding of the processes that take place in the engine and powertrain and using modern coatings, it would be possible to cut emissions by 10 to 20 percent. In addition to mechanical issues of this nature, we will also focus on the thermodynamics of internal combustion engines – this is where modern combustion processes and an optimized charge cycle are of particular interest. The subject of supercharging will also play a central role.



Two-step supercharging for engines with cylinderdeactivation

IAV already has experts in many of these subject areas. How do you see collaboration with existing departments?

Dr. Ross: We intend to work with other specialists as part of a team in the field of thermodynamics, for instance. Instead of reinventing the wheel so to speak, it would also be foolhardy not to utilize the expertise that already exists. And we certainly do not want to look like an "elite troop" at IAV. To get collaboration off the ground, we have already spoken to our colleagues in Gifhorn and Chemnitz, and initial talks with the experts in Berlin have also taken place.

What is your vision of future mobility?

Dr. Ross: The coming decades will continue to see a mix of different drive systems. But the number of combinations will grow: whereas the electric motor assists the combustion engine in today's hybrid vehicles, it could also be, in some cases, the other way around in the future. We will also see more electric cars on our roads, but in 20 years not everyone will be driving one. That will take much longer because huge advances are necessary in battery technology.

The launch of your new division coincides with the deepest post-war crisis economies have witnessed and is producing tremendous problems for automobile manufacturers in particular. Do you see the crisis as a risk to your work or rather as a golden opportunity?

Dr. Ross: Obviously, I would have preferred a better time for the launch. But I feel sure that OEMs will remain open to developments that make sense – after all, they can only stand apart from the competition if they have innovative products that allow them to survive long-term. For me, the difficult underlying conditions are more of an incentive and give me encouragement.

What made you decide to work for IAV?

Dr. Ross: I used to work as part of a small team at Ferrari in Maranello and strongly believe in compact groups. They are very efficient, which is why you can achieve a lot with them. In large organizations, on the other hand, decision-making processes follow 'political' channels that are not necessarily good for the work that goes on. In my opinion, IAV is an ideal employer because the company benefits from lean structures and is highly dynamic. I also know many IAV colleagues from my time in Formula 1, where we worked very well together for many years.

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Dyno's & Donuts

Morning coffee among the machines

by Jeremy Goddard

IAV Inc. is justifiably proud of its new Technical Center in Northville, and we are all enjoying the background sounds of engines under load in the facility's four state-of-the-art test and development cells behind the engineering offices.

On the first Friday of each month, we invite our customers from the OEM and supplier community to come before work and share breakfast with us at IAV in the workshops adjacent to the test cells: Dynos and Donuts. In this relaxed setting before the start of the day, we are able to talk together about what is going on in the industry; to review the effects of new regulations; to debate the benefits of a new technology; and even to discuss first-hand when there might be a test cell available at IAV for a few weeks to meet an urgent need.

Dynos and Donuts will also provide our customers with the opportunity to compare notes in an informal setting, to talk with IAV engineers about new technologies or to discuss the outlines of a new turnkey project being contemplated. We will normally select a theme for discussion together as a lead-in topic of conversation, for example, "The Potential for Diesel Engines in Passenger Cars in North America". We anticipate that having a broader familiarity with IAV, its capabilities and its people for the several companies present will help foster more effective business relationships with them.

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IAV's New Test Cells

State-of-the-Art test and development support

by Kathleen Rafalko

automotion sat down with Dr. Michael Traver, who oversees Testing Services at IAV's Technical Center in Northville, MI, to discuss the technical capabilities of the four new dynamometer test cells that have recently been commissioned.

What size engines can the test cells handle?

M. Traver: When we planned our technical center, we decided to target several engine ranges in the heavy-duty and light-duty industries. Two of our dynamometers are sized for typical passenger car applications, capable of engine speeds up to 10,000 RPM. Another was sized for low-speed/high-torque applications, as well as high-speed/low-torque, such as hybrid systems. This dyno is also well suited for medium-duty diesel engines. The fourth one was targeted towards the heavy-duty industry and is capable of handling engines up to 660kW and 3500 Nm. All of the test cells are capable of performing transient cycle testing for either gasoline or diesel engines.

What about alternative fuels?

M. Traver: We plumbed stainless steel fuel lines to one of the fuel tanks in our system to specifically handle alternative fuels like methanol, ethanol and biodiesel. As such, we have no problem handling blends of petroleum and alternative fuels up to and including 100% straight fuel.

Does that include gaseous fuels like CNG?

M. Traver: Although we do not currently have the ability to flow gaseous fuels to our test cells, we've investigated the zoning and safety requirements and have quotations in hand to upgrade the cells as soon as the market demands it.

Are there any unique conditioning systems?

M. Traver: The heavy-duty test cell, in addition to combustion air humidity and temperature control, features a special pressure balancing system that allows us to simulate 990 mbar and correlate to other test cells at this standard pressure. We've also installed air circulation systems to condition the cell air independently from outside temperature (winter/summer). This is particularly important when calibrating the powertrains of tomorrow with ever decreasing emission levels. We also have high capacity fluid cooling systems to remove the tremendous amounts of heat that modern engines can produce.

What other advanced technology do these test cells feature?

M. Traver: We've ensured that the software used to control our systems is state-of-the-art and able to deliver all the demands of our engineering teams. This includes the installation of PUMA Open and advanced tools like Orion to fully automate our test cells and greatly increase our data generation capacity. This unique combination of hardware and software will drive higher efficiencies and allow us to drastically cut the time necessary to fill the control maps during an engine calibration. In addition to base engine development tools like the Knock Indication System (KIS) and combustion analyzers, we've invested in state-of-the-art gaseous emissions analyzers, opacity meters and particulate measurement systems that allow us to demonstrate very low emissions for full engine systems.

Does that mean that they're Part 1065 compliant?

M. Traver: The Part 1065 regulations are very explicit in the necessary practices used to certify an engine for EPA approval, and IAV has made a conscious decision not to install the required full dilution tunnel in our facility, until the question of whether partial flow particulate systems will be allowed for transient cycle testing or not.

What features are available with the Hybrid Test Cell?

M. Traver: The hybrid test cell was designed to incorporate a powertrain battery simulation system to allow us to recreate an engine/transmission/electric motor setup. With a torque capacity of 1400 Nm, we believe this will cover a wide range of future hybrid powertrains. We're very excited about the capability of the test cell and look forward to developing future hybrid technologies.

One last question for you: when do you expect to have the test cells up and running?

M. Traver: Engines have been operating in our test cells since late April to fine tune the supporting systems. We are now fully operational and ready to work on our customer's future powertrain needs.

Thanks for your time and we'll see you at the Grand Opening in September.

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Formula SAE

UoM and IAV in the forefront of student competition

by Eileen Lord

Once a year, just before the summer months roll in, one can expect to find a bevy of UM Formula SAE team members assembled somewhat haphazardly among the auto labs and offices which comprise the University of Michigan's Northern Campus. Their sole objective: to design, manufacture, test and develop a Formula-style race car fit for what has always proven to be an intense competition. Whether evaluating the controlling electronics or reworking the drivetrain, exhaust, fuel system and more, students, professors – including UM professor of Mechanical Engineering, Volker Sick – and volunteers alike set their sights on effecting a successful mid-May performance at the Michigan International Speedway. This year was no exception.

Of 120 entrants, the UM team, led in part by IAV intern Philip Bonkoski, placed 7th overall. Judged according to cost, presentation, design, acceleration, skid pad, autocross and endurance/economy, the MRacing prototype realized the following individual event standings:

Design	6th (tied)
Business Presentation	20th
Cost	13th
Acceleration	3rd
Skidpad	12th
Autocross	35th
Endurance	10th
Fuel Economy	12th

Dr. Sick commended the team's efforts and IAV's involvement, acknowledging that "through a combination of student internships, technical and financial support, [IAV] enabled the Michigan team to leap forward by developing a power train design that is reliable, well-tuned and competitive at the forefront of Formula SAE." Despite such praise, group leaders have candidly, yet determinedly, conceded that there exists much room for improvement. "We will be working hard in these next few months to further improve the car based on its performance and the feedback received at MIS," Bonkoski put forward. "We are also entering the design phase of the 2010 car, which will be a similar, but refined version of our current car," he continued. With a planned trip to Hockenheim, Germany, to compete in Formula Student Germany on August 5th - 9th, 2009 in the works, this comes as no surprise.

For their tremendous efforts in this year's Formula SAE competition, IAV wishes to congratulate Professor Sick, Philip Bonkoski and the team on a job well done.

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Public Appearances & Publications

September

September 11, 2009
SAE International "Homogeneous Charge Compression Ignition Symposium"
Malmo, Sweden

Paper: "Gasoline HCCI / CAI on a Four-Cylinder Test Bench and Vehicle Engine – Results and Conclusions for the Next Investigation Steps"
wolfram.gottschalk@iav.de

September 17 - 27, 2009
63rd International Motor Show
Frankfurt/Main, Germany
Hall 4.0, booth B16

The IAA will showcase the continuing optimization of classical powertrains – clean diesels and supercharged gasoline engines with direct injection – and also progress in vehicle electrification, ranging from the mild hybrid to the passenger car with pure electric propulsion. Alongside the reduction of consumption – and CO_2 emissions – the focus will be on new types of driver assistance systems that make driving even safer and more comfortable.

September 23 -24, 2009
SIA 15th International Conference "Dynamique du Véhicule"
Lyon, France

September 23 - 25, 2009
North American International Powertrain Conference
Toronto, Canada

MTZ 9/2009
"Model-Based Approaches for the Virtual Calibration of Engine Control Units"
michael.guenther@iav.de, nick.elsner@iav.de, Steffen Zwahr (University of Applied Sciences Zwickau)

October

October 5 – 7, 2009
18th International Aachen Colloquium "Automobile and Engine Technology"
Aachen, Germany

The congress will provide a wide range of technical presentations addressing current challenges of the vehicle and powertrain industry. Program-related test vehicles and prototypes from participating companies and institutions will be presented on the ika test track.

October 6 - 8, 2009
Commercial Vehicle Engineering Congress & Exhibition
Rosemont, IL

October 7 – 8, 2009
Electronics in Motor Vehicles
Baden-Baden, Germany

October 13 -14, 2009
4th Symposium "Gas-Powered Vehicles – The Key Technology on the Road to the Emission-Free Propulsion of the Future?"
Stuttgart, Germany

October 20 -21, 2009
VDI Conference "Tires – Chassis – Road"
Hanover, Germany

November

November 30 – December 4, 2009
8th International CTI Symposium & Transmission Expo
Berlin, Germany

The symposium will discuss the newest technical innovations on automotive transmissions, hybrid and alternative drivetrains. Transmissions are an integral part of an efficient drive train. With electrification, the transmission and e-motors handle additional tasks, too. They help to generate power and manage drive trains, and are thus adopting a driving role for tomorrow's development challenges.

ATZ 11/2009
"Application of Photometric Imaging Systems in Testing of Vehicle Lighting"
peter.schintag@iav.de, thorsten.rehberg@iav.de, michael.marutzky@iav.de

MTZ 11/2009
"KatSim – A Tool for Numerically Simulating Exhaust-Gas Catalysts"
kay-jochen.langeheinecke@iav.de, robert.blank@iav.de, sandra.dusemund@iav.de

December

December 2 – 3, 2009
SIA International Conference "The Spark-Ignition Engine of the Future"
Strasbourg, France
This new SIA international conference is intended to provide the opportunity for experts from the automotive industry (OEMs and their suppliers), the oil industry, research laboratories and universities to exchange their points of view and information on the potential of the future spark ignition engine to respond to the combined low CO_2 and electrification challenges of the future.

"IEE Transactions on Control Systems Technology"

"Feedback Control Structures, Embedded Residual Signals and Feedback Control Schemes with Integrated Residual Access"
T. Jeinsch, N, Weinhold, M. Schultalbers, S. X. Ding, G. Yang, P. Zhang (University Dresden), E. L. Ding (University Gelsenkirchen)