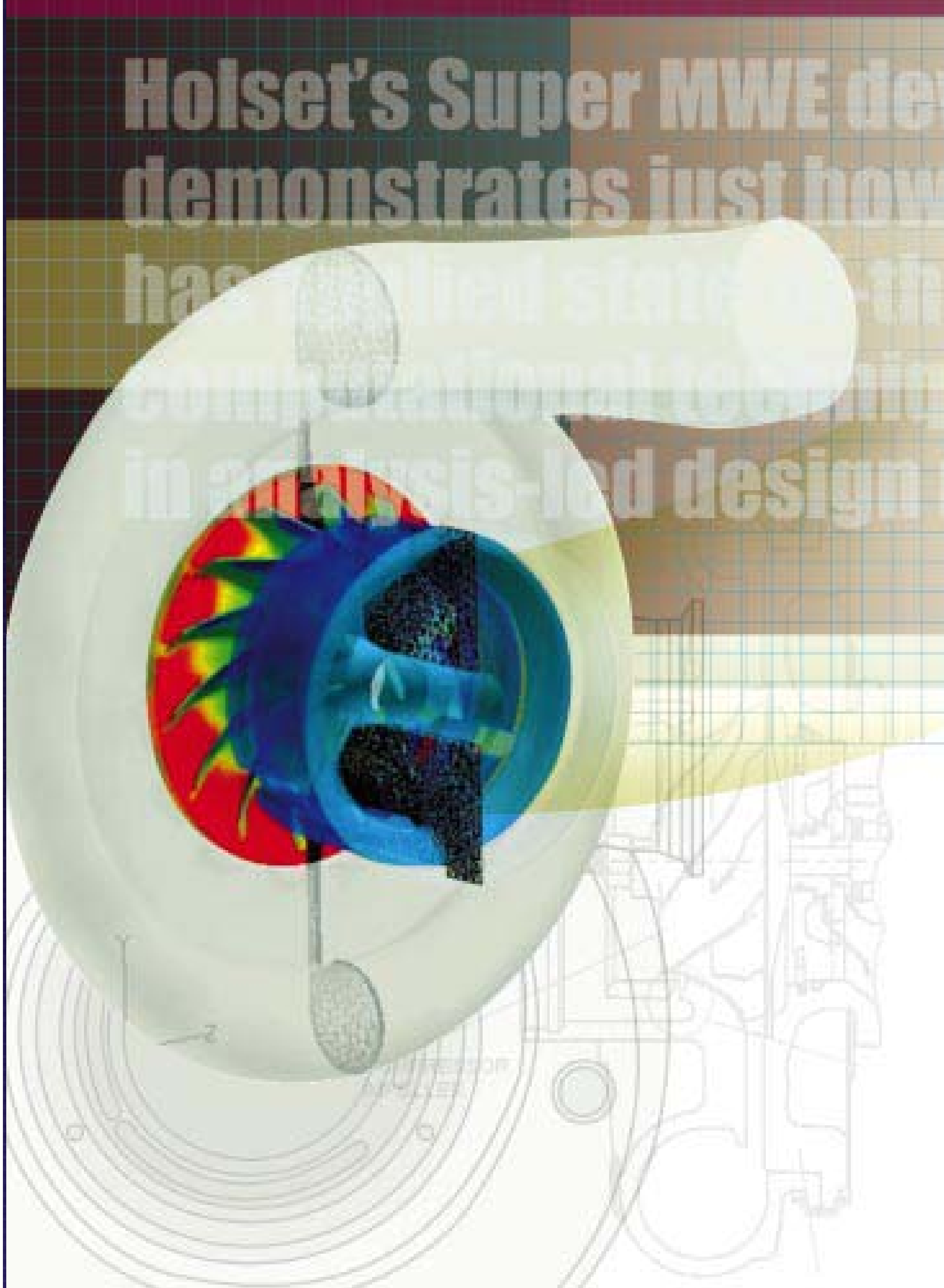
HOLSET
TURBOCHARGERS

HTi

THE LATEST NEWS FOR HOLSET TURBOCHARGERS' CUSTOMERS

EDITION 4

Super MWE



INSIDE THIS EDITION:

HOLSET CONSOLIDATES ITS MARKET LEADERSHIP IN 2004

Mark Firth
Worldwide Sales & Marketing Director

For Holset, 2004 was another record year, notably in terms of production output. We produced over 1.3 million turbochargers worldwide. That is a 30% year-on-year increase, with sales approaching £250 million ($450 million). This unprecedented sales growth was supported by our new facility in Wuxi, China and a substantial expansion of our facility in Dewas, India.

We also set new production records in Holset's main Huddersfield plant in the UK and our aftermarket business enjoyed healthy growth, which can also be said for our USA operations in Charleston and our Brazilian facility in São Paulo.

However, it has not just been about strong sales and high production output. Let us look at a few of Holset's other accomplishments:

The account management teams responsible for each of our established engine-manufacturing customers or OEMs, have shown their resilience in responding to what has been a phenomenal demand for turbochargers. Working closely with our customers' engine manufacturing people and their parts divisions, we have done our utmost to meet their needs on product supply and technical back-up services.

At the same time, we have won substantial new business for turbocharger installations embodying our latest technology, tailored to meet the more stringent demands of upcoming emissions legislation, particularly in Europe and North America. Global engine and truck producers in other markets, for example China and India are looking to more advanced and sophisticated turbocharger packages as local emission laws are brought into force.

Our product development and engineering teams have undoubtedly faced challenges in meeting the greatly increased customer interest in advancing turbocharger technology we have seen in the last year or two. It has led to unprecedented demand for product born out of new technological developments. I am particularly excited about the progress made on Holset's next generation of variable geometry turbochargers (VGT™) and our new compressor wheel technology, with its impressively high pressure ratios and wide flow-range capability. We still have a lot of work to do before the commercial launch stages but progress to date is very encouraging.

Our supply chain organisation has played a crucial role in supporting the increase in manufacturing output. The supply base has continued to expand, delivered quality has improved and we have worked hard with suppliers to mitigate the impact of steeply rising metal costs, while delivering real bottom-line cost reductions.

Our plants around the world last year produced a record number of turbochargers, together with higher delivered quality levels. Wuxi Holset in China moved to a brand new facility early in the year, with an official opening in May 2004. Meanwhile the new facility at Tata Holset in India was already producing our HX20-HX25 range of turbochargers ahead of its official opening in February 2005.

Holset's aftermarket division in the Netherlands has moved to a new purpose-built facility, ready for the growth in business we are expecting in 2005, given the additional manufacturing capacity we are now putting in place.

As far as human resources are concerned, good progress has been made in building a more diverse workforce at all Holset locations. There has been significant recruitment of new people, introducing fresh talent and a wider range of skills.

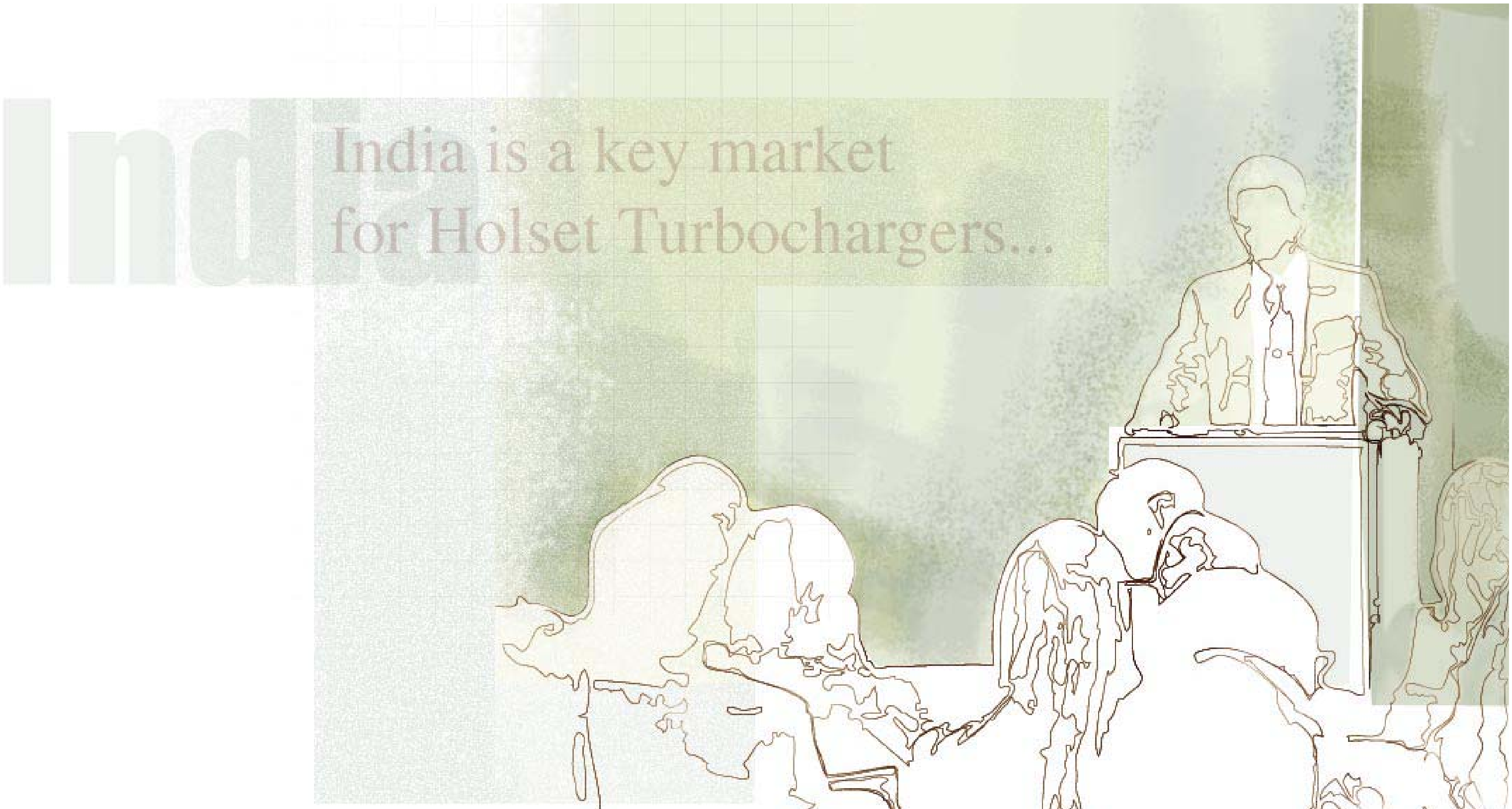
From a marketing perspective, we are continuing to build on Holset's image as a global leader in commercial diesel turbocharger development and manufacture. This provides reassurance to our customers that they will continue to receive consistent, high-quality products, services and information, no matter where they are in the world or whichever plant is responsible for supplying them.

We are looking forward to a further period of growth in 2005. Demand for ever more sophisticated turbocharger technology remains strong as our key customers prepare for new emissions legislation in the USA, Europe and Asia, and our customers continue to strive for ever higher standards of quality and delivery.

Mark Firth
Worldwide Sales & Marketing Director

HTi is the Holset magazine focusing on the world of heavy-duty turbocharging.
It aims to bring you news on product and market developments.

HTi is produced using an environmentally approved printing process and is printed on fully recyclable and biodegradable paper.



HOLSET'S TECHNOLOGY DAY FOR INDIA

India is a key market for Holset Turbochargers. With the growing call for clean and fuel-efficient high-performance diesels in Asia, against the background of imminent new emissions legislation, the demand for advanced turbocharger technology that Holset can offer is strong.

In December 2004 Holset, through its joint venture Tata Holset, hosted its first Technology Day, focusing on developments and solutions in air handling systems for the engines of today and tomorrow. Tata Holset, Holset's joint venture with the Tata Group of Companies has recently expanded its operations in Dewas and opened a new sales office in Pune.

The three day event showcased Holset's latest technology, turbocharger products and installations to existing and potential customers in the Indian market. Holset's alliance partner, Mitsubishi Heavy Industries displayed their product range for passenger car and light duty commercial vehicles.

Held at three different locations: the Le Meridian Hotel, Pune, Tata Motors' facility in Pune and Ashok Leyland's plant in Bangalore, the event attracted over 200 visitors, comprising of primarily engineers and senior management from Ashok Leyland, Bajaj Tempo Ltd, Cummins India Ltd, Kirloskar Oil Engines Ltd, Mahindra & Mahindra, Tata Motors and Tata Cummins Ltd.

Delegates to the trade show's associated conference also had the opportunity to examine some of Holset's latest turbocharger technology, including turbocompounding, electronically and pneumatically actuated VGT™ systems, low-inertia titanium compressor wheels, MFS aluminium wheels and Command Valve™ wastegating, along with the full range of Holset's HX range turbocharger products.

A number of speakers from Holset UK addressed the conference. Mark Firth, Sales and Marketing Director, gave an overview of the Holset family worldwide and discussed the company's forward moving business strategy. Stuart Kitson, Chief Engineer - Technology, reviewed Holset's latest research and development work, including programmes centred around noise reduction and compressor and turbine improvements. These included the Super MWE™ programme (this is discussed in more detail on pages 7 & 8), background on emission legislation and engine developments, work on advanced materials and Holset's Command Valve wastegate, VGT and turbocompound systems technology. Pierre French, Chief Engineer - Customer Engineering, discussed turbocharger applications. There were also sessions on quality, service and the aftermarket.

The event was considered a great success by all those who attended and Holset would like to thank Mitsubishi Heavy Industries for their contribution and Tata Motors and Ashok Leyland for enabling us to host the event at their training premises.

The three day event showcased Holset's latest technology, turbocharger products and installations to existing and potential customers in the Indian market.

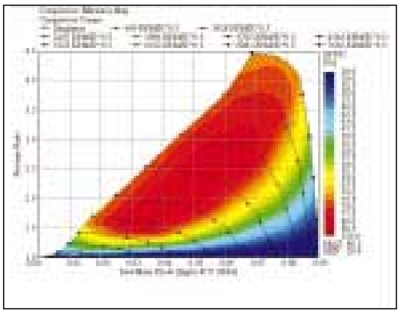
Stuart Kitson, Chief Engineer - Technology


Conference attendees at Tata Motors

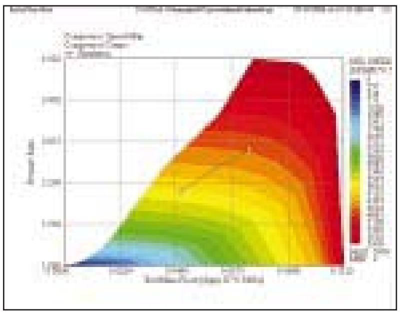

Discussing turbocharger technology

SOFTWARE BREATHING NEW LIFE INTO ENGINES

Holset has been using computers to simulate the turbocharging of diesel engines since the early 1980s with the company's own in-house programs.



A Holset compressor map uploaded into GT-Power, showing the high efficiency available across a large proportion of the compressor running conditions



A GT-Power compressor map showing the speed contours and running points for a 12 litre engine

Since that time, simulation techniques and available software have advanced to such an extent that complete engine air management systems can be simulated, together with emissions predictions. The original turbocharger matching software at Holset has also been progressively developed to maintain its value as one of the most useful tools our engineers have for predicting turbocharger performance on engines.

Our aerodynamics engineers can also predict the performance of new wheel and housing designs using computational fluid dynamics (CFD) software packages. Our applied mechanics group can calculate turbocharger component thermal and fatigue stresses, while their colleagues in the rotor systems department can simulate shaft motion and stability.

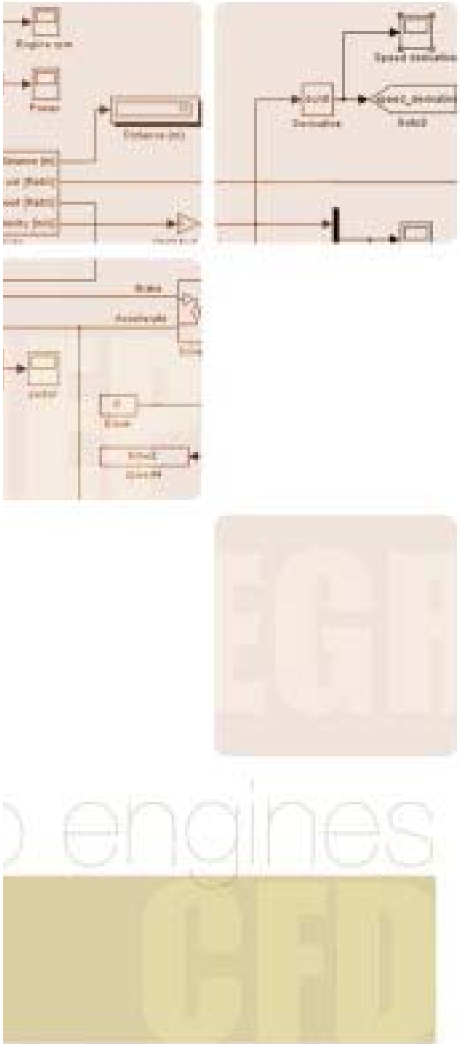
Having the software to design and predict the performance of your own components is not sufficient in a competitive world. Holset must also understand its customers' needs by helping to solve their air management problems. As a turbocharger supplier Holset accordingly has an engine air systems department, solely devoted to meeting air handling problems from the point of view of our customers, that is the engine manufacturers. To this end, we have software that you would normally only expect to find in the research department of an engine manufacturer.

Formulae used to calculate reciprocating engine performance have been around a lot longer than computers however, only when computers came along could these complex calculations be undertaken within an acceptable timescale.

Many different types of computer modelling are used at Holset. There are turbocharger energy balance models, quasi-steady models, 'filling and emptying' models and fluid dynamic models.

Turbocharging matching is mainly approached using a simple energy balance calculation. The engine parameters are fixed and different turbocharger hardware is evaluated against laid down boost pressure requirements, within set speed and temperature limits. It can be run very quickly, though it does require key engine conditions to be established in advance.

With the use of customer compatible software, it is possible to exchange files with the customer on a common project and work on them in parallel, knowing that the models are accurate.



Quasi-steady flow models are used to simulate a series of flow restrictions, typically the air filter, manifolds, valves and exhaust system. They are conceptually and computationally simple and continue to be used in several simulation programs, particularly where the whole drivetrain or vehicle is being modelled. However, quasi-steady methods are not particularly accurate if engine performance in isolation is the focus of investigation.

'Filling and emptying' models are generally more accurate. They are able to simulate the engine by separating the air handling system into a series of linked volumes, usually representing manifolds and cylinders and calculating the mass flow into and out of each section, per degree of crank rotation. After a few engine cycles, the calculated values converge and the mass flow can be established. This method can accurately predict average pressures but because of gas dynamic effects cannot account for variations in pressure within the individual sections. Such programs can however be run reasonably quickly, with analysis of one engine speed taking only a few seconds on a standard desktop computer. Some transient effects can also be analysed, for example when an engine running at a fixed speed has load suddenly added or removed.

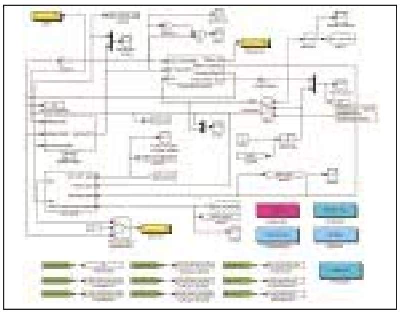
Modelling packages such as Gamma Technologies GT-Power software, provide the most recent types of engine simulation. They allow engine conditions to be predicted with greater accuracy and in more detail; at the price of extended calculation processing that requires a high speed computer cluster to provide answers within an acceptable timescale.

The use of these packages allows us to work closely with our customers in a number of ways:

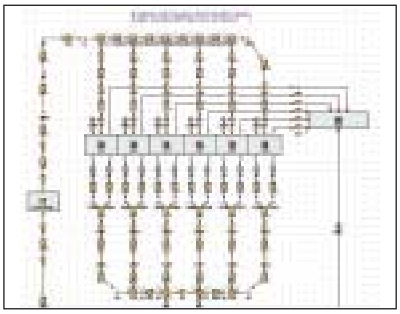
- With the use of customer compatible software, it is possible to exchange files with the customer on a common project and work on them in parallel, knowing that the models are accurate.
- We can also understand any problems they have in operating that software, in particular with turbocharger modelling.
- With an ability to simulate and investigate entire engines rather than just turbocharger installations, we can undertake research and development work on complete engine systems, to understand better how turbocharger development needs to advance in the future.
- Engine simulation work using computer modelling now saves immense amounts of time. Theoretical solutions and new systems can be accurately simulated and tested without the cost and delay of building hardware and testing 'real' engines.

As well as simulating the gas flow through the engine, applications like GT-Power can be linked to 'logic modelling' software like Matlab Simulink, which also allows modelling of control systems. This has taken on added importance with the advent of variable geometry turbines, Command Valve™ controllable wastegates and electrically-assisted turbocharging.

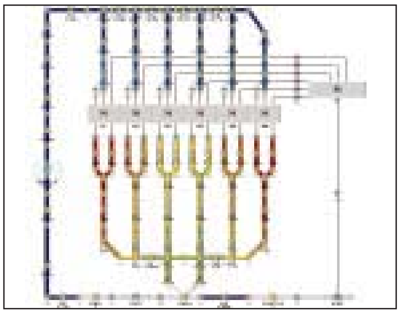
Other recent Holset simulations have included turbocompound installations, wastegated engines with EGR, performance at altitude and turbocharging on Miller Cycle engines. It is part of our mission to be more than a turbocharger supplier but a partner with our OEM customers in air handling system development.



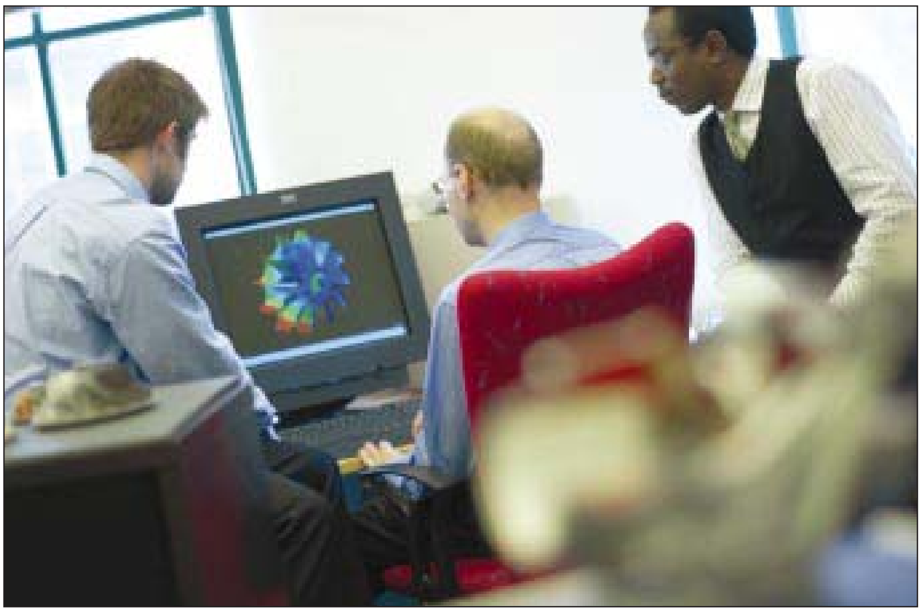
Modest software can quickly model engine, drivetrain and vehicle interactions



A GT-Power project map showing how the different elements of the engine model are connected together



GT-Power can show parameter values clearly in pictorial format



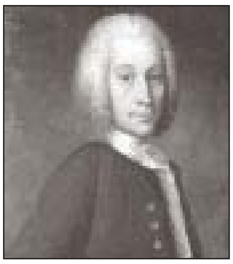
THEY EACH PLAYED A PART…
IN THE TURBOCHARGING STORY

Turbocharging and its development have been fundamental in the diesel engine development through the 20th Century. In HTi issue 3 we discussed the history of turbocharging and looked at how Dr. Alfred Buchi was responsible for developing the first working turbocharger. However, there were many notable scientists and engineers before him who contributed significantly to the understanding of the physics behind the principle of the turbocharger.

In some cases, their work has been given special recognition from their peers and successors, that is from the science and engineering community, through the use of their names for units of measurement or physical quantities routinely used in the design, specification and analysis of a turbocharger.

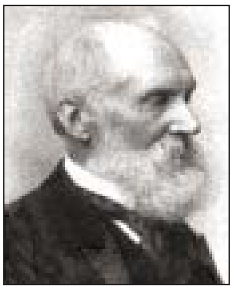
Blase Pascal
1623 – 1662
Blase Pascal was born in Clermont, France, in 1623 and was, by common consent, the greatest natural genius of the mid-17th Century. At the tender age of 21 he had invented a calculating machine, by 25 proved to his satisfaction that there was such a thing as a vacuum and later invented a barometer which led to Pascal's Law of Pressure. Today the international standard unit used for expressing pressure of gases is named after him (the Pascal).

Daniel Bernoulli
1700 – 1782
Daniel Bernoulli was born in Groningen in Holland in 1700 and came from a long line of mathematicians. He was responsible for discovering that as the velocity of a fluid increases, its pressure decreases. In his earlier work, he had found that a moving body exchanges its kinetic energy for potential energy when it gains height. Bernoulli realised that in a similar way, a moving fluid exchanges its kinetic energy for pressure. A corollary of this law is that if the velocity increases then the pressure falls, something exploited by the aerofoil section of an aircraft wing, which is designed to create an area of fast flowing air above its surface. As the pressure there is lower, the wing is 'sucked' upwards, creating lift. Bernoulli's equation, a formulation of that principle, is today used by engineers as the basis of one of the most fundamental fluid flow relationships.

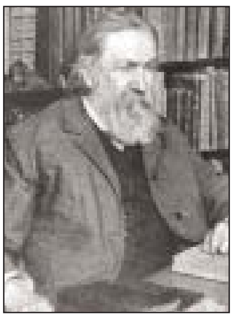


Anders Celsius
1701 – 1744
Anders Celsius was a Swedish astronomer who came from a large family of scientists from the small town of Ovanåker in the rural province of Hälsingland. He was said to be a talented mathematician from an early age and was appointed Professor of Astronomy in 1730. Celsius was one of the founders of the Uppsala astronomical observatory in 1741. He is best known for the Celsius temperature scale, first proposed in a paper to the Royal Swedish Academy of Sciences in 1742. The Celsius temperature scale, sometimes referred to as Centigrade, is widely used by engineers to express temperature measurement.

Leonhard Euler
1707 – 1783
Leonhard Euler, born in Basle, Switzerland, was educated by John Bernoulli and formed a lifelong friendship with his son, Daniel Bernoulli. Euler assisted Daniel in his work to discover more about the phenomenon of fluid flow. Although Euler lost the sight of his right eye in 1735 and became completely blind in 1766, aided by his phenomenal memory he continued to publish his results. He became the most prolific mathematical writer of all time, having 800 of his papers published in his lifetime and winning the Paris Academy of Sciences award twelve times. Euler's turbomachinery equation is one of the fundamental mathematical relationships used by today's engineers when designing turbochargers. This equation is used to calculate the work/energy output of turbomachinery.



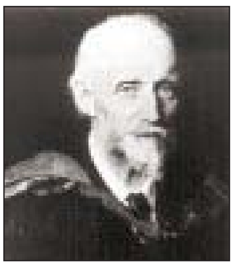
Lord William Thomson Kelvin 1824 – 1907
Lord Kelvin was a Scottish mathematician and physicist who contributed to the many branches of physics and gained his peerage in 1866.
His contributions to science included a major role in the development of the second law of thermodynamics. He established the absolute temperature scale (measured in Kelvin), propounded the dynamical theory of heat and the mathematical analysis of electricity and magnetism, including the basic ideas for the electromagnetic theory of light. Kelvin also calculated, through geophysical determination, the age of the Earth and carried out fundamental work in the field of hydrodynamics. 'Kelvin' or 'K' (°C + 273.15) is the international standard unit used for all temperature measurements. 'Absolute zero', which is the term used for zero degrees on the Kelvin temperature scale is, according to the laws of thermodynamics, the lowest temperature possible in the universe!



Ernst Mach
1838 – 1916
Ernst Mach was born at Chrlice, now part of Brno in the Czech Republic and received his technical education in Austria. He was a physicist and philosopher who established important principles of optics, mechanics and wave dynamics. He put forward the view that all knowledge is 'a conceptual organisation of the data of sensory experience or observation'. Mach was the first person to realise that if matter travelling through the air moved faster than the speed of sound, it drastically altered the quality of the space in which it moved. The Mach number, as it is known, expresses the speed of matter relative to the speed of sound at a given temperature. When supersonic planes travel today, their speed is measured in terms that keep Mach's name alive.

Rudolf Diesel
1858 – 1913
Rudolf Diesel was born in Paris in 1858 and was educated at Munich Polytechnic. After graduation he was employed as a refrigerator engineer, however, his true love lay in engine design. Rudolf Diesel designed many heat engines, including a solar-powered air engine. In 1893, he published a paper describing an engine with combustion within a cylinder, the internal combustion engine. In 1894, he filed for a patent for his new invention, dubbed the diesel engine, which relied on cylinder pressure alone to ignite the fuel-air mixture. Rudolf Diesel was almost killed by his engine when it exploded, however this engine proved that fuel could be ignited without a spark. He operated his first successful engine in 1897. In 1898, he was granted patent no. 608,845 for an 'internal combustion engine', which was in essence the now familiar diesel engine.

Lord Rayleigh
1842 – 1919
John William Strutt, third Baron of Rayleigh, was one of the few members of the British nobility who won fame as an outstanding scientist. A former Chancellor of the University of Cambridge, Lord Rayleigh's first researches were mainly mathematical, concerning optics and vibrating systems. His later work covered sound, wave theory, colour vision, electrodynamics, electromagnetism, light scattering, flow of liquids, hydrodynamics, density of gases, viscosity, capillarity, elasticity and photography. The 'Rayleigh' number (Ra) is one of the parameters used in forced convection heat transfer calculations.



Osbourne Reynolds
1842 – 1912
Reynolds was a British engineer and physicist who is remembered for his analysis of turbulent flow. Most of all, he is famous for the 'Reynolds Number', which was defined in 1883 as 'a dimensionless quantity used to determine whether flow is laminar or turbulent'. The number depends on viscosity, velocity, density and linear dimension of the flow. Reynolds also studied lubrication and heat phenomena.

MEETING USA EMISSION CHALLENGES

Truck sales in North America, one of the world's largest markets, has fluctuated wildly over the last five or six years. The volatility and in particular, the steep fall-away in demand for new vehicles since 1999 can be attributed to a slowing USA economy, late-model used trucks flooding the market and the aftershocks of the September 11 terrorist attacks in 2001.

However, from early 2002 the market began to be stimulated by new, more stringent EPA emission limits coming into force for most heavy-duty automotive diesel engines in October that year, when a new generation of much modified, emission law compliant engines, made their debut.

Many incorporated innovative technology, notably cooled EGR (exhaust gas recirculation), designed to comply with the new control standards, due to remain in force until 2007. Operators in the market for new equipment had no choice but to pay for what were inevitably more costly, emission-compliant trucks, which in turn led to the upturn in sales long awaited by vehicle and engine manufacturers.

Today, the USA and Canadian heavy truck markets have made a full recovery, after sales through 2003 and 2004 grew faster than expected. The market last year was strong and is predicted to continue to grow through 2005 as truck builders and their engine suppliers prepare for even tougher emission limits due in 2007 and 2010.

Many incorporated innovative technology, notably cooled EGR, designed to comply with the new control standards, due to remain in force until 2007.

Emission regulations will see oxides of nitrogen (NOx) and particulate matter (PM) limits reduced by up to 90% from current levels. Specifically, permitted NOx will be reduced to 0.2g/hp.hr by 2010 whilst the particulate limit will be reduced to 0.01g/hp.hr in 2007.

As well as lower NOx and PM levels, the tougher legislation will impose limits on crankcase gases allowed to escape to atmosphere. In support of the lower permitted exhaust emission levels, the legislative authority, the Environmental Protection Agency (EPA) is also lowering the allowable sulphur content of on-highway diesel fuel from 500 parts per million (ppm) to 15 ppm. New specifications are also being developed for engine lube oil, compatible with the EGR and aftertreatment technologies being projected for EPA 2007 and 2010 compliance.

Cooled EGR is an in-cylinder technology for reducing NOx but there are several aftertreatment solutions that can cut NOx levels by treating the exhaust gases after they leave the engine. These include selective catalytic reduction (SCR), NOx adsorbers (sometimes called lean NOx traps) and lean NOx catalysts.

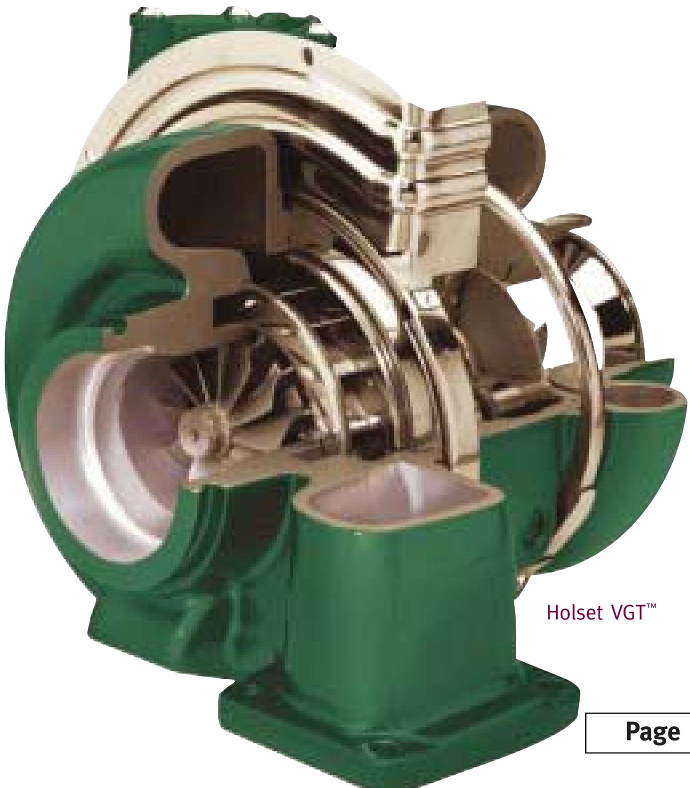
What do these developments mean for Holset? Cooled EGR is a very effective NOx control and can be used to attain the NOx levels being introduced in 2007 and beyond. However, in order to control both NOx and particulate emissions accurately, the mix of recirculated exhaust gas and intake air has to be precisely controlled, in line with the amount of NOx being generated by the combustion process, under all operating conditions. Variable geometry turbocharging plays a vital role in regulating the quantity of air delivered to the engine.

Holset's sliding-nozzle VGT™ provides a relatively simple and effective means of ensuring that the EGR rate matches the demands of the engine management system in controlling NOx levels. On Iveco Cursor and Cummins truck diesels it has proved to be the world's most reliable variable nozzle turbocharger.

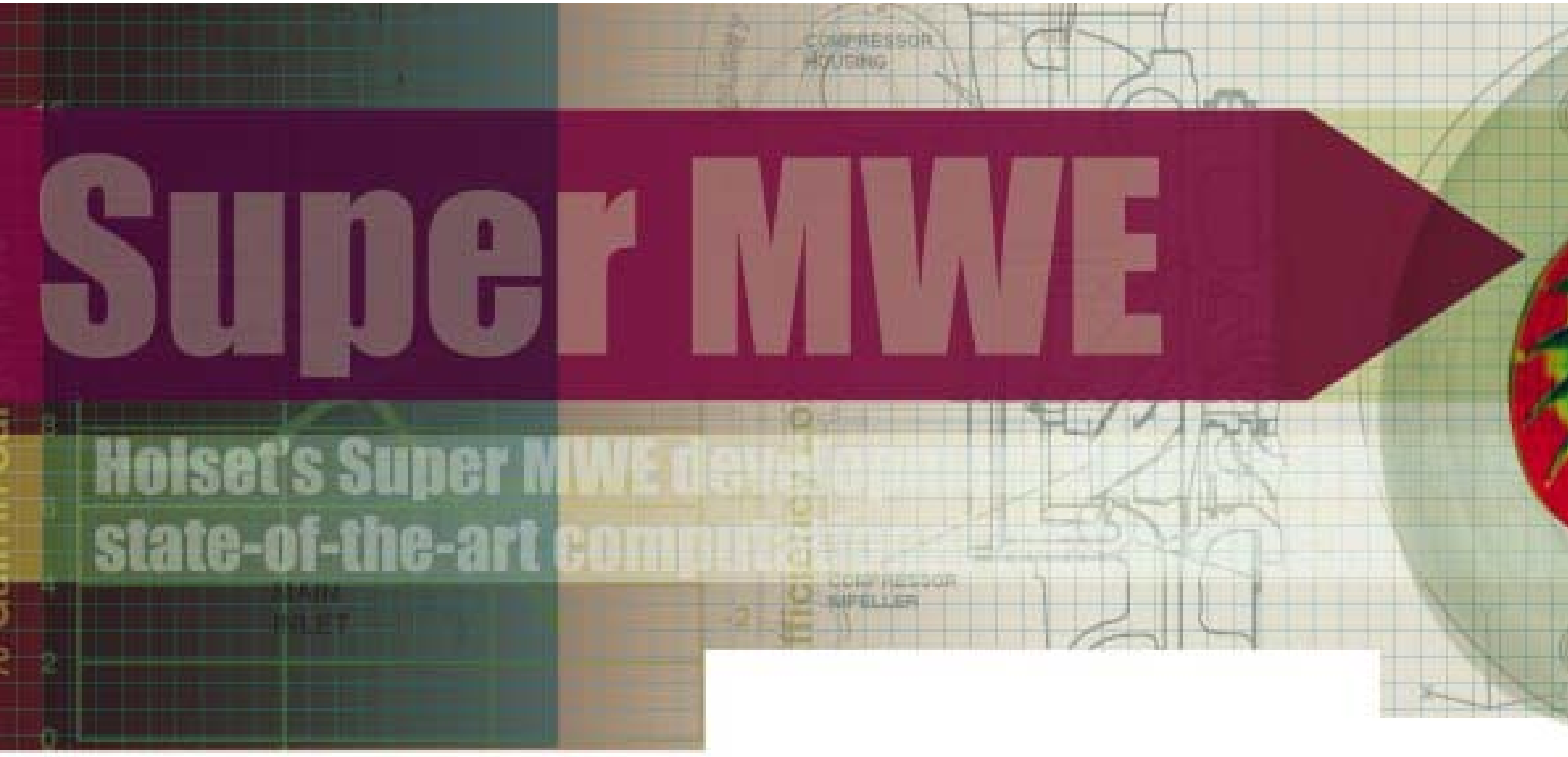
As engine manufacturers prepare for the 2007 emission regulations, Holset is best placed to provide and support its customers with technology solutions.

HD 2007 Rule: Basic Program Requirements

	2006	2007	2008	2009	2010	2011	2012
PM		100% at 0.01-g/hp.hr					
NOx		50% at 0.2-g/hp.hr			100% at 0.2-g/hp.hr		
Fuel		80% at 15ppm maximum sulfur (under voluntary compliance option)			100% at 15ppm		



Holset VGT™



Super MWE

At a time of ever tougher legislative demands on the diesel engine, centred chiefly on exhaust emissions, one of the key challenges for turbocharger designers has been to improve the centrifugal compressor's flow range.

Holset has in recent years explored a number of technologies targeting such improvements. Among the most promising areas of development over the years has been map width enhancement (MWE), which has progressed through several stages to Super MWE™ on which Holset has detailed design patent applications and trademark applications.

For a diesel engine, the air flow and pressure ratio requirements can be translated onto the flow map of a centrifugal compressor as a series of operating lines for various engine speeds (fig 1). The low engine speed lines are close to and almost parallel to the surge line of the compressor. Increasing the speed range of the engine increases the requirement for a correspondingly wider compressor map. Dynamic conditions during gear changing or changes in fuelling rate also require a generous air-flow margin around the engine operating lines.

Surge is a condition of instability created at any given speed as the flow rate through the compressor is reduced. Surge is a 'system' dependent event. The volume and length of a system's pipes affect the onset of surge. Large fluctuations in pressure and mass flow occur when the compressor is in surge. This unstable running condition can lead to eventual failure of the turbocharger.

Clearly it is desirable during normal engine operation to maintain a 'safe' margin away from surge. This is sometimes referred to as the 'surge margin'. If the surge flow can be reduced (thereby increasing the surge margin), the additional flow range can be harnessed to enhance the torque curve and hence the driveability of the engine. In some cases it can also help utilisation of more effective emissions reducing technology.

Use of a MWE slot (fig 2), also known as a 'shroud bleed', is an established technique for improving the surge margin of the centrifugal compressor. It helps improve the surge margin by recirculating the reverse flow to the front of the impeller when surge is imminent. The MWE slot also helps improve the choke side of the map by allowing additional air into the compressor past the throat area of the impeller (fig 3).

In the most recently developed Super MWE compressor (fig 4), the MWE inlet pipe length is optimised to provide additional flow range under surge conditions. We have shown that it is possible to get surge margin improvements of up to 15% by optimising the compressor inlet. Fig 5 shows the relative improvements achieved through the application of MWE and of Super MWE compared with a simple non-MWE compressor.

Holset's Super MWE development demonstrates just how Holset has applied state-of-the-art computational techniques in analysis-led design methodology. Computational fluid dynamics (CFD) models of the MWE pipe length extensions were generated and run in the computer to simulate real operating conditions under near-surge conditions. The CFD model represented the entire compressor stage (i.e. from impeller inlet to compressor housing outlet). Fig 6 shows a cross-section of the computational mesh used and fig 7 shows a sample of the results, again for a near-surge condition, at maximum impeller speed.

Holset's Super MWE development demonstrates how Holset has applied state-of-the-art computational techniques in analysis-led design methodology.

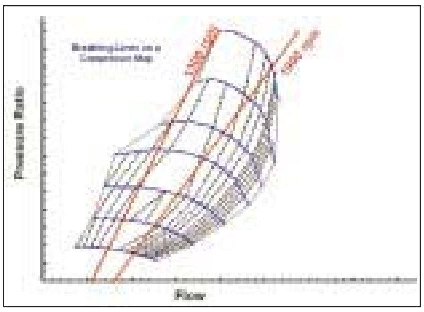


Fig 1 – Typical Engine running lines superimposed on compressor map

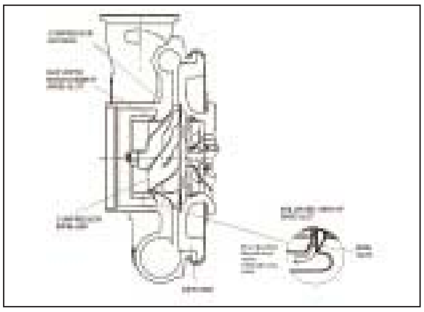


Fig 2 – Standard MWE slot

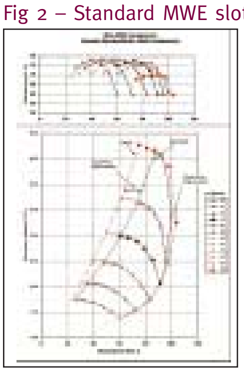
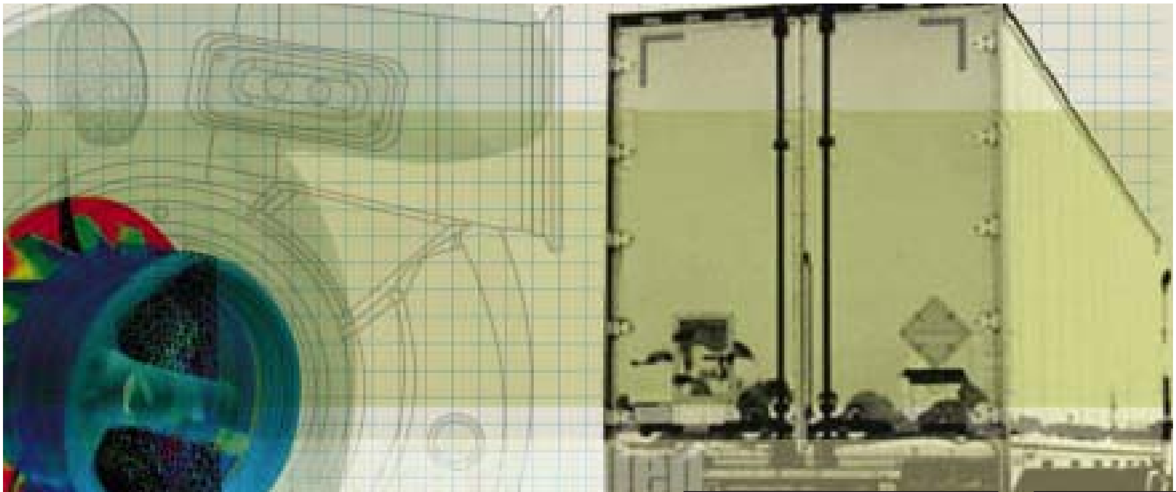


Fig 3 – Effect of MWE on compressor performance



All three cases shown on fig 7 were run to the same mass flow rate. In the standard MWE case, the reverse flow coming out of the MWE slot is remixing with the main inlet flow to cause a disturbance to this flow. Evidence for this is apparent in the Mach number contours at the tip of the MWE inlet pipe. The longer MWE inlet pipe results shows that the disturbance to the flow (due to MWE flow) occurs further upstream so the impeller inlet flow is more uniform. Our CFD results confirm that Super MWE is particularly effective under near surge conditions because it helps move the recirculating MWE flow further upstream from the impeller inlet.

Fig 8 shows (presented in performance map format) the CFD stage results for the standard and the longest MWE inlet pipe seen in fig 7. The CFD prediction shows a significant level of surge-margin improvement.

Testing of fabricated compressor housings with varying MWE inlet pipe lengths (fig 9) has verified our CFD data. Test results (summarised in fig 10) show that by increasing the MWE inlet pipe length, surge-margin improvements of up to 15% are achievable. However, the benefits do level off with increasing length. The longer pipes bring a drop in efficiency of around 2%. A compromise therefore needs to be made between the level of surge-margin improvement, package size increase and loss of efficiency.

The map over-plot shown in fig 11 demonstrates however that a moderate increase in inlet pipe length (as in fig 4) can yield an up to 12% surge-margin improvement with only about a 1% drop in efficiency.

With such an increase in map width, engine manufacturers have the option to run at conditions not previously possible, without the need to resort to complicated variable geometry compressor (VGC) technology.

Engine manufacturers will soon be able to take advantage of this technology as Holset are in the position to implement Super MWE into production.

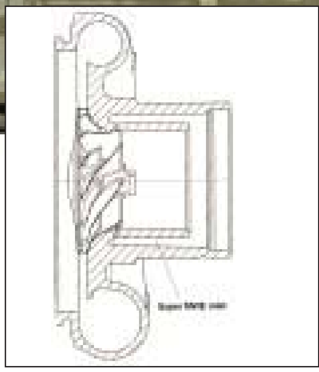


Fig 4 – Super MWE inlet

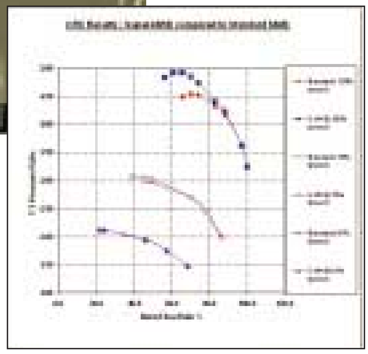


Fig 8 – CFD predicted performance map for Super MWE

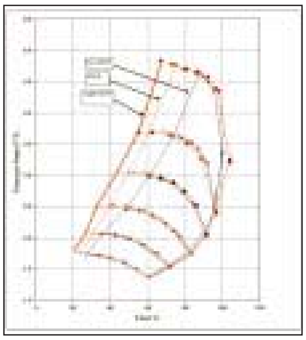


Fig 5 – Relative effects of MWE & Super MWE on compressor performance

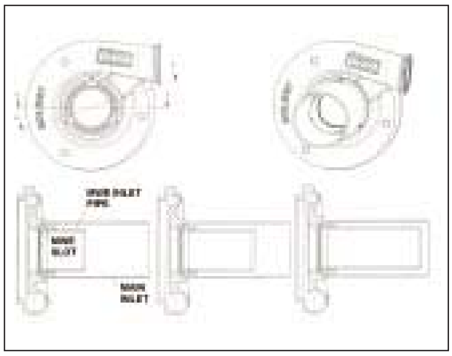


Fig 9 – Super MWE fabricated pipe extensions used for test validation

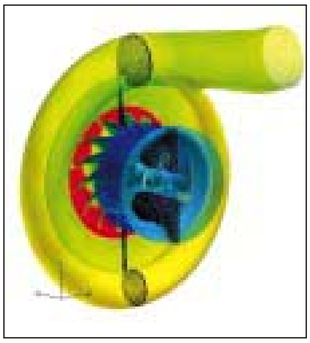


Fig 6 – Example of the CFD mesh used

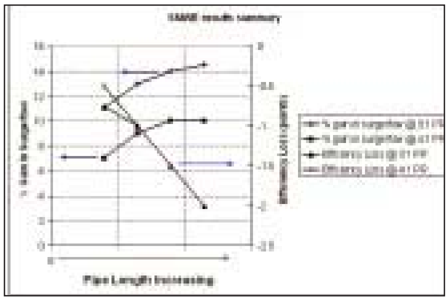


Fig 10 – Super MWE test result summary

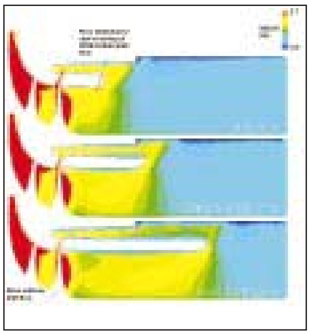


Fig 7 – CFD results for pipe extensions showing how Super MWE works

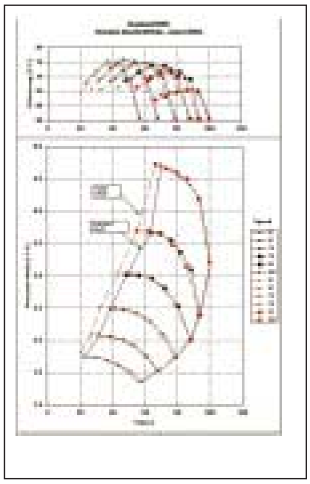
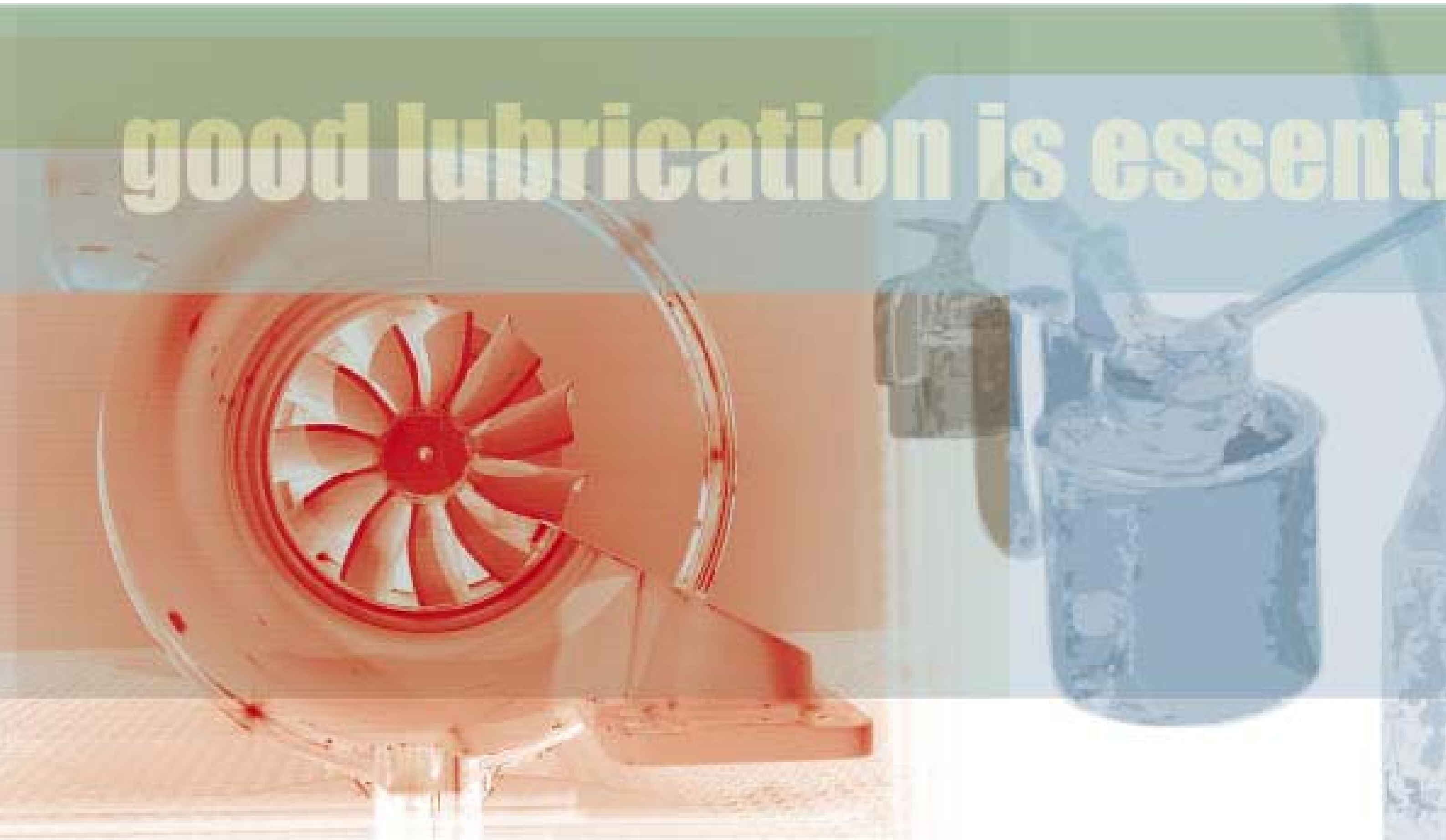


Fig 11 – Super MWE performance map comparison



GOOD LUBRICATION IS ESSENTIAL FOR TURBOCHARGER LIFE

In a modern high performance engine, lubrication receives critical attention from designers and subsequently from end-users, at least from those end users who follow maintenance recommendations diligently. They are aware of the potential hazards of poor lubrication, probably envisaging a shortened overhaul life through prematurely worn cylinder bores or main, or big end bearings.

Far fewer are inclined to give thought to need for proper lubrication of the engine's turbocharger. Arguably, only those whose everyday business focuses on turbochargers and their installation give lubrication of the rotor the attention it merits.

It is worth considering the issue from first principles. A lubricant is a fluid that is designed to keep two moving surfaces apart so as to reduce friction and wear. However, wear can be caused both through mechanical contact between metal boundaries and as the result of chemical corrosion. Hence wear is not always due to friction alone.

In many engine applications the lubricant also serves to cool hot metal surfaces, as well as clearing lacquers, sludge and soot deposits from those surfaces. Thanks to the use of sophisticated chemical additives, the soot and other solids are maintained in suspension in modern lubricants to prevent blockage of oil galleries, leading to pressure drops and oil starvation. It means the accumulated solid matter is removed at the next oil drain.

How does a fluid lubricate? It comes down to 'viscosity, viscosity, viscosity'.

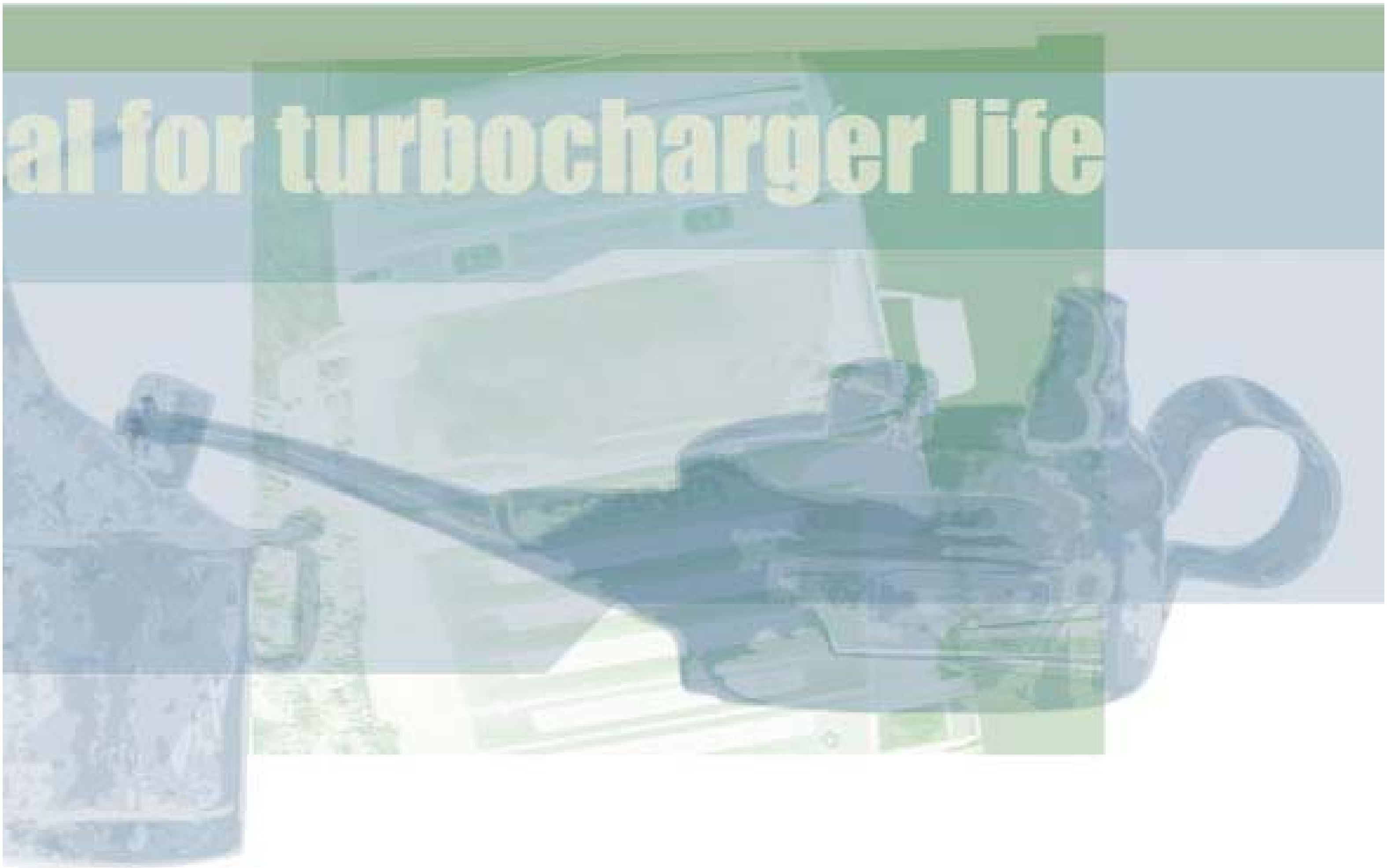
Viscosity is the property that gives a fluid the ability to lubricate. It can be related to the ease or difficulty with which an object passes through a fluid; a simple example can demonstrate that a steel ball dropped in water falls quicker than the same ball dropped in typical engine lube oil, which has a higher viscosity than water.

It was Sir Isaac Newton who showed that for most fluids their shear force is proportional to the viscosity and rate of change of velocity (shear) between the fluid particles. In his honour, these fluids are still referred to as Newtonian. The shear force on the one hand creates the lubricant film that keeps the surfaces apart but on the other creates friction between the fluid molecules. The film needs to be thick enough to prevent solid particles from becoming trapped between the surfaces and causing abrasion, which is another form of mechanical wear. This is where filtration becomes important at minimising the solid particles in the oil and reducing abrasive wear.

Numerous conditions other than viscosity determine the thickness of the film, such as the relative speed between the two surfaces and the load that is pushing them together. Lubrication is classically defined into three typical regimes as shown in the Stribeck curve (fig 1). Boundary lubrication has the highest friction and is therefore associated with the highest wear rate because the surfaces are in only occasional contact with each other. In a turbocharger this can occur when the shaft is running without oil, something that can arise when cold starting an engine, or it can be caused by a blocked filter or again by a severe unbalance condition resulting from rotor damage. Such wear can be minimised through anti-wear oil additives, such as zinc dialkyldithiophosphates (ZDDPs) which can comprise up to 11% of the total lubricant volume, typically 80% of which is the base oil.

Mixed flow is the regime between boundary and hydrodynamic lubrication, which in turn is where a turbocharger bearing system is designed to operate, to produce low friction and good durability. Unfortunately, at higher relative surface speeds, high shear forces within the oil start to align the molecules in the direction of the shear force, which can lead to a significant reduction in effective viscosity. This is known as high-temperature high-shear viscosity and has far more significance than the bulk or static viscosity in determining turbocharger bearing design characteristics. To measure it requires special test apparatus.

In many engine applications the lubricant also serves to cool hot metal surfaces, as well as clearing lacquers, sludge and soot deposits from those surfaces.



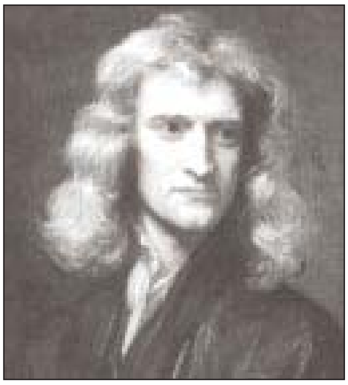
Getting the balance right between friction and oil film thickness is accordingly crucial in achieving engine and turbocharger efficiency and durability. From fig 2 it is clear that viscosity changes rapidly with temperature, by far the most important determining factor. The effects of high or low viscosity are high friction (with thicker oil films) or higher efficiency (thinner oil films) respectively. However, a multigrade oil can partially offset the temperature factor. Compared with a monograde oil, a multigrade is tailored for lower viscosity at low temperatures and higher at high temperatures, through the use of a viscosity modifier in the base oil. A multigrade is therefore said to have a higher Viscosity Index (VI) compared with a monograde. However, in some climates the extreme range of temperatures from winter to summer may still require a specific oil grade change to suit the seasonal conditions, e.g. a 40 summer or 15W winter grade.

Corrosion from two separate but related sources has to be dealt with by an engine lubricant. The first comes from engine combustion gases. Small amounts of sulphur in the diesel fuel oxidise and in the presence of water condensate (another combustion by-product), form undesirable sulphuric acid. It cannot be ignored and modern lube oils are accordingly buffered with additives to absorb the acids. Over time the oil oxidises from exposure to high temperatures (typically over 135°C) and the additives in the oil progressively lose their potency. Due to high shear rates the oil molecules are also broken down. The oxidation process itself releases acidic compounds leading to cross linking of the molecules. A sequence of events is triggered that sees an initial reduction in viscosity followed by a relatively rapid increase.

During the life of the oil the pH is buffered and the alkalinity is measured as the total base number (TBN). The anti-corrosion additives are depleted, while simultaneously the total acidity or total acid number (TAN) increases. Careful life predictions from typical duty cycles enable the engine OEMs to determine recommended oil change intervals. These tend to be conservative, in order to allow for the harshest application, with an added safety margin. Vehicle or engine management systems can today provide engine temperature monitoring and recording of cold starts and delivery vehicle stop-starts to calculate oil deterioration and the consequent scheduling of oil changes. However, oil sampling and condition monitoring arguably provides the most reliable and risk free guide.

Detergent additives are used to remove soot deposits and clean varnish or lacquers from lubricated surfaces. If allowed to build up, such deposits can increase friction and form a thermal barrier, both effects leading to higher temperatures, wasted energy and ultimately a fuel penalty.
In order to maintain good heat absorption it is also important to minimise foaming or aeration of the oil, which would can lead to reduced pumping efficiency and a thinner oil film because the gas bubbles in the film collapse under high surface pressures. Various additives have been engineered over recent years to improve the anti-foaming properties of oil.

Holset does not issue minimum oil specification guidelines because each application requires a thorough understanding of the duty cycle and implications for the bearing system to ensure the turbocharger will be durable under all engine operating conditions. We rely instead on the engine manufacturer using a suitably specified lubricant (e.g. ACEA, API or JASO). Nevertheless we have an engineering team that is focused on understanding the complex relationship between the turbocharger and the engine and the interactions of their respective lubrication systems.



Sir Isaac Newton

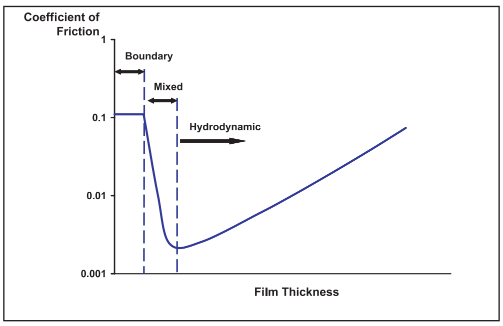


Fig 1 - Stribeck Curve

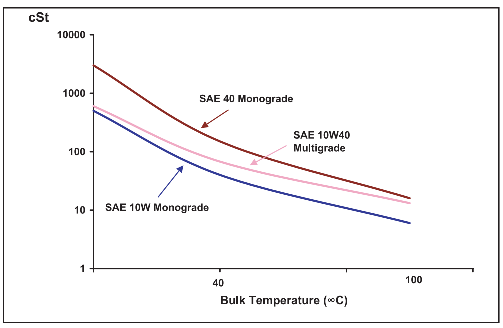


Fig 2 - Viscosity vs Temperature

WUXI HOLSET'S TECHNICAL CENTRE OPENS FOR BUSINESS

Last year marked a new chapter for Holset's turbocharger business in China as a new expanded facility was opened. Adjoining the plant, a technical centre was built and it is now open for business.

Operating the new test cells

For over 30 years turbocharger testing has been carried out at the old Nanchang Street site in Wuxi. The closure of this test facility in September 2004 signified the end of an era but also marked the opening of the first part of the test facilities at the new site in the Wuxi National High and New Technology Zone.

Newly established customer engineering, product engineering, design, local release document control activity and a new laboratory area have been combined in the new technical centre with existing test functions that support the needs of the Chinese turbocharger market and Holset's global growth strategy.

Wuxi Holset has worked closely with Holset UK in planning the layout of the new laboratory operations area in Wuxi. It includes three turbocharger test cells, a more comprehensive engine test bed, a turbocharger assembly laboratory for sample preparation and an area for engine preparation and parts storage.

Two of the new test cells; Cell 211, a compressor mapping cell and Cell 208, the engine test bed, meet 21st Century global standards with their state-of-the-art test equipment. The construction of the cells relied on both local skills from Chinese subcontractors and those of specialist UK based software engineers and a broader facilities team from Huddersfield in the UK.

Cell 211 has the capability of measuring compressor performance up to HX55 frame size. It can also run turbocharger hot tests, validating production units. There are ongoing tests to assess the cell's capability for testing larger turbochargers.

Cell 208 has been fitted with a 400kW dynamometer enabling heavy duty engines and turbochargers to be tested. It can measure fuel consumption and exhaust smoke emissions. Additional space is available to install more elaborate emissions measuring equipment in due course.

Work has begun on fitting out Cell 209 for burst containment and general purpose testing and construction of Cell 210 is expected to be completed later this year.

Given its established ability to analyse turbine blade strain levels using modern telemetry methods, the new technical centre can now undertake most of the work required to support local sourcing of end-housings.

With its prospering economy, China is becoming an ever more important market for Holset Turbochargers. With the opening of its impressive new technical centre in Wuxi, the company has strengthened its position to support the increasing demand for turbocharger equipment in the world's largest country.

The construction of the cells relied on both local skills from Chinese subcontractors and those of specialist UK based software engineers and a broader facilities team from Huddersfield in the UK.

New test cells

IMPROVING CUSTOMER SUPPORT

Holset recently opened extensive new facilities in China and India, as part of a broader strategy designed to increase worldwide manufacturing capacity and at the same time, to provide aftersales support to match the growing demand for turbochargers.

As part of its declared policy of providing best value turbocharger technology, as a supplier-partner to our global customers, Holset also recently opened a new customer service centre in Pune, India. Meanwhile, the company's USA facility in Columbus, Indiana, has been relocated.

Opening the customer service centre in Pune has brought Holset nearer to its fast growing customer base in India, providing better service support through more rapid response times. The major supply chain base of the company's joint venture operation Tata Holset is also in Pune, where it is able to provide top class service levels.

The service centre serves as a single point of contact for all customers and manages the turbocharger supply chain with support from Dewas, the home of Tata Holset's manufacturing facility. It embraces sales and marketing, supply chain management, applications engineering and service, and together they are able to provide a complete support solution.

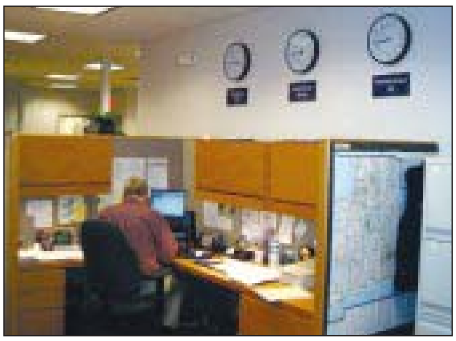
Housed in a new remodelled facility, Holset's support centre in the USA has brought together and improved communications between account managers and customer engineers, who were previously located in different parts of the town of Columbus.

As the USA truck and bus market strengthened after a period of stagnation and following Holset's success in winning new OEM business, it became essential commercially for Holset to be located on its own dedicated site, separate from Cummins engine business operations. Previously the company's personnel were located within Cummins' technical centre and corporate office buildings. Although the majority of Holset's USA business is still in support of our parent company Cummins, an increasing percentage is for other USA based, though not necessarily USA owned customers.

Holset's new facility in Columbus comprises an expanded laboratory area where OEM customers' turbocharger installations can be stripped and examined. Prototypes can be built or modified for customer testing. Data logging equipment is prepared by a four man team of technicians. In the administration area housing account management and customer engineering staff, workspaces are also provided for other Holset personnel visiting from the company's other worldwide sites.

Housed in a new remodelled facility, Holset's support centre in the USA has brought together and improved communications between account managers and customer engineers.

Columbus laboratory area



Columbus office

Pune office

Customer support at Tata Holset

PARTNERSHIP FOCUS: VANGUARD FOUNDRY LTD

One of Holset's key component supplier-partners is Vanguard Foundry. Based at Lye in Stourbridge, UK, the company produces high quality spheroidal graphite and Molysil (SiMo) cast iron turbine housings. Employing around 65 people, Vanguard currently meets around two thirds of Holset's requirement for high horsepower (HHP) turbocharger housings.

Established in 1983 by seven former employees of GKN's Shotton foundry in North Wales, Vanguard began by leasing its plant from another foundry that was in decline. By 1987 Vanguard had purchased the whole site complete with offices. Its consistent focus has been low volume, technically demanding cast components predominantly associated with commercial vehicles.

In 1990 its first turbine housing was produced and in 1991 Vanguard supplied its first housing to Holset, who now accounts for half of the foundry's turnover, with other casting products being exported to Europe, Japan and the USA.

Demand for Vanguard castings from Holset is inevitably cyclical and subject to fluctuation. As a relatively small company, Vanguard is potentially vulnerable to rising and falling demand. A sudden increase in demand for example can create cash flow strains and a lack of manpower. Vanguard was prepared to invest but it envisaged problems when demand fell and different challenges in responding to a sudden need for increased capacity. Finding skilled foundry personnel had proved difficult in the past, which had led to bottlenecks in supplying Holset.

Vanguard discussed its fluctuating demand problems with Holset, highlighting concerns of stability in relation to Holset's longer-term requirements. It was suggested that if Holset could give an estimate of the number of foundry boxes (one box can produce up to four castings, depending on size and weight) Vanguard would ensure that the capacity was available. The casting supply and demand situation could then be evaluated at Holset's quarterly business review meetings, where a decision could be made on whether to increase or decrease its requirements. The demand also had to include new product introduction (NPI) requirements as this would impact capacity.

Holset's product demand from Vanguard over a 12 month period was analysed to provide a broader understanding of its requirements and the average weekly box quantities that could be expected on an ongoing basis. It was agreed that a tolerance of 10% would be allowed to cover unforeseen fluctuations in demand. An allowance was made for possible NPI requirements to ensure that customer prototypes and sales samples could be delivered on schedule.

The cost contribution that each box made to the foundry was calculated, so that if demand from Holset fell short of the calculated demand, it would pay the contribution. By the same token, should Vanguard fail to meet the projected demand it would pay Holset the same amount.

Vanguard for its part has to ensure that its holiday or other shutdowns do not impact on Holset's supply of castings. The process is averaged over a monthly period so that any shortfalls are identified immediately and rectified.

Working in partnership, Holset and Vanguard have put in place a process that is working to the benefit of both companies. In place now for over 12 months, it requires careful management but so far neither party has had to make any 'penalty' payments. Vanguard's delivery performance has been 99% on time throughout 2004 – previously it had averaged around 70%. All NPI samples have been delivered on time and a reduction in lead time for these parts has also been achieved.

Holset receives its HHP turbine housings on time, while Vanguard are now able to invest in capacity and review new processes for casting production, with the aim of staying at the forefront of foundry technology for the specialist markets it serves.

Working in partnership, Holset and Vanguard have put in place a process that is working to the benefit of both companies.

Holset and Vanguard working in partnership

Holset castings

Holset pattern

Vanguard Foundry Ltd.

TRAINING THE NEXT GENERATION OF TURBOCHARGER ENGINEERS

Turbocharging is a complex technology. Even for someone deeply involved in the subject for 20 years or more, there is always something new to learn. Engineers new to Holset therefore need plenty of guidance in getting to understand, in particular, the interactions between the turbocharger and the engine.

Holset is accordingly committed to training its engineering staff, who are regularly sent on courses aimed at increasing their technical knowledge. Some of these courses are quite specialised so often we have to rely on our university contacts to find appropriate courses or sometimes conference events. Typical courses are Computational Fluid Dynamics (CFD) in turbomachinery, tribology, wear and vibration of rotating machinery.

Other courses aimed at improving engineers' understanding of computer-aided analysis or measurement techniques are often provided by our suppliers. They include ProEngineer training at PTC, ANSYS and CFX Training. Such courses have produced in-house experts with the skills to drive the software, interpret the results and suggest improvements to the system suppliers.

However, the one area of training where we could not find any external course that entirely matched Holset's needs was that of understanding the fundamentals of engine-turbocharger interaction. So in 1995 we collaborated with our parent company Cummins to set up a tailor-made course under the title 'The Application of Turbomachinery to Reciprocating Engines'. It was a formidable undertaking, resulting in 170 pages of text, over 60 pages of appendices and nearly 400 slide illustrations.

The course comprises of ten sessions, each covered by a chapter in the course notes:

1. A turbocharger hardware overview in which the main components of a turbocharger are described, including their operational function and ways of manufacture.
2. Reviews of basic thermodynamic concepts relating to turbochargers and their functional interface with the engine are described.
3. An examination of compressor design in detail.
4. A corresponding review of different turbine configurations.
5. A review of the rotor system as an entity, with an analysis of its performance and an explanation of the critical motion of the shaft.
6. A detailed look at how turbocharger to engine matching is achieved and how the 'breathing line' helps to relate back to compressor flow and pressure ratio. This chapter also explains the need for wastegate and variable geometry turbocharging.

Sessions/chapters 7, 8, 9 and 10 focus on specialised turbocharger applications including those relating to spark ignition engines, two stage turbocharging, turbocompounding and diesels featuring exhaust gas recirculation (EGR).

The first of the new two day training courses was held at Holset's headquarters in Huddersfield, UK in December 1996. Since then over 200 engineers have successfully completed the course. At selected points throughout the course, in order to ensure each section is being understood, exercises are run enabling the students to practice their newly acquired skills. They are required to plot engine data on compressor and turbine maps and select the right match for given engine characteristics. Finally, through feedback from each student under each chapter heading, the content of each session/chapter can be continually reviewed and the content updated to ensure that it is clear and is in line with Holset's latest technology and as such meets the training needs of our engineers.

Over 200 engineers have successfully completed the course

HOLSET TURBOCOMPOUNDING HELPS MAKE SCANIA R-SERIES 'TRUCK OF THE YEAR'

Congratulations to Scania, whose handsome new R Series was awarded the prestigious 'International Truck of the Year 2005' title.

The R Series

Image supplied courtesy of Scania

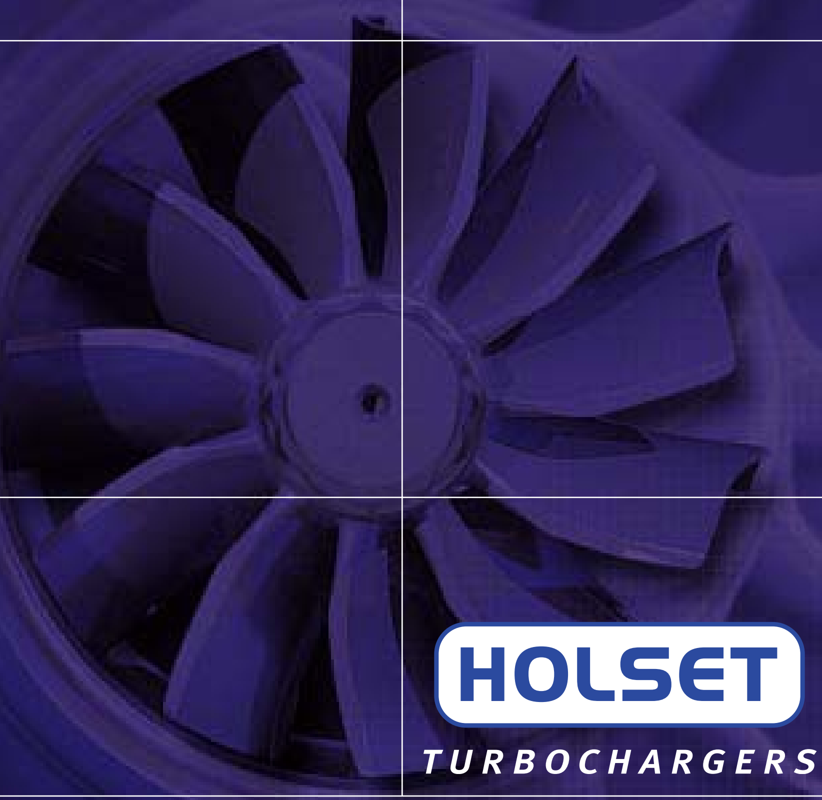
Scania's R Series is offered with an impressive choice of turbocharged and intercooled diesel engines: 580 and 500hp 16 litre V8s; 470 and 420hp 12 litre straight-sixes (the lower rating already available in Euro 4 form) and shorter-stroke 380 and 340hp 11 litre units.
The R Series can even be specified with the newest addition to Scania's engine line-up, the five-cylinder 9 litre, offered in 310, 270 and 230hp ratings.

The 420hp 12 litre Euro 4 engine features 30% lower emissions, achieved using several innovative technologies, including Scania's HPI (high pressure injection) fuel system, developed as a joint venture with Cummins, exhaust gas recirculation (EGR) and Holset turbocompounding.

The verdict of the judging panel of 18 leading European truck journalists on the latest-generation Scania is as follows:

"The R Series impressed the jury with its particular attention to driver comfort through a wholesale revision of the cab interior. Improved ergonomics, better cab comfort and a more refined driving environment all combine to give the R Series enhanced driver appeal. In addition, Scania's attention to the driveline, new electronic architecture and cleaner more efficient engines was worthy of particular note."

Ahead of the award, 2004 was a good year for Scania, which followed up the launch of the R Series with the lower-cabbed P and bonneted T Series models. Offering an outstanding driver environment and excellent operating economy, along with payload enhancing weight savings and better aerodynamics, as well as numerous technical improvements, they replaced the Swedish company's already successful 4 Series chassis dating from 1996.



HOLSET

TURBOCHARGERS

Our Goals

Holset Turbochargers place the utmost importance on achieving high levels of product and service quality.

Our people are the single most valuable asset we have to ensure we meet your requirements. Through structured training development programmes we encourage our employees to spend approximately 5% of their working time in training and personal development.

Our operations worldwide are certified to TS16949 quality standard and we welcome suggestions as to how we can further improve our performance to meet your needs.

We take our environmental obligations seriously and all our worldwide sites have achieved ISO14001. Our products have an important part to play in helping to improve engine emissions.

Our goal is to provide the lowest total cost solution for your turbocharging needs.

www.holset.com

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