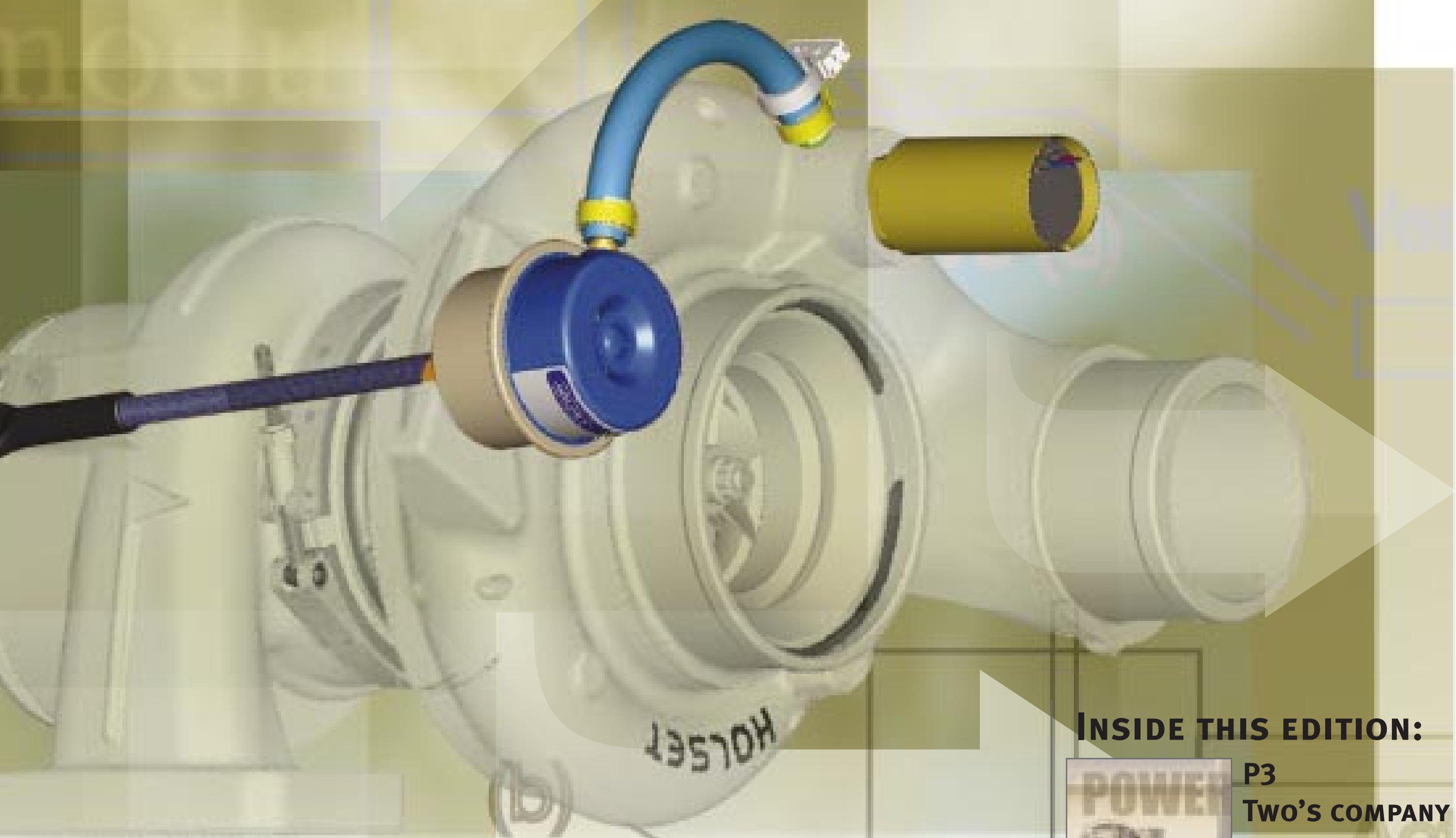
HOLSET TURBOCHARGERS

HTi

THE LATEST NEWS FOR HOLSET TURBOCHARGERS' CUSTOMERS

EDITION 3

COMMAND VALVE WASTEGATE CONTROL POINTS THE WAY FORWARD



INSIDE THIS EDITION:

SUCCESS FOR HOLSET GROWS HAND-IN-HAND WITH GLOBAL USE OF TURBOCHARGERS

Paul Ibbotson with 'horsepower'

Sales of Holset turbochargers for medium and heavy duty diesel engines have reached a record high in 2004. Improved market conditions in the USA have played their part together with the continued success of the company's variable geometry turbocharger (VGT™) in a number of markets worldwide.

Increased demand for 'clean' and fuel-efficient high-performance diesels in China and India has also boosted the demand for Holset's turbocharger range.

This continued growth in worldwide demand has confirmed Holset's strategy of continued growth, leading to an expansion of turbocharger manufacturing capacity in two key locations: Dewas, India and Wuxi, China.

In March 2004, Holset moved its China operation to a new, purpose-built, world-class production facility in Wuxi serving both domestic engine manufacturers and global customers as an export base. Additionally, in Dewas, Holset is also expanding its manufacturing capacity to meet the needs of the growing domestic and export markets in India.

These new manufacturing facilities, as well as Holset's longer-established plants in Europe and North America, serving what has become a global customer base, are supported by the company's turbocharger dedicated technical centres; in the UK and China. Their ever more vital and sophisticated research and development role continues to be driven by a need for new technology solutions to meet progressively tougher exhaust emission standards, improved power density and greater durability – typically matching that of the engine itself. All this within a shorter product life cycle, as the pace of engineering advance increases to maintain Holset's technology leadership.

In the UK, Holset has recruited many new highly-qualified specialist engineers. This is to support the increased R&D and applications engineering challenges brought by new emissions standards, ever higher output-per-litre power densities, whilst maintaining or even improving fuel efficiency.

In China, Holset's technical centre has been expanded to support its Asian customers with new turbocharger applications, whilst undertaking performance test and approval work for company operations in other parts of the world.

We look forward to strengthening our relationship with you and to meeting your current and future needs.

Paul Ibbotson,
Managing Director

HTi is the Holset magazine focussing 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.

India follows China in Holset's plant expansion programme

Tata Holset increases capacity to meet growing market demands

Artist impression of new facility

New facility in progress

During 2004 Holset has expanded its operation in India, through Tata Holset, the company's joint venture with the Tata Group of Companies, to increase its turbocharger manufacturing and supply capability in line with the needs of a number of markets, including those of India's domestic diesel engine makers.

It comes as a further move in Holset's strategy of expanding its worldwide manufacturing capacity, which last year saw the opening of a new world class facility at Wuxi in China to support the growing numbers of engine manufacturers now established in China.

The new facility at Dewas in India is an expansion of the established Tata Holset facility. The current and new buildings are joined by interconnecting link corridors for the movement of materials and people. Space is available to expand the new building in future years as the further increase manufacturing capacity as the use of turbocharged engines in road vehicles and for off-highway diesel applications grows in the sub-continent. Fixed-geometry light to medium range turbochargers will remain the focus of the Tata Holset product line, with an emphasis on maintaining the high quality standards that both OEM and end-user customers of the Dewas plant have come to expect.

Built to world class standards, based on a zero-defect manufacturing strategy, the plant is equipped with a fail-safe conveyor assembly line, replacing the previous method of turbocharger bench assembly. There are separate raw materials and finished component stores.

The new Dewas plant is quite complex and unique to India. The pre-engineered structure of the main building is designed for earthquake resistance and can be readily extended in the future. Maximum use is made in the new facility of natural light. New reception and meeting rooms project Holset's corporate image. The open-plan office area is equipped with modular furniture and centralised air conditioning, whilst great care has been taken to maintain a lush green environment around the plant.

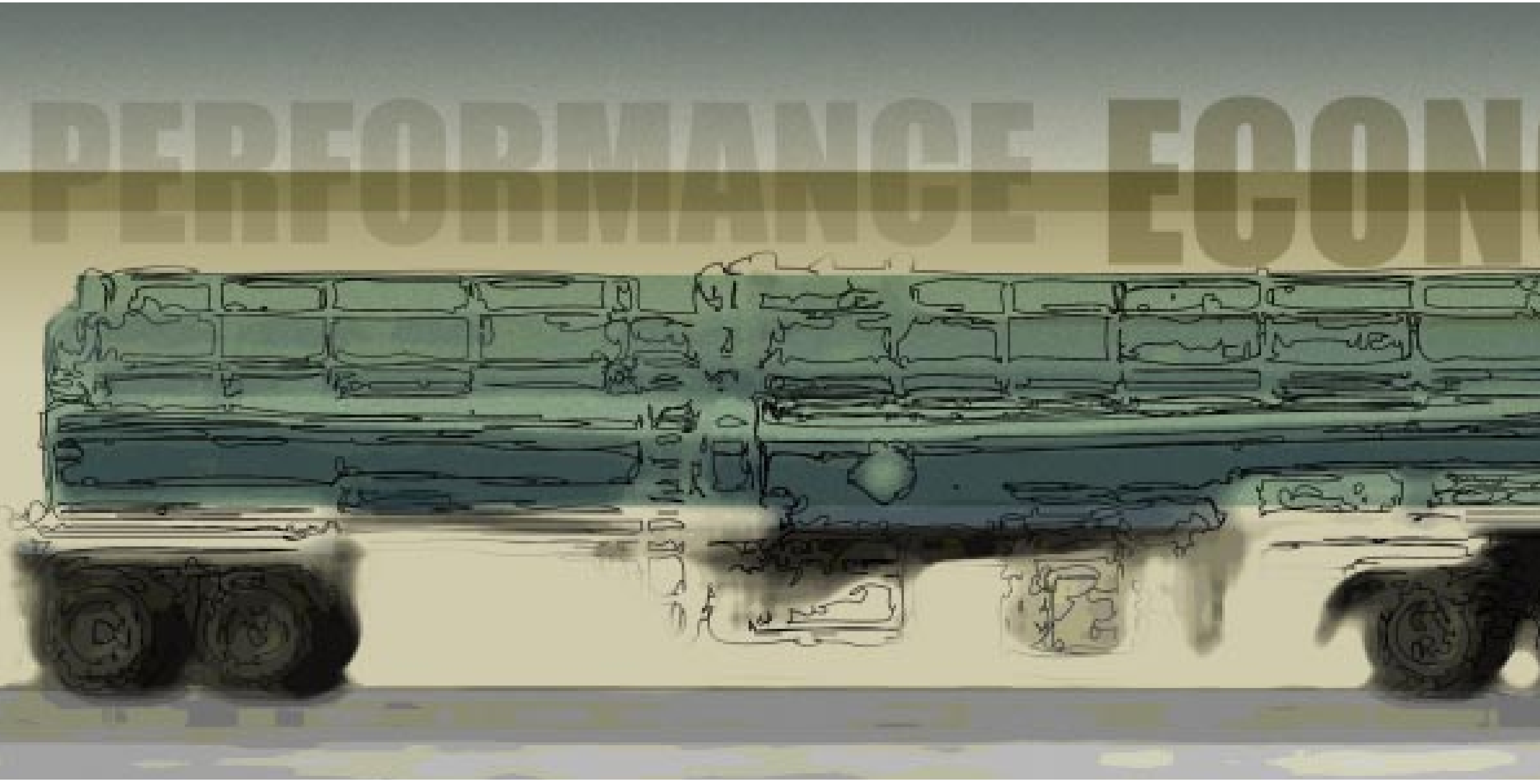
The newly expanded site will help Tata Holset maintain the same global high standards in its manufacturing and customer service activities as those for which other Holset facilities around the world are already recognised.

Holset's policy is to continue to expand its worldwide manufacturing capacity to meet the growing worldwide demand for diesel engine turbochargers. India is a key market for Holset and the company expects to build further on its position as market leader in the sub-continent and other parts of Asia, through long-term investment in Tata Holset.

The newly expanded site will help Tata Holset maintain the same global high standards in its manufacturing and customer service

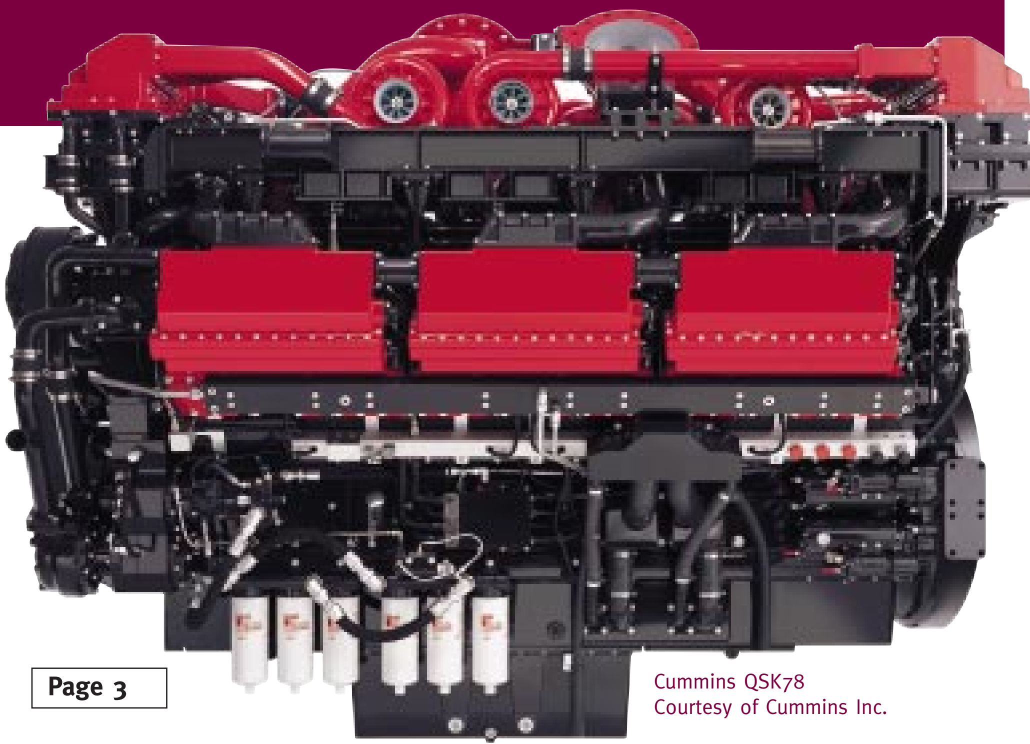
Artist impression of the vision area

Artist impression of the reception



Two's Company

Truck and bus engine manufacturers are continually driven by competitive market pressures to improve performance and fuel economy from power units of given weight, size and swept volume. End-user customers demand more horsepower and higher but flatter torque. Meanwhile, ever tougher environmental legislation requires progressively lower noxious exhaust emissions.



Cummins QSK78
Courtesy of Cummins Inc.

Greater demand is inevitably made on the turbocharger installation, in order to 'squeeze more air' into the same cylinder space. Increased air density can only come from a higher turbocharger boost pressure.

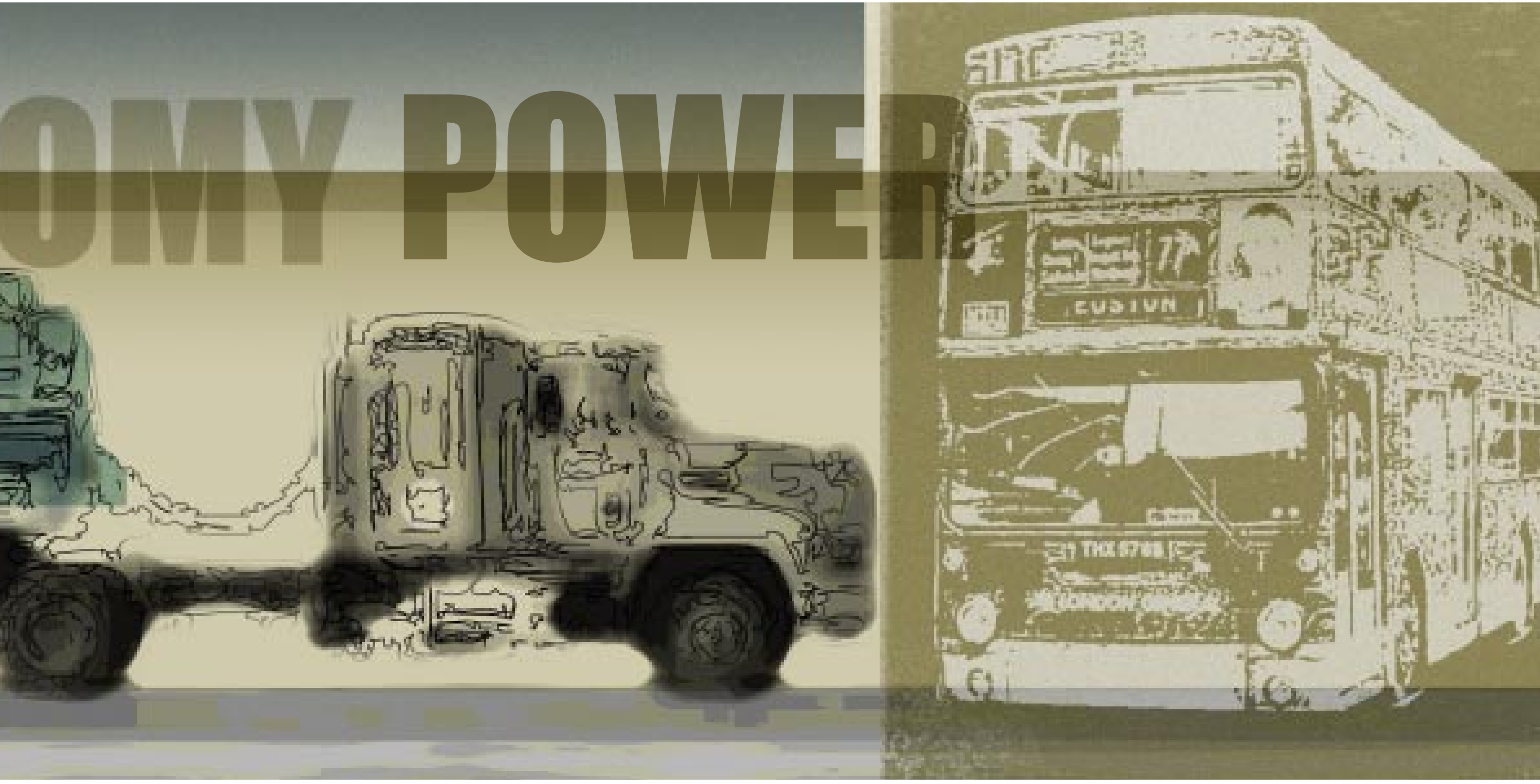
Demand for higher boost pressures looks certain to continue as emission limits get tighter and tighter. With the implementation of Euro 4 and three years later, Euro 5 legislation, matched in North America by EPA '07 and '10, progressively higher pressure ratios will be needed to enhance combustion efficiency and help to contain the peak combustion temperatures that promote the formation of NOx (nitrogen oxide) emissions.

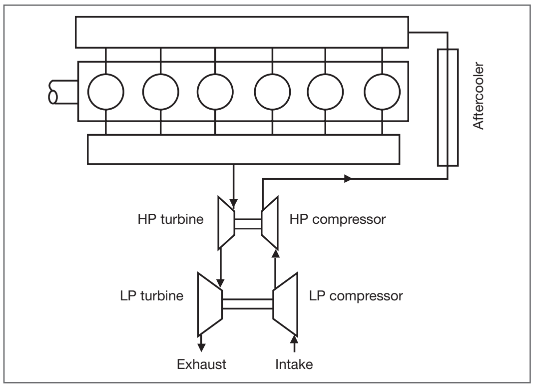
At the same time, the trend of engine downsizing brings a further demand for power and torque per litre of engine displacement.

Developing high pressure-ratio compressors with a wide flow range has always been a key element of Holset's turbocharger development. It is a strategy, which under today's market conditions assumes even greater importance.

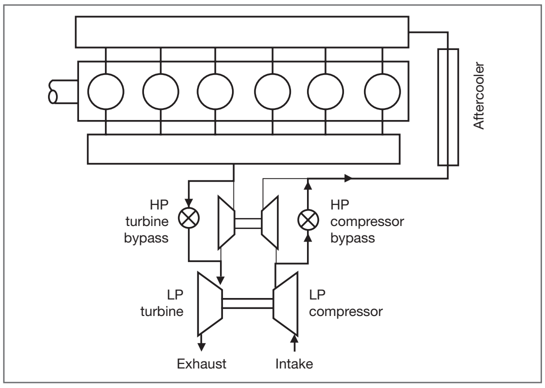
Increasing pressure ratios in single-stage compressors invariably means the compressor wheel has to rotate at higher speeds and to withstand higher temperatures. Advances in design, manufacturing processes and materials technology have made significant improvements possible but there is a practical limit beyond which pressure ratio increases are no longer feasible or economically viable.

It is at this point that two-stage turbocharging becomes a serious option. When two turbochargers are connected in series, the overall pressure ratio is the mathematical product of the two stages' individual pressure ratios. For example, if the two stages each deliver a 2.5:1 pressure ratio, then an overall 6.25:1 ratio is possible, in theory at least. In practice, pressure losses in the system mean that the overall pressure ratio tends to be somewhat lower. Similarly, on the exhaust side, the turbine expansion ratio is split between the two units.





Two-Stage
Turbocharging



Modulated
Two-Stage
Turbocharging

Two-stage turbocharging is sometimes confused with so-called 'sequential' turbocharging, where two different sized single-stage turbochargers are used with no multiplication of pressure ratios. Typically, the smaller turbocharger is 'active' at low engine speeds and the second, larger, unit with its higher-inertia rotor, is brought into use by suitable control valves at higher engine speeds. In this way fixed-geometry turbochargers and narrow map compressors can maximise boost across a wider engine speed range.

Typically, two-stage series turbocharging is applied to engines that need high pressure ratios in order to cope with 'thin' air at high altitude, without losing power. For example, Cummins' big 78 litre QSK78 industrial V18 diesel, fitted with HX60 and HX83 Holset turbochargers, has an impressive 6.7:1 pressure ratio at 12,000ft (3,600m) altitude, where it can still develop its full 3,500hp (2,600kW) power rating. Inevitably, on such engines, the air handling system accounts for a large part of the total installation's bulk. In road vehicle applications packaging of two-stage systems remains a challenge for manufacturers.

Selecting the best high and low pressure turbocharger sizes for a two-stage installation is clearly critical, deriving from the engine performance required and the application. In an industrial engine the turbochargers are often sized so that an equal pressure-ratio split is achieved at rated power.

However, in automotive engine applications where good low speed performance with high torque is required the high-pressure turbocharger is much smaller, matched to low engine speed, where it is ideally sized for giving good boost pressure and transient response. In this region two stage operation is achieved with high overall pressure ratios.

Two-stage turbocharging can be applied to engines that need high pressure ratios, for example, 6.7:1 at 12,000ft (3,600m) altitude

A high-pressure turbine bypass is used to regulate control system pressures on the exhaust side. The bypass, opens as mass flow increases, in line with engine speed. Depending on how much bypass flow is allowed, the system either remains in two-stage configuration or, at higher engine speeds, effectively reverts to single-stage operation, with almost no contribution from the high-pressure turbocharger.

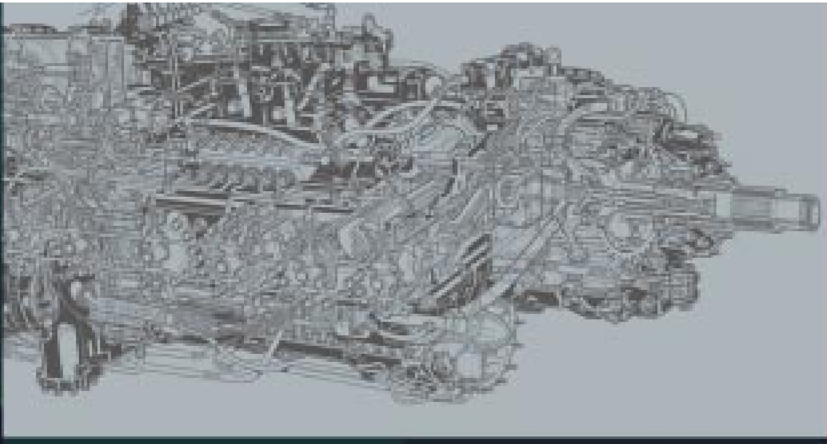
On the intake side, a bypass around the high-pressure compressor may also be needed. Use of such a feature is called modulated or switched two-stage operation and can offer optimised turbocharging across a wider range of engine speeds than the more basic two-stage system.

High boost pressures are inevitably and unfortunately accompanied by high boost temperatures. Once they exceed about 230°C, then aluminium turbocharger components are liable to be structurally weakened. Special intercooling, using an additional heat-exchanger type air cooler between the compressor stages, therefore becomes necessary to prevent the high pressure turbo's compressor from overheating. The only feasible alternative is for aluminium to be replaced with a more thermally resistant and expensive material in the temperature vulnerable compressor.

How does two-stage turbocharging fit in with other emission control strategies, notably cooled exhaust gas recirculation (EGR)?

High EGR rates by definition require high turbo boost pressures for which two-stage systems are ideally suited. The two-stage concept also has its place on engines designed for use with filter or catalytic aftertreatment systems, where back pressure issues can arise, such that the high overall efficiency of a two-stage system enables the best possible engine performance to be obtained.

Two-stage turbocharging is not just technology for the future though. Whether it be a car, truck or an industrial application, two-stage is here today!



Dr. Büchi gradu
the Swiss Feder
of Technology i
in 1903 and wo
subsequently w
engine manufac
Belgium and Sw
where his ideas
fruition.

Dr. Alfred Büchi

The History of Turbocharging in Diesel Engines

The evolution of the turbocharger has been fundamental to the development of the diesel engine. It has made possible the immense advances in performance, fuel economy and emissions reduction we have seen in all diesel power applications, particularly over the past 40 years- but where did the idea come from and how was it developed into today's turbocharger?

At the end of the 19th Century huge progress had been made in the development of machines, particularly in steam-powered prime movers and in engineers' understanding of the processes at work. Otto had demonstrated the four-stroke spark-ignition engine. Akroyd Stuart and other pioneers in Britain and elsewhere were working on the principle of compression ignition, often using additional heating sources outside the engine cylinder.

However it was Rudolf Diesel in Germany who is generally credited with the design in 1893 of a practical engine in which combustion is initiated entirely by the heat generated during compression of the fuel-air mixture.

Surprisingly, it was barely ten years later that the Swiss engineer Alfred Büchi started thinking about pressure charging the compression-ignition engine. His proposed system incorporated all the essential elements of the modern turbocharged engine. Power output and operating efficiency was enhanced by an exhaust gas turbine driven intake air compressor.

Dr. Büchi graduated from the Swiss Federal Institute of Technology in Zurich in 1903 and subsequently worked with diesel engine manufacturers in Belgium and Switzerland where his ideas came to fruition.

Fig 1 shows the patent Büchi obtained in 1911. His turbocharger consisted of a multi-stage axial-flow compressor, complete with a simple intercooler, driven by a multi-stage axial-flow turbine on the same shaft, rotated by the kinetic energy of the exhaust gases leaving the reciprocating engine.

Acceptance of his innovative ideas were slow and he had to make many detailed experiments to convince others of the benefits of the system. Eventually Dr. Büchi succeeded in convincing a German engine manufacturer to put his ideas into production and in 1925 MAN began making the first ever engines with Buchi turbochargers for marine applications.

Other experimenters were working around the same time with boost-charged spark-ignition engines. Professor Rateau in France and Dr Sanford Moss in the USA had experimented with turbocharged aircraft engines, while in Britain, Major Frank Halford designed and built an experimental 1.5 litre racing car engine in 1923 – one of the earliest turbocharged automotive engines (Fig 2).

Halford had been involved with aircraft engine design and manufacture for some 10 years and would have been well aware of current developments. His engine featured a neatly installed radial compressor. Its air inlet was drawn through the centre of the engine, driven by a close coupled axial flow turbine. The installation included an air-to-air intercooler below the engine sump. Halford went on to become a successful reciprocating engine and gas turbine designer for the Napier and deHavilland companies.

Meanwhile, Dr Büchi realised that constant pressure turbine inlet conditions impaired cylinder scavenging at all engine speeds and loads. This shortcoming would hamper the application of turbocharging to high speed automotive engines. He carried out experiments that led to an understanding of 'pulse charging', using small volume exhaust manifolds and turbines with a restricted throat area. It was a technique that preserved a high energy, high pressure pulse when the exhaust valve first opened, but delivered low manifold pressures later in the exhaust stroke to promote cylinder scavenging.

Based on these principles, Saurer, the Swiss engine manufacturer went into production in 1938 with what is probably the first turbocharged heavy-duty road vehicle diesel engine, shown in Fig 3.

In 1951, The Napier Company produced a somewhat complex turbocharged and turbocompounded diesel engine for aircraft use (Fig 4).

The Nomad was intended to be a low fuel consumption engine for freight-carrying aircraft. It was a flat 12 cylinder two stroke diesel, whose turbocharger compressor and turbine were derived from a Napier gas turbine engine. The common turbine to compressor shaft was driven from the engine crankshaft via a variable-speed gearbox. Thus the engine could drive the compressor if required, but when excess turbine power was available, the system became a turbocompound engine. This engine developed 3,250hp at an altitude of 11,000ft (3,350m).

Saurer went into production in 1938 with what is probably the first turbocharged heavy-duty road vehicle diesel engine

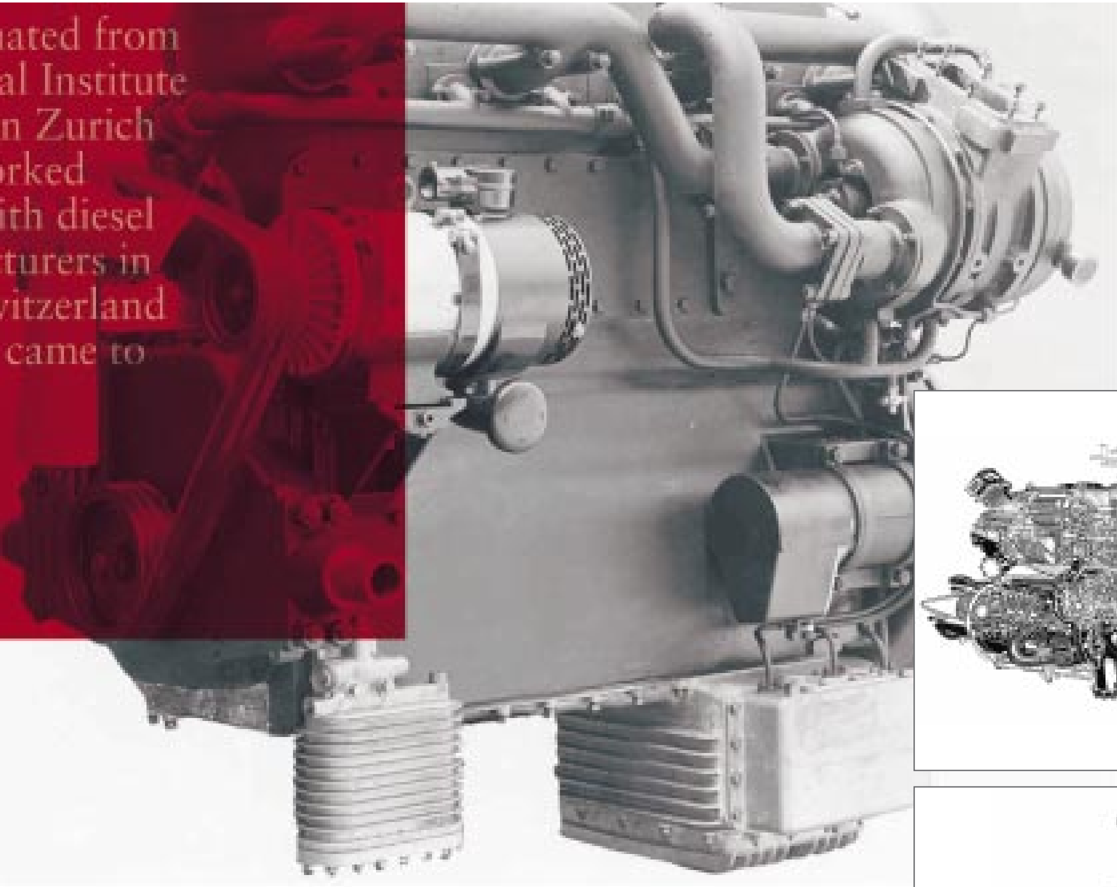
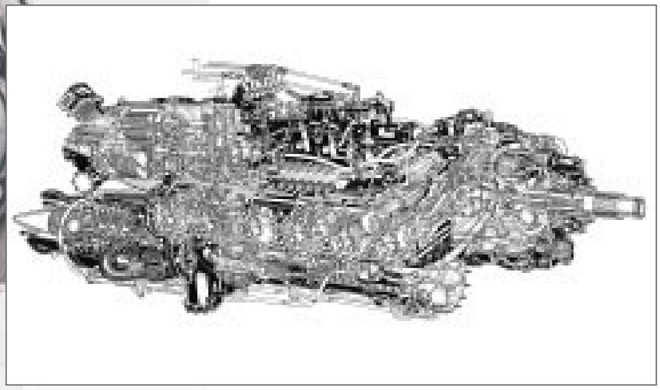


Figure 4
Napier Nomad Aircraft Engine
courtesy of Rolls Royce Heritage Trust



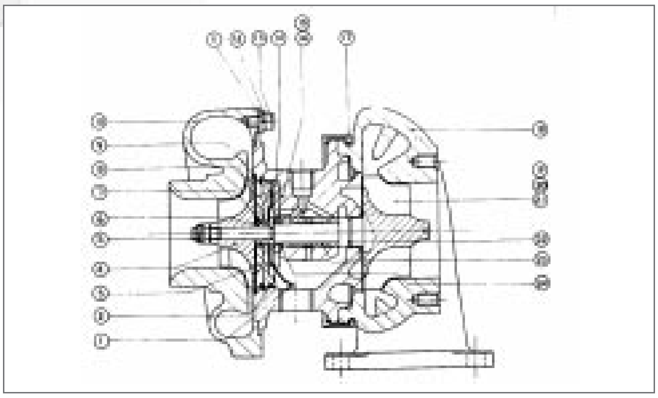


Figure 5
Holset 3LD 1973
Turbocharger

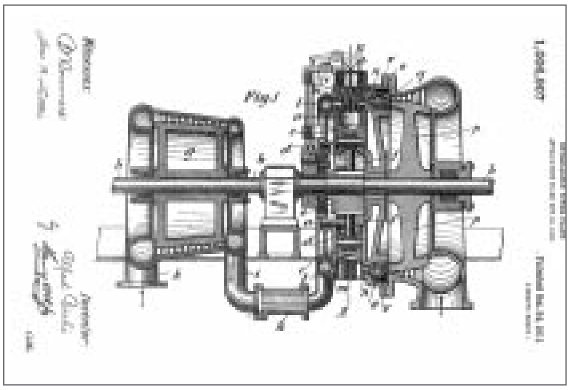


Figure 1
Buchi 1911
patent

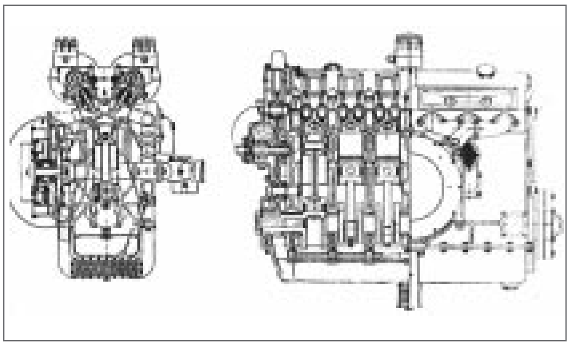


Figure 2
Halford Engine
(1923)
courtesy of
Douglas R. Taylor

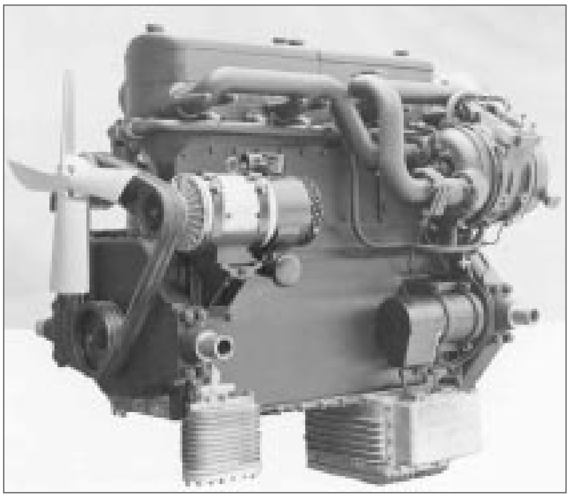


Figure 3
Saurer Engine
(1938)
courtesy
of Iveco

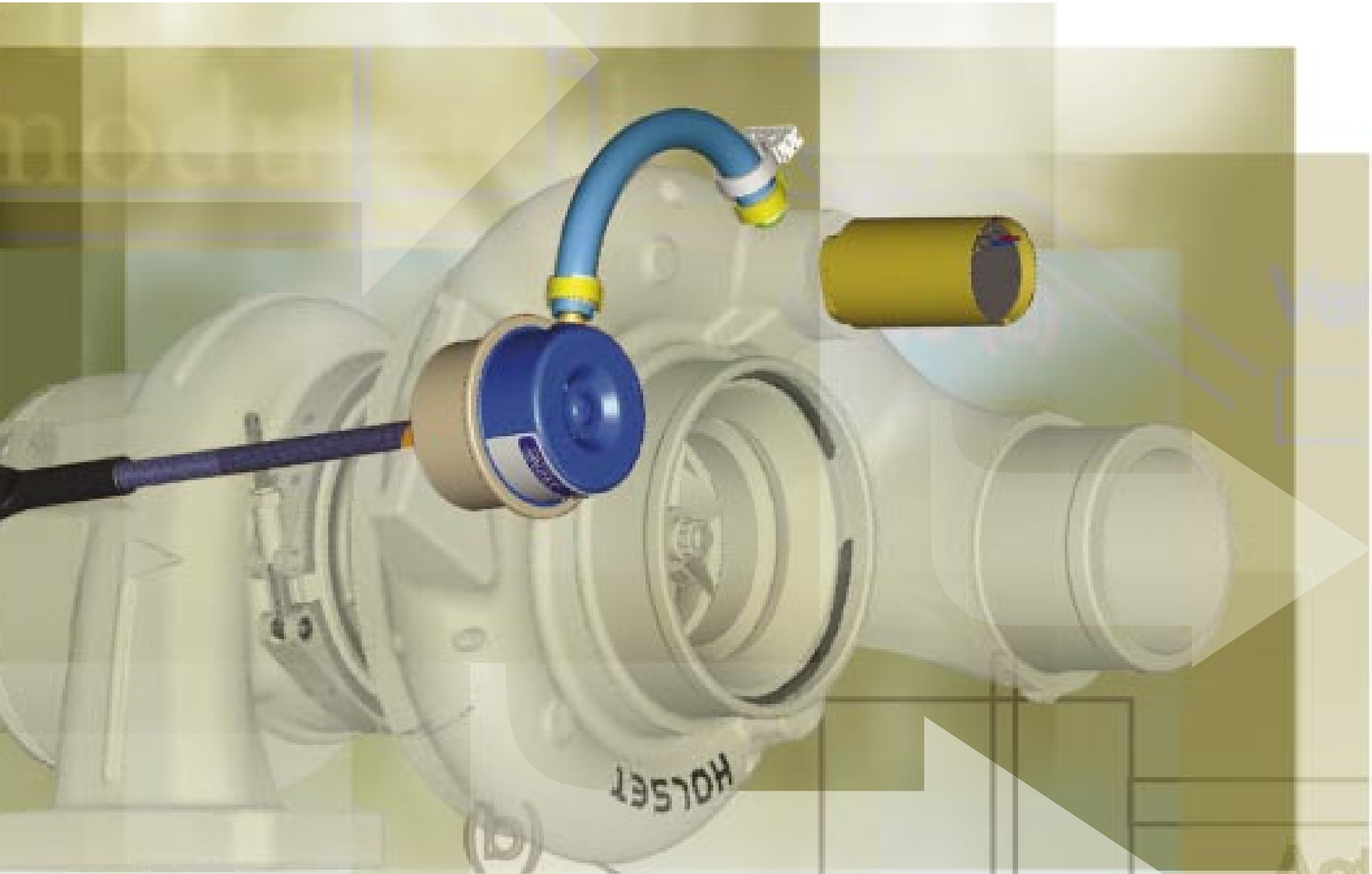
Some flight development was undertaken, but unfortunately the complexity of the engine compared with the relatively simple gas turbine being developed at around the same time put a halt to the project.

From the 1950's onwards, most heavy-duty truck and bus engine manufacturers experimented with turbocharging and many put such power units into production. The turbochargers in these early automotive engines were relatively bulky, derived from larger industrial engine turbocharger designs. It was the design for a lightweight automotive turbocharger from the Schwitzer Company in 1957, which led to licences being taken out by Holset for a turbocharger with a simple but robust bearing system that forms the basis of the modern automotive turbocharger. Fig 5 shows the Holset 3LD turbocharger of 1973.

Since these early days, Holset has developed its own turbocharger technology leading to the H range, HX range and more recently, HE range products.

Turbocharging is now practically universal on all automotive diesel engines and developments continue apace. Turbocompounding proposed by Dr. Büchi in the 1930's, has been pursued by a number of truck engine makers in the search for improved thermal efficiency and fuel consumption. In 1991, Scania in Sweden put the first example into series production, an 11 litre in-line six cylinder engine utilising a Holset designed power turbine able to harness much of the energy remaining in the exhaust gases downstream of the main engine turbocharger, to augment the mechanical power delivered through the crankshaft. The crucial on-highway power and torque requirements of a variable-speed engine, where high torque-rise and/or a very wide speed range are key attributes, has led to the successful development of wastegated and subsequently variable-geometry turbochargers. The introduction in 1998 of the Iveco Cursor range of 8, 10 and 13 litre truck diesels in 1998 featuring Holset variable-geometry turbochargers (VGTs™) became the first such heavy-duty volume production application.

For the future, the now ubiquitous turbocharger is certain to remain a vital component of all low-emissions diesels. Further exciting and innovative developments are sure to take what is a fundamentally simple concept into its second century, largely thanks to the remarkable vision and determination of Dr. Alfred Büchi.



COMMAND VALVE WASTEGATE CONTROL POINTS THE WAY FORWARD

Pulse-width modulated (PWM) command valve controlled wastegate technology is well established on small, passenger car, mainly gasoline engines. Given a stoichiometric engine's requirement for accurate control of the air-fuel ratio, external control of gas flow through precise regulation of the wastegate is essential.

Operation of the valve in a PWM wastegate installation relies on the principle of sensing a pressure drop across an orifice. A restricting orifice, (a) in fig 1, is placed in the feed pipe, upstream from an electronically-controlled valve (d). When the valve is opened, the flow is increased, resulting in a greater pressure difference across the orifice. That is to say the pressure, immediately downstream of the orifice is reduced. This pressure is communicated to the wastegate actuator by a connecting pipe (b).

Addition of a 'Command Valve' PWM in the system allows the turbo boost curve shape to be tailored to match the required performance characteristics of the engine. As shown in fig 2, operation of the valve can increase or reduce the charge air pressure ratio and hence the airflow delivered to the engine right through its load and speed range. The valve allows more precise regulation of the air-fuel ratio, a vital requirement in a modern diesel engine, especially within the framework of ever more stringent emissions legislation.

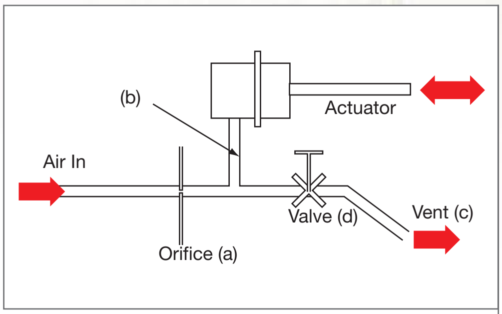


Figure 1

One of the effects of EPA 2004 diesel engine emissions requirements in North America has been the need for a similar degree of air-fuel ratio control in the medium/heavy-duty truck and bus diesel engine market. Command Valve PWM hardware already available was adequate for turbocharged passenger car engines. However, Holset's primary market segment, trucks and buses, required a new approach, with mechanical durability over a service life of up to 1,000,000 miles as a prime requirement. However, the componentry, typically using plastic mouldings, fell short on both durability and its capacity to withstand sustained temperatures well above the 120°C experienced in light vehicle turbocharger environment.

In partnership with KIP Inc, a subsidiary of Norgren, Holset developed a valve capable of meeting the much more rigorous needs of the medium-duty truck and bus diesel market.

Customer input and analysis of typical installations in our market showed that for ease of installation and reliability, as well as cost, the Command Valve should be mounted directly on to the compressor cover, making the valve an integral part of the turbocharger assembly rather than an externally mounted 'accessory'. This enabled most of the associated 'plumbing' to take the form of drillings in the compressor cover.

The valve allows more precise regulation of the air-fuel ratio, a vital requirement in a modern diesel engine

Avoidance of external plumbing brought a number of manufacturing and operational benefits:

Piping of any kind on the outside of an engine or any other part of a driveline becomes a potential source of problems. Leakage either at joints or in the pipe itself due to mechanical failure or inadvertent damage in a fleet workshop can bring reliability and durability problems. External piping clearly adds cost, not only for the pipes, clips and other fittings, but also the indirect cost of having to manage and document additional part numbers in service manuals and parts order documentation. Separate piping also implied extra liaison between Holset, the engine manufacturer and the vehicle builder to ensure correct installation. Factory fitting of the Command Valve into the turbocharger gives Holset full control of the installation and assembly.

However, an integrated Command Valve has to tolerate a harsher environment. The temperature of the feed air to the valve, if taken directly from the volute, can be up to 220°C. The metal temperature, if the valve is mounted directly into the compressor cover, could be up to 200°C, and that of the ambient air adjacent to the valve up to 140°C. Furthermore, if the valve is mounted direct to the turbocharger, it becomes inevitably subjected to full engine vibration effects.

Holset's chosen solution, after an extensive test programme, is a metal bodied PWM Command Valve mounted directly into a boss on the compressor cover by a single large thread and sealed by three O-rings as shown in fig 3.

All external plumbing is eliminated, with the exception of the short flexible pipe connecting the signal port (on the compressor cover's command valve mounting boss) to the wastegate actuator, in a similar way to the compressor cover/actuator pipe connection used on conventional boost controlled systems. The twin design challenges of thermal and mechanical loading were addressed by careful detail design of both the valve and its mounting. Internally the electrically-actuated Command Valve has windings, wiring and seat materials of the highest specification, which ensure their lifetime capability of withstanding the high temperatures that characterise medium/heavy-duty diesel turbocharger applications.

Meanwhile critical internal moving parts are plated to ensure that wear rates are compatible with modern commercial vehicle diesel engine durability targets. Externally, a specially designed metal sheath provides support and protection to the electrical windings. The large single-thread valve mounting is simple and robust to ensure vibration resistance, while the radial compression O-rings ensure the best possible sealing.

Command Valve Function

Air is drawn from the volute through the pressure drop orifice (a) in fig 4. Flow is controlled by the valve (d) and vented via the drilling at (c). Signal pressure is connected to the actuator via vent (b).

Further Product Functionality

Swirl is naturally induced in the air entering the turbocharger's compressor volute at high velocity from the compressor wheel – via the diffuser. The centrifugal motion drives any suspended particles or droplets towards the wall. This inherent turbocharger flow characteristic was exploited in the design of the Command Valve by extending its 'nose' to draw air from the centre of the volute, which means that only clean air can enter the valve. This avoids jeopardising the valve through abrasive wear or contamination, making it suitable for use on engines with closed crankcase ventilation.

The Command Valve found in the HE351CW is currently in production and available on the Cummins 600 Turbo Diesel engine in the Dodge Ram Heavy Duty pick-up.

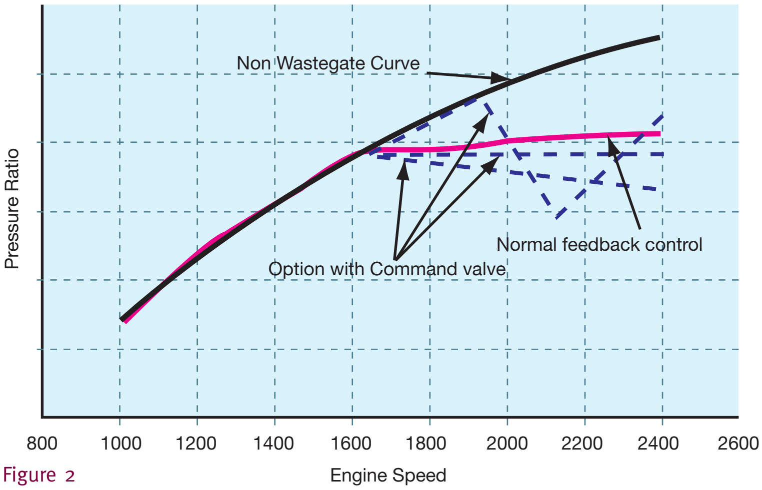


Figure 2

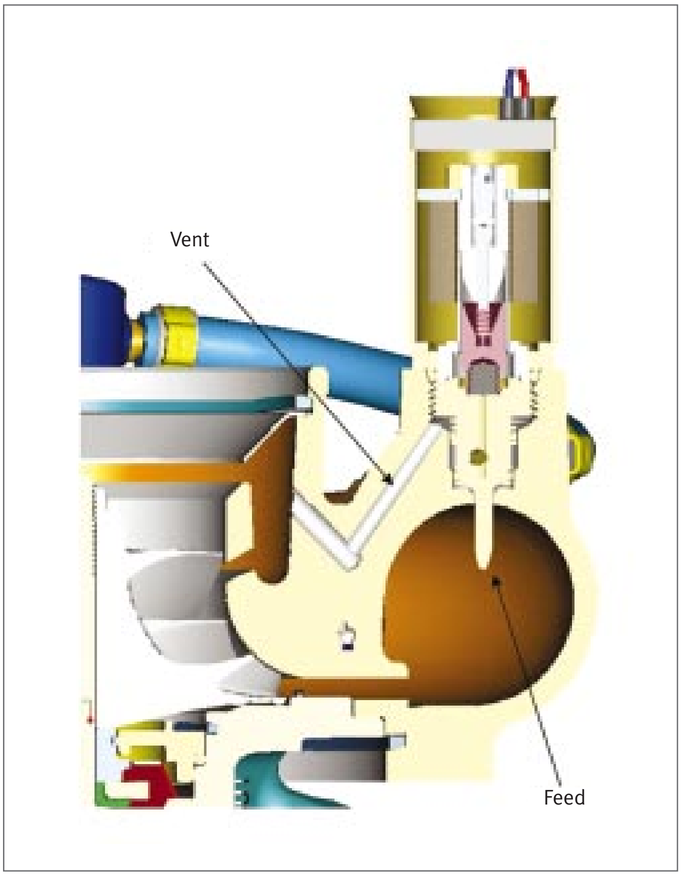


Figure 3 Construction of a Command Valve

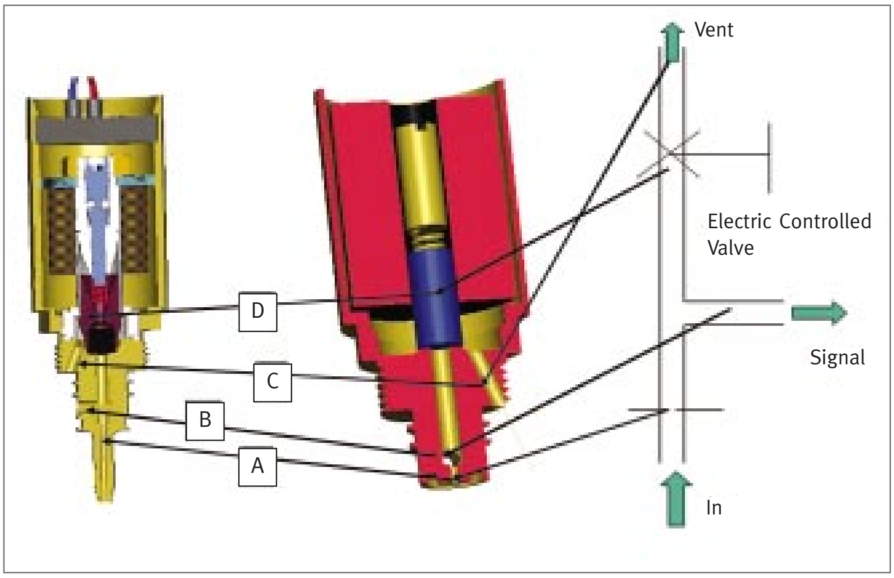


Figure 4 How a Command Valve Works

Alternative Bearing Systems

It is an unavoidable fact of life that viscous drag in the bearings of a turbocharger prevents a significant proportion of the power developed by the turbine from being 'translated' into worthwhile output from the compressor. At low turbo speeds this effect is more pronounced, contributing to turbo lag.

At a time when any improvement in overall turbocharger efficiency can contribute critically to an engine's ability to meet more stringent emission limits and performance targets, even modest percentage reductions in viscous bearing drag become technically attractive.

There are numerous emerging bearing system technologies, which at the cost of extensive development programmes, are poised to one day take over from the typical hydrodynamic floating ring bearing used in today's mass market automotive turbochargers. Together with the axial thrust bearing, it has remained an intrinsic feature of Holset's turbocharger range since the 1950's.

To describe the floating ring bearing as simply 'a metal ring of some axial length with radial holes' is reasonably accurate, but tends to trivialise the complexity of the design. The main purpose of the floating ring bearing (see fig 1) is to create an inner and outer oil film, so that the shaft journal surface is constrained radially within the bearing, which in turn is constrained radially by the housing. The floating ring bearing is designed to rotate at a fraction of rotor speed, which allows the rotor system to remain stable at high rotational speeds that would normally lead to instability in a plain journal bearing.

In contrast the axial thrust bearing (fig 2) is a relatively simple device that develops a hydrodynamic load due to the 'wedge' created by the geometry of the tapered pads and the load carrying surface of the thrust collar and oil slinger. Oil is dragged into the wedge under the influence of viscous forces and because the oil is incompressible, pressure builds up and hence the load is generated.

Why do we want to change floating ring bearings and axial thrust bearings?

Today's floating ring bearings and axial thrust bearings are very cost effective to produce. Dimensional tolerances are easily controlled, given modern manufacturing methods and they deliver an acceptable performance for the present generation of diesel engines. Also, they provide good shaft motion control with proven reliability and durability. However, tomorrow's high performance, low emission engines are almost certain to demand higher turbo efficiencies. Meanwhile the advent of a quite new bearing technology will offer the opportunity to address secondary issues like oil leakage, blowby and noise generation from out of balance and sub-synchronous vibrations that beset some current turbo installations.

Dimensional tolerances are easily controlled, given modern manufacturing methods and they deliver an acceptable performance for the present generation of diesel engines

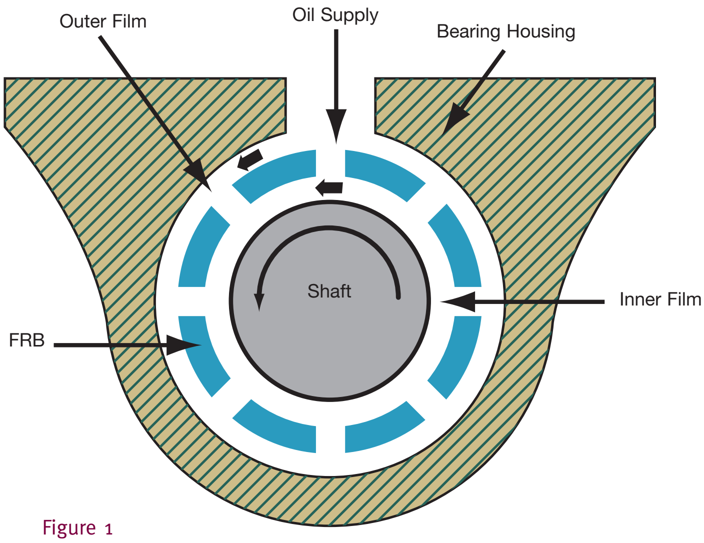


Figure 1
Floating Ring Bearing

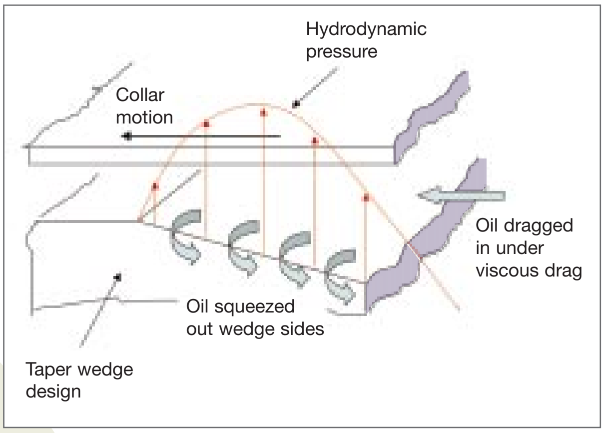


Figure 2 Axial Thrust Bearing

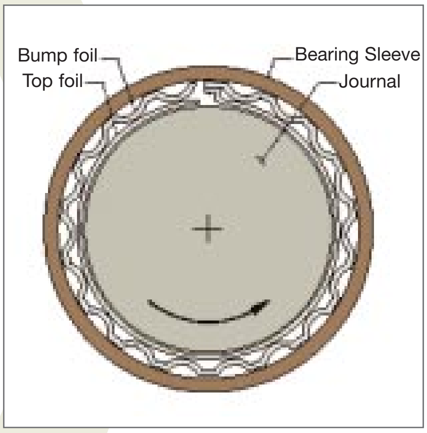


Figure 3 Air Foil Bearing

Where do we go from here – what are the options?

Bearing systems offering potential advantages over current designs include:

a) Hydrodynamic air bearings use air as the 'lubricant' separating the adjacent bearing surfaces. Among the technology challenges are the needs, at considerable extra cost, for very small clearances and the probable use of ceramic in place of metal materials. However, they have been shown conclusively to deliver the key benefit of very low parasitic drag.

b) Airfoil bearings (fig 3) consist of a compliant spring-mounted metal foil that wraps around the shaft surface. Parasitic losses are commendably low, but initial start-up friction and associated wear pose a significant technical challenge given the extended durability demands now made of turbochargers.

c) Rolling-element designs typically feature deep-groove ball bearings with ceramic balls and ceramic or metal races. Parasitic drag would be significantly reduced, but rolling-element bearings are unlikely to match current floating ring bearing durability standards.

d) Hydrostatic bearings require a high pressure gas to maintain the clearance between two surfaces. Durability is expected to be excellent, parasitic losses are low and small aerodynamic clearances can be maintained.

e) Active magnetic bearings (fig 4) use an electronically-controlled series of magnetic coils at each bearing station to centre the shaft precisely. This offers the prospect of very low vibrations, with correspondingly low parasitic drag.

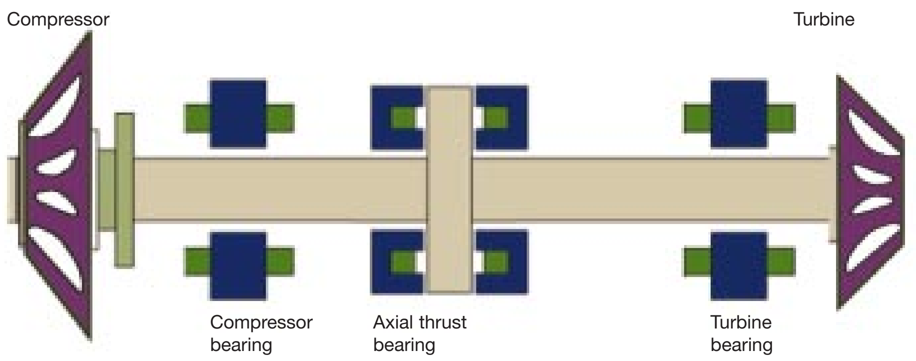


Figure 4 Active Magnetic Bearings

Spoilt for choice?

There is no single factor that makes any of the above options an obvious choice. Holset has accordingly applied a technique known as Quality Function Deployment (QFD). It involves a detailed evaluation of the design features of today's floating ring bearing and axial thrust bearing turbo bearings, allocating to each a plus or minus value depending on its respective degree of advantage or disadvantage to the finished product. It was necessary to group those factors into various categories, according to their different levels of importance attributed by particular OEM customers.

Bearing durability and reduced noise continue to dominate many OEM customers' expectations, which often correlate with numbers of warranty claims. Within this category, specific issues include:

Sub-synchronous noise: vibration attributable to fluid (oil) film instabilities.
Once per rev noise (or synchronous vibrations): due to imbalance.
Degree of imbalance tolerance: related to available machinery and manufacturing process capability.
Emergency failsafe: consequences of mechanical failure.
Cooling: efficiency of oil's cooling medium role.
Dirt tolerance: critical to bearing durability.
Thermal effects: local 'hot spots' can affect stability and durability.

In addition, the following bearing-related issues can arise under sustained high performance conditions:

Motion control: affecting aerodynamic clearances.
Parasitic viscous losses: potentially impairing overall efficiency.
Oil leakage into air or gas flow: adding to engine's particulate emissions.
External control: bearing configuration affected by external power source, for example, electric motor drive (see article on page 11).

Risk assessment: is the proposed new bearing technology already established in other applications?
Current: is there an example in current technology of the application of the system?
Future: possible technical risks must be considered and evaluated.

The ever present COST factor

Among the cost and added-value factors needing to be considered are:

Bearing system: the cost of new and innovative bearing components eg ceramics, and related surface tribology (friction) control.
External control: the additional cost of an external drive system, probably requiring magnetic or hydrostatic bearings.

Conclusions

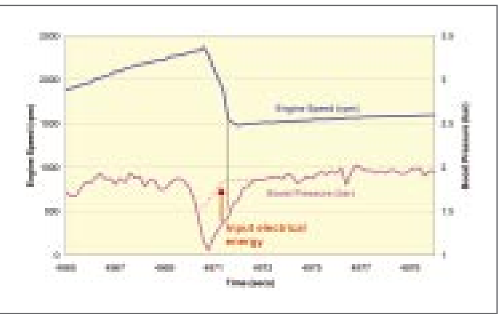
Perhaps not surprisingly, Holset's extensive bearing analysis programme suggests that the well proven floating ring bearing and axial thrust bearing designs continue to perform well in today's turbocharger applications. Achieving the levels of bearing performance in current turbo rotor systems using alternative bearing technologies and at an acceptable on cost remains a formidable challenge. Holset is accordingly embarking on a series of R&D projects aimed at improving, especially in durability terms, those floating ring bearing and axial thrust bearing types of bearing, without significant increases in cost.

At the same time, those ever present goals of enhancing turbocharger performance and reducing noise and vibration will not be neglected. This requires a holistic approach, through the integration of the design and manufacturing processes, making use of computer based tools, such as 6 Sigma quality methods (see article on page 13).

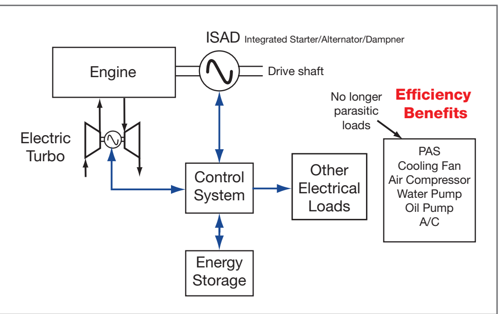
Where unprecedentedly high turbocharger performance is demanded in the future, Holset envisages, in the light of its bearing technology study, some form of magnetic bearing system as the most promising alternative to current floating ring bearing/axial thrust bearing configurations. Apart from the more obvious advantages of low parasitic losses and potentially reduced aerodynamic clearances, magnetic bearings promise reduced blow-by and virtually no oil leakage. However, incorporating the electrics and electronics associated with a magnetic bearing system into a turbocharger's high temperature, vibration prone operating environment poses a significant engineering challenge. The technology is likely to emerge only if and when legislation or market pressures demand it.

An electric future for turbochargers?

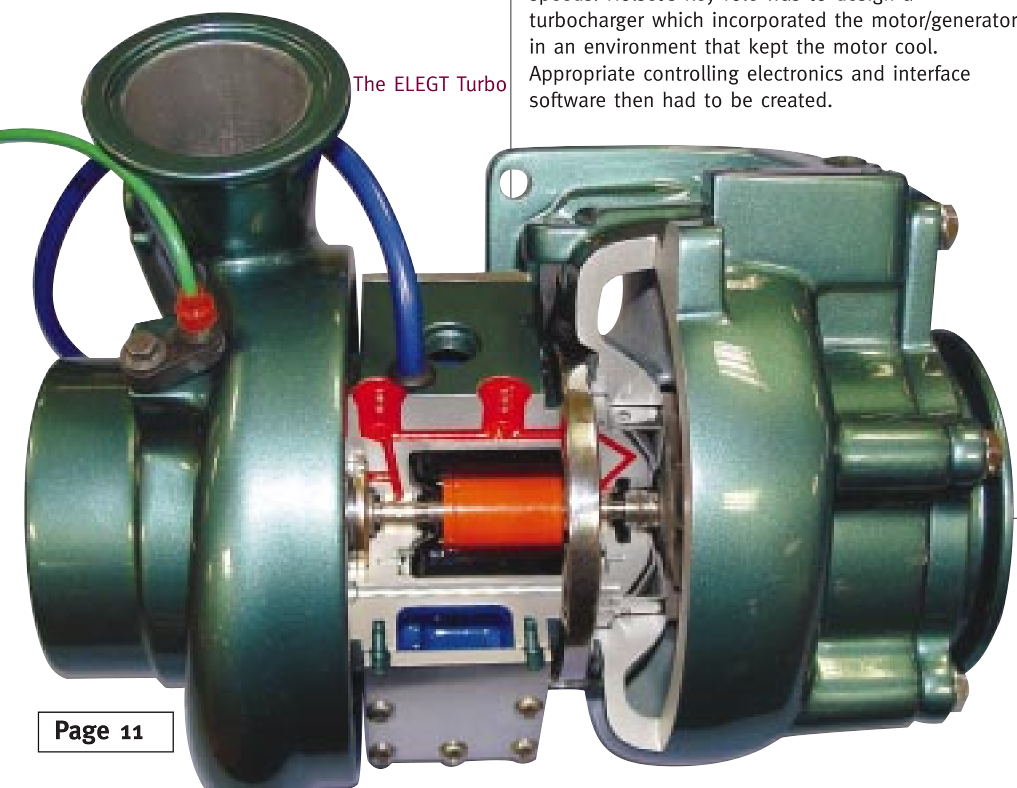
Holset is a key member of a research consortium set up to develop an ELectric Exhaust Gas Turbocharger (ELEGT). The prime objective was to develop a turbocharger with an additional, electrically-assisted, drive to the rotor. It enables compressor output and air-fuel ratio to be boosted under conditions of low or transient speed/load, or during engine starting sequences, to meet the increasingly greater intake-air demands of new, more competitive, lower-emission vehicle powertrains.



Electric Assist Turbo - Gearshift Transient



Integrated Electrical System



The ELEGT Turbo

ELEGT is a three year project initiated by Iveco as part of a broader research programme aimed at developing more "efficient, clean and intelligent vehicles". The prototype electric-turbo machine was shown for the first time at the IAA commercial vehicle show at Hanover in September. The project is 50% EU funded and consists of five participating partners:

Iveco (Italy/Switzerland) – engine and vehicle
Holset (UK) – turbochargers
ATE (Germany) – electric motor/generators
Thien (Austria) – electronics
University of Durham (UK) – computer simulation work

A secondary objective of the ELEGT project is to harness excess exhaust gas energy through the generation of additional electrical power. As with the now widely recognised concept of regenerative braking, the electrical energy thus recovered can be used to charge the vehicle battery, conserving the engine power which would otherwise be used in battery charging. Under such conditions, turbocharger speed and boost can be limited to the levels needed for required engine performance at the time, avoiding wasted turbo output.

What does the ELEGT project involve?

Firstly an induction electric motor/generator had to be developed that was able to survive turbocharger speeds. Holset's key role was to design a turbocharger which incorporated the motor/generator in an environment that kept the motor cool. Appropriate controlling electronics and interface software then had to be created.

Prototype units were built and tested to verify that their characteristics matched preliminary simulation work results. Further simulation work is being carried out to study how best to store and utilise the 'turbo generated' excess electrical energy on the vehicle. A regular Iveco diesel engine will then be modified to accept the ELEGT electric-turbo machine.

Culmination of the project will come with a detailed assessment of the electric turbo system's performance prior to the building of a demonstration vehicle to show the full potential of the ELEGT technology.

Where are we today?

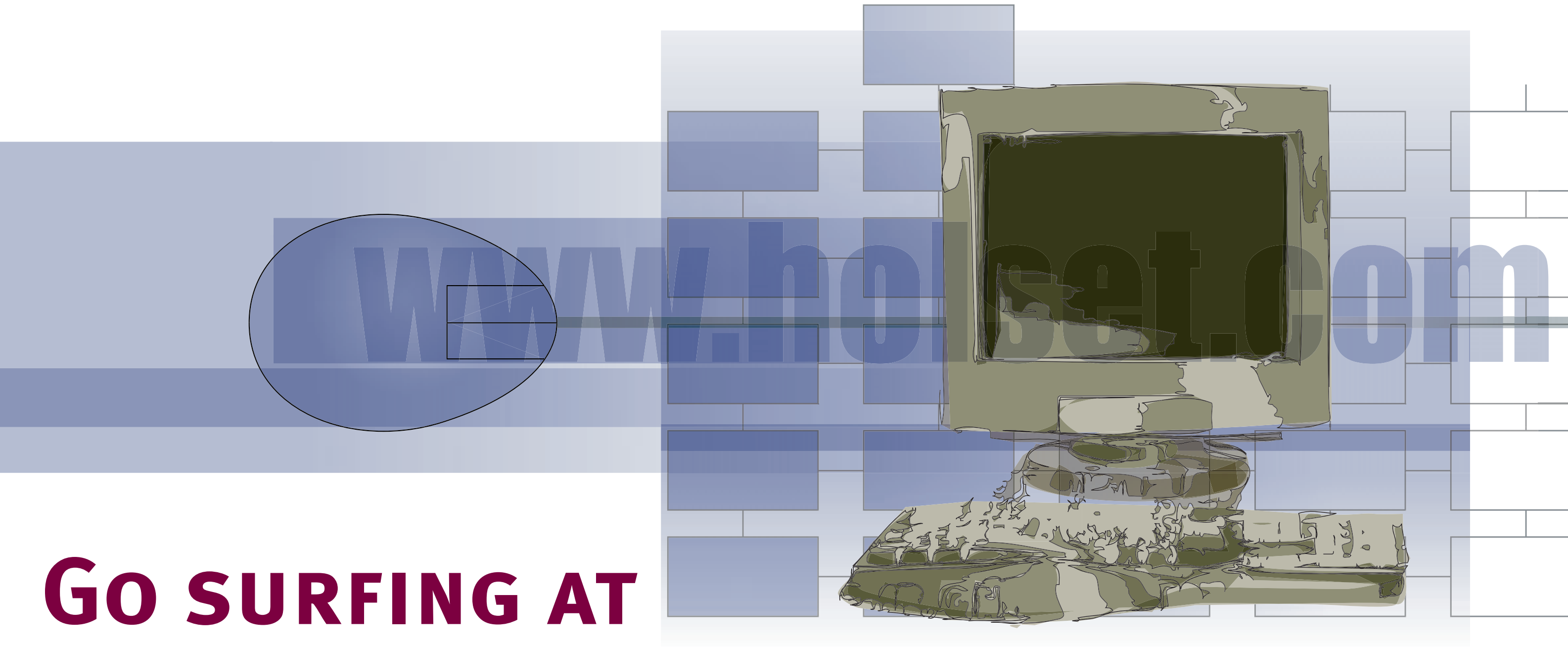
Prototype simulation work has already been carried out in conjunction with the University of Durham and hardware testing took place in May 2004. In terms of basic functionality, the system worked first time, though test results highlighted areas that called for further development work. An upgraded 'Mk 2' ELEGT is now being designed, on which tests are due to begin at the beginning of 2005.

What are the benefits?

The ELEGT concept bring somewhat similar benefits to a Holset VGT™ (variable geometry turbocharger). Additional fuel economy advantages flow from having 'turbo-assisted electrics'. The supplementary electrical power recovered whenever excess exhaust gas energy is available can be used to supply vehicle auxiliaries, such as power-assisted steering, cooling fan, air compressor, water pump, oil pump and cab air conditioning, which traditionally have been driven mechanically from the engine. Removing these 'parasitic' loads can make the engine more fuel efficient, whilst at the same time reducing emissions.

ELEGT is one of a number of ongoing Holset projects involving the development of products and tools needed to bring new turbochargers to the market in five to ten years time. Many involve preparing the technology well in advance so that when emissions legislation is upgraded or the company's OEM customers need to respond to new competitive market challenges, Holset will be ready with purpose engineered and functionally proven products.

Holset's key role was to design a turbocharger which incorporated the motor/generator in an environment that kept the motor cool



Go surfing at www.holset.com

Holset has a new website. It is bright and easy to navigate, giving the 'outside world' a fresh and detailed perspective on the company's manufacturing, commercial and after-sales activities, as well as providing detailed information on the Holset product range.

Visually the **www.holset.com** site creates a new feeling, based around the company's worldwide corporate logo and predominantly blue, colour scheme image. Aimed at OEM and end-user customers, as well as suppliers and technology partners, the key content of the new website is designed to underline Holset's core values, based on five key focus areas: product, people, partnership, quality, environment.

Typically, the visitor to a company website is seeking answers to one or more questions or queries. On the new Holset site, a number of additional functions have been built in to help the user find those answers as quickly and as easily as possible. Navigation menus in the same position on every page help avoid confusion. Each page also offers a search facility and there is a simple and easy to use site map, offering links to other relevant sections of the website.

For those users wanting more information, through direct contact with Holset, there is a contact button on every page so by a couple of clicks of the mouse they can obtain key managers' names, telephone numbers and e-mail addresses.

As a global company we plan to offer the website in two languages; English and Mandarin Chinese. China has become the world's largest single market for key engine components, including turbochargers. Therefore to provide that market with all the product and support information it needs, we are developing a Holset-Chinese website. In due course there will be buttons found on all site pages enabling site visitors to select their preferred language - English or Chinese.

One of the key objectives of the website is to provide a 'one-stop shop' for turbocharger knowledge. The 'Products and Technology' section includes pages on the fundamentals of turbocharging as well as more advanced turbocharger technologies. The latter, as an eye-catching innovation, features animations of the workings of a VGT™ and a turbocompound installation.

Under the heading of 'Applications', a number of Holset turbocharger case studies are featured, including some 'industry firsts', notably the VGT™ units specified by Iveco on its Cursor truck diesels, turbocompounding by Scania and cast titanium compressor wheels.

Under 'Media Communications' there is an interactive news section where journalists or others can review past news coverage of Holset activities. A link to an image library brings up numerous photographs and other illustrations relating to Holset. An innovation in this section of the site is the 'Chat Forum', where users can post questions to be answered by Holset personnel.

Another Holset website innovation is the Partner Zone. This is a password protected site, providing links to other customer-secured websites. These 'portals', currently under development, enable Holset and its OEM customers to 'see' into each other's operating systems, using dedicated web enabling software. The aim is to eliminate non-value added telephone calls and data extraction allowing Holset and its customers to concentrate their respective resources on their core business activities. For example, Holset will have ready access to customers' engine build programmes, while it will be possible for the OEMs to review Holset production planning data. It will also make instantly available to both parties, warranty data and failure mode information, needed for analysis and possible corrective action.

We hope you enjoy surfing the new website. If you have any comments, please do not hesitate to contact us at **turbo.enquiries@holset.com**

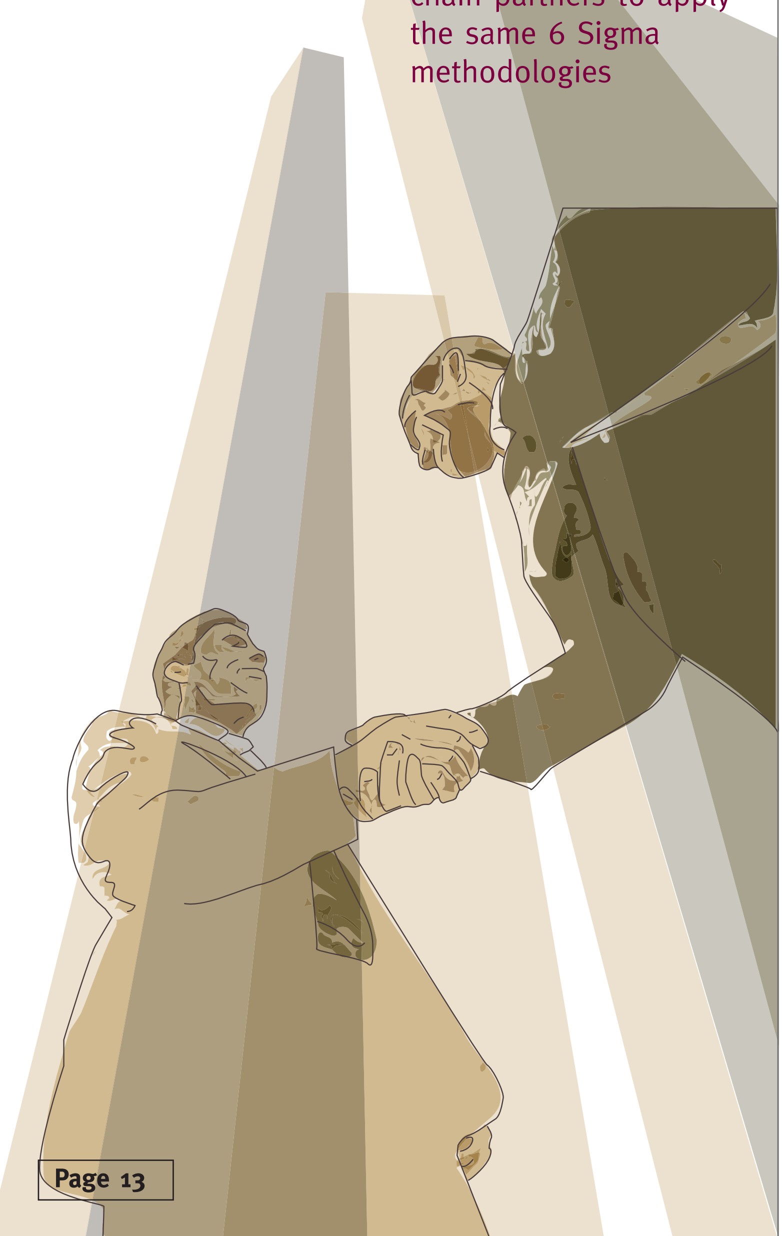
6 Sigma

Now cutting waste for Holset's suppliers

Holset has for some years applied 6 Sigma methodologies as a vital contributor to operational efficiency and improvement of the quality achieved in the company's plants. By making process excellence a standard through the adoption of 6 Sigma practices in Holset's business processes, quality variation is reduced and waste eliminated, leading to improved profitability.

Holset is actively encouraging its supply chain partners to apply the same 6 Sigma methodologies to bring their manufacturing efficiencies into line with the standards already demonstrated by our internal operations.

Holset is actively encouraging its supply chain partners to apply the same 6 Sigma methodologies

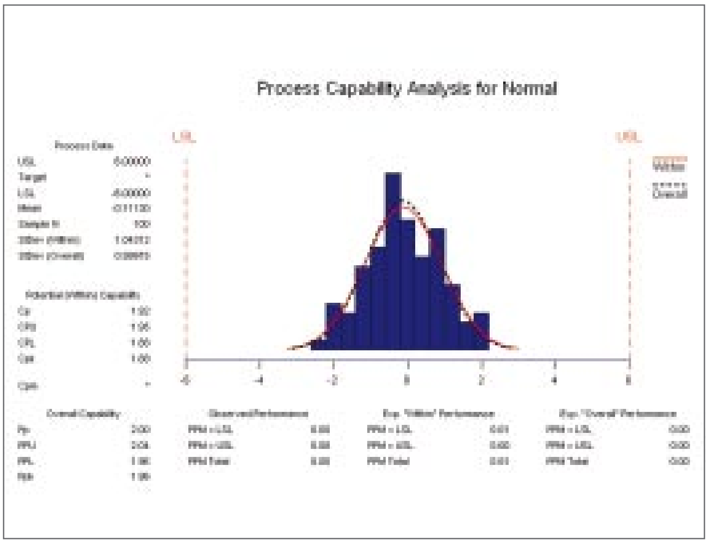


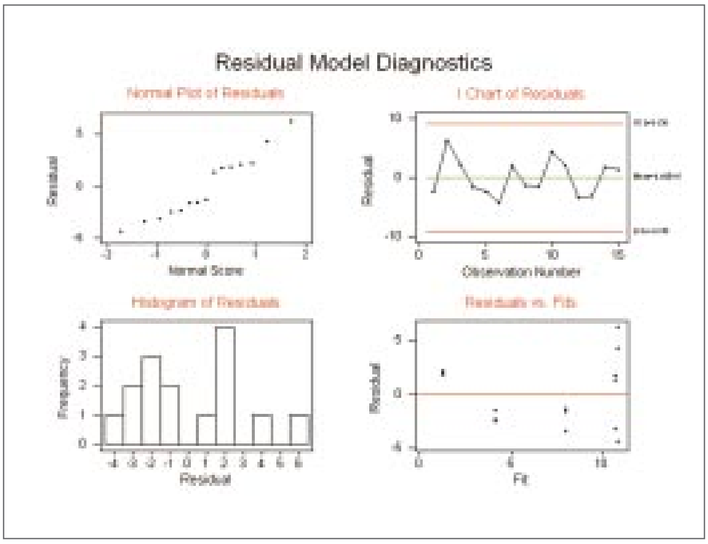
Unwanted variation from laid down standards and procedures creates waste. Waste can be defined as 'any activity that takes time, resources and space, but fails to address internal or external customer requirements'. An alternative definition is that waste is 'anything other than the minimum amount of time, material, equipment, information and space essential to add value to the product'.

Holset spends around 65% of its sales revenue with suppliers, underlining the company's vital dependence on those supply chain partners. To be successful at the customer/supplier level, 6 Sigma practices require a high level of trust, communication and information exchange between the partners. Without it, the methodology would not be effective.

As an incentive to ensure suppliers participate fully in 6 Sigma programmes, Holset is offering training and support to the supplier 6 Sigma belts for projects offering mutual benefits. In return the supplier is expected to nominate a project leader, backed by firm management commitment and a sponsor.

Holset is committed to continue its application of 6 Sigma methodologies in partnership with its suppliers. Holset recognises that there must be a focus on all aspects of supplier contact with the goal of eliminating waste, to the commercial benefit of all involved, not forgetting Holset's own customers, where 6 Sigma practices inevitably lead to consistency of product quality.





Bentz Diesel Dragster

Since 1999, Scott Bentz from Denver, Colorado, has been working, helped by family and friends, to build a unique Diesel Dragster.

The engine in the Bentz dragster is an in-line Cummins six-cylinder 5.9 litre ISB diesel adapted for two-stage turbocharging using a Holset HX35/40 hybrid and a HX55/60 hybrid and develops up to 5.5 bar boost pressure. The engine is a modified version of the Cummins diesel engine, which powers all Dodge Ram diesel trucks.

Recent developments on the machine have improved performance, leading to its best ever run. On a track at Muncie, Scott's machine achieved a standing quarter mile (0.402km) in just 8.75 seconds. At the end of the measured distance he had reached a speed of 148mph (238km/h).

The crew consisted of driver Dustin Bentz, Les Culliton and Joe Percoco. A unique feature of the dragster is that its engine is fuelled entirely with biodiesel, derived from vegetable biomass, a completely renewable feedstock. This has a higher cetane number and in the two-stage Holset turbocharged engine in the Bentz dragstar, delivers higher performance than regular oil-based diesel fuel. Scott Bentz says that through further refinements to the turbocharged engine he aims to get his standing quarter-mile time down to 7 seconds or less.

Recent developments on the machine have improved performance, leading to its best ever run

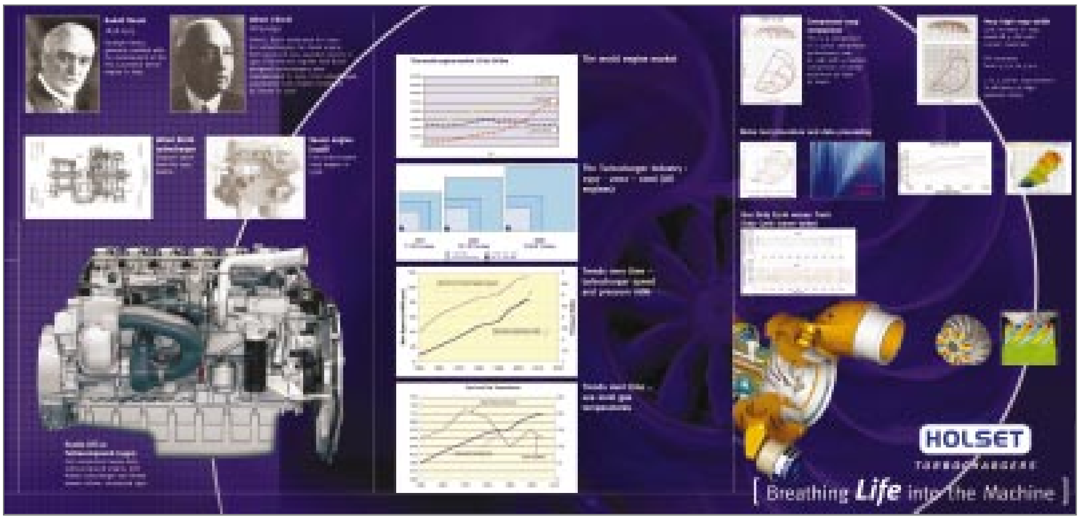
Thiesel conference showcases turbocharger innovations

Holset was strongly represented at the third international conference on thermo and fluid dynamic processes in diesel engines (THIESEL 2004), which is held bi-annually at the University of Valencia in Spain. The university has an active diesel research group specialising in engine performance, combustion and noise.

The conference was attended by over 200 delegates, mainly from diesel engine R&D departments from engine and vehicle/plant manufacturers, universities and independent research organisations. Key topics discussed at the conference were wide ranging. They included computer-modelling and related experimental investigations into turbocharger aerodynamics against the background of the tough challenges posed by future emissions legislation, through to Euro 5 and US-EPA 2010.

Holset researchers presented two papers in a session devoted to turbocharger-related aerodynamics. Senior Technical Advisor, Henry Tennant's, keynote address was entitled "The Evolution of Turbocharging in Diesel Engines". This looked at the history of turbocharging, the current market for turbochargers and the air system requirements for future engines. The substance of his paper is contained in the article on pages 5 and 6 of this edition of HTi.

Principal Engineer, Bahram Nikpour's paper, entitled "Turbocharger Compressor Flow Range Improvement for Future Heavy Duty Diesel Engines" discussed three aspects of flow range improvement: diffuser recess, variable inlet guide vanes and map-width enhancement developments, all of which are subject to Holset patents or patent applications.



Henry Tennant's keynote address

Bahram Nikpour discussing flow range improvements

The conference was attended by over 200 delegates, mainly from diesel engine R&D departments

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

Part No. 3766118 Issue 3 Ref: AJS/OR