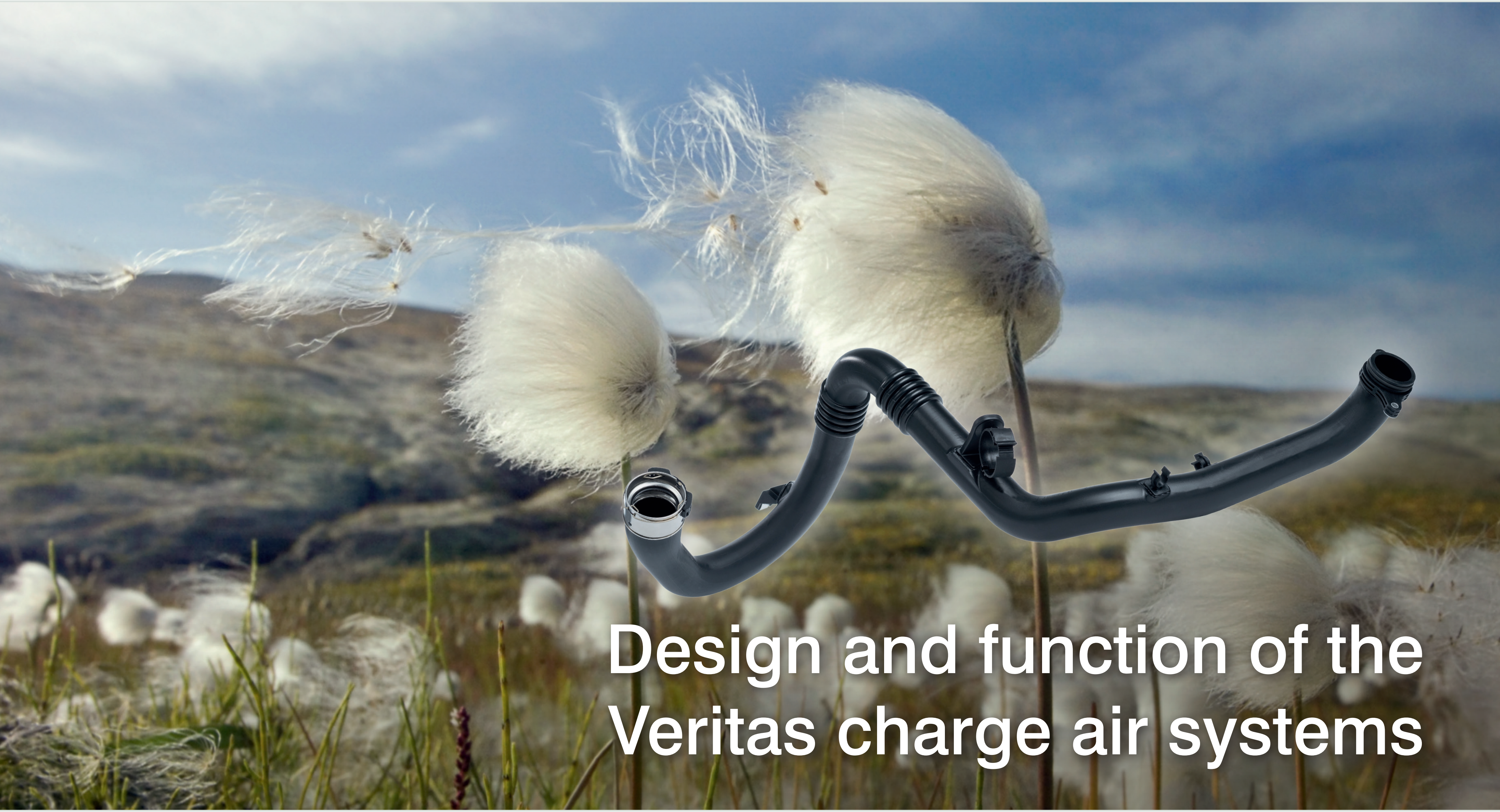
Veritas



Design and function of the Veritas charge air systems

Veritas connects! People, products, functions

Connecting, sealing and transporting –
these are the functions performed by Veritas products in motor vehicles.
However, there is a lot more to this than you may initially think.

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1. Function of the charge air system

Increasing the engine performance of vehicles fitted with a combustion engine has always been a key focus of engine developers.

There are various ways to increase engine output. The obvious approaches to this include increasing displacement, increasing the number of cylinders, allowing the engine to turn at a higher speed and increasing fuel combustion. However, all of these measures come with undesirable side-effects, such as additional costs, consumption, weight, wear or the need for a greater air supply and thereby a stronger vacuum. The solution? Compressing the intake air (for example, using a turbocharger) takes a great deal of the vacuum work away from the engine.

"When residual energy in the exhaust gases is used for precompression, this is known as boosting."

(Source: Motair GmbH, http://www.motair.de/index.php?id=167)

The stricter exhaust emissions legislation introduced back at the end of the 1980s means that virtually all commercial vehicle engines today employ some form of engine boosting, and turbocharged passenger cars have also been on the rise ever since. A turbocharger allows the efficiency of a diesel engine to be increased, so that it can virtually match the driving performance characteristics of petrol engines.
The intake air that is compressed by the impeller gets very hot, so it is first cooled down in the intercooler before being injected into the combustion chamber.

Cold air contains significantly more oxygen molecules than hot air, and cooling the charge air therefore leads to a higher oxygen content in the combustion chamber. This results in greater engine power output and torque, as well as reduced fuel consumption and lower exhaust emissions.

The intercooler is a heat exchanger which is fitted to all turbocharged vehicles and is generally positioned between the turbocharger and the throttle valve. The components responsible for transporting the air in the charge air system are referred to as charge air ducts.

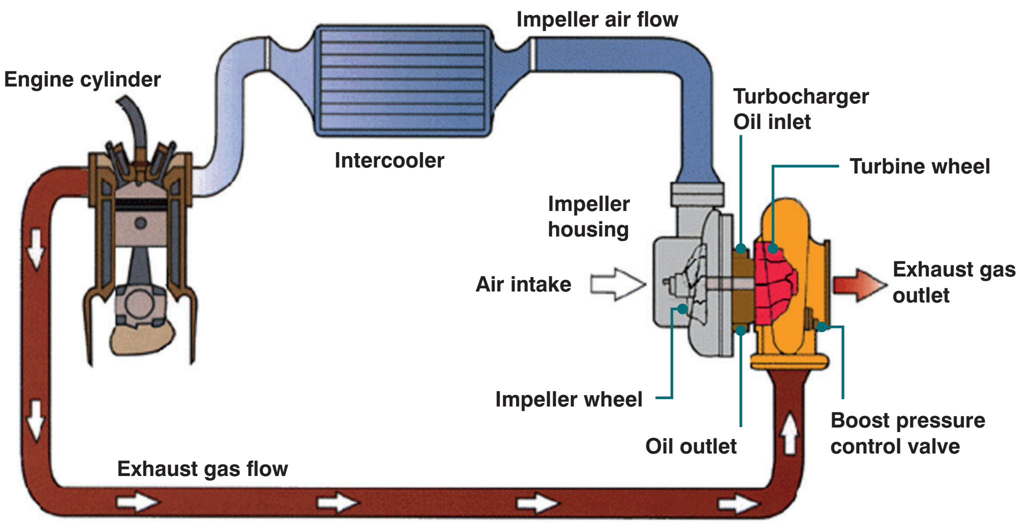
Internal combustion engines are today no longer primarily fitted with turbochargers to increase performance. The ability to reduce fuel consumption while maintaining the same performance is becoming increasingly important. Together with ever more advanced materials development and new production methods, the benefits of engine boosting are leading to increasing use of turbocharging.

(Source: Ostwestfalen-Lippe University of Applied Sciences, http://www.hs-owl.de/fb6/labore/stroemungsmaschinen/diplom-sm/abgasturbo/geschichte/print.html)

Functions of a typical charge air duct

- Cooling the medium
- Ensuring media resistance from inside and outside
- Dynamic decoupling
- Securing installation and connection
- Guaranteeing pressure and temperature resistance
- Fulfilling crash requirements
- Maintaining low flow resistance
- Enabling movement and tolerance compensation
- Maintaining low noise generation
- Maintaining low permeability
- Fulfilling design requirements
- Enabling application of measuring equipment

Air duct of a turbocharged internal combustion engine



(Source: PowerLine, http://www.turbolader.de/info_pages.php?pages_id=5)

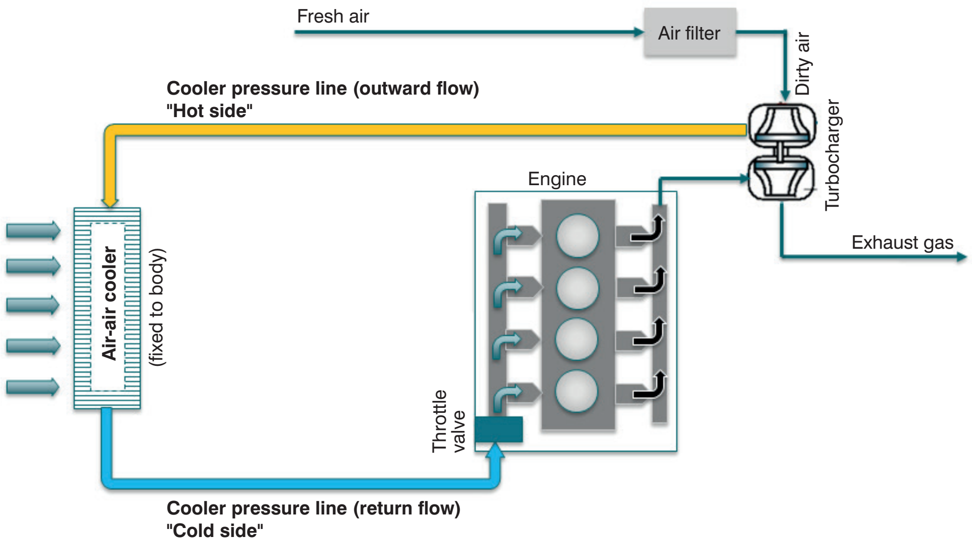
2. Description of various systems

There are various ways of cooling the hot charge air. Three systems have established themselves here. The design of the charge air ducts varies depending on which of these systems is selected:

- **Direct intercooling:** **Air-air**
- **Indirect intercooling:** **Air-water**
- **Indirect intercooling integrated in the intake manifold:** **Air-water**

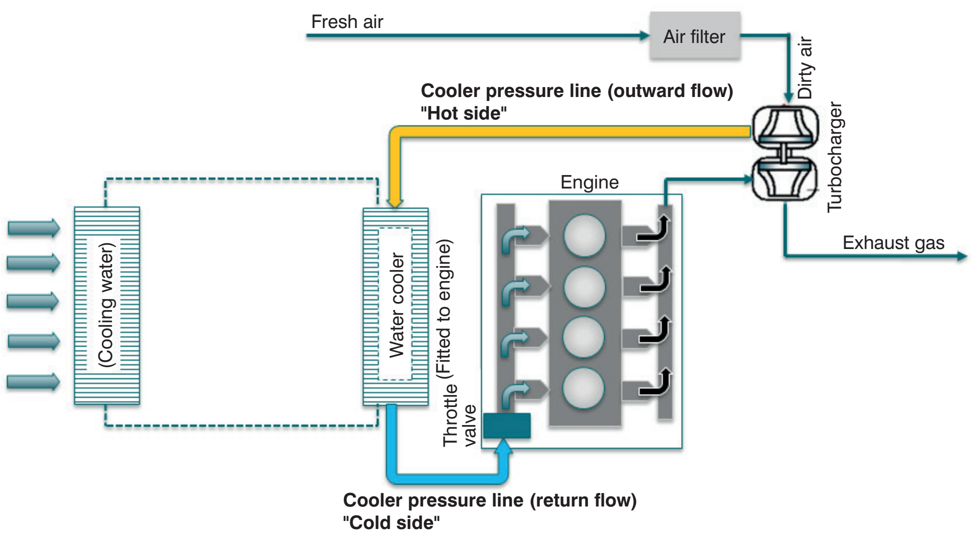
Direct intercooling: Air-air cooler

Here, cooling is performed using a cooler with air flowing over it. The cooler itself is generally positioned at the front of the vehicle. The charge air lines must be capable of transporting the medium over the necessary distances. Since the cooler is fixed to the car body, the charge air lines must also allow a certain degree of movement.



Indirect intercooling: Air-water cooler

Here, cooling is performed using a cooler with water flowing through it. The charge air lines transport the medium over short distances. Since the cooler is typically permanently attached to the engine here, the charge air lines only have to meet the installation tolerances and compensate for vibrations. There is no need to compensate for the movement between the body and the engine with this system, as would otherwise generally be required when using air-air cooling systems. Another advantage of this kind of system is the fact that the intercooling can generally be controlled via the water cooler, which is not possible when using a direct system.



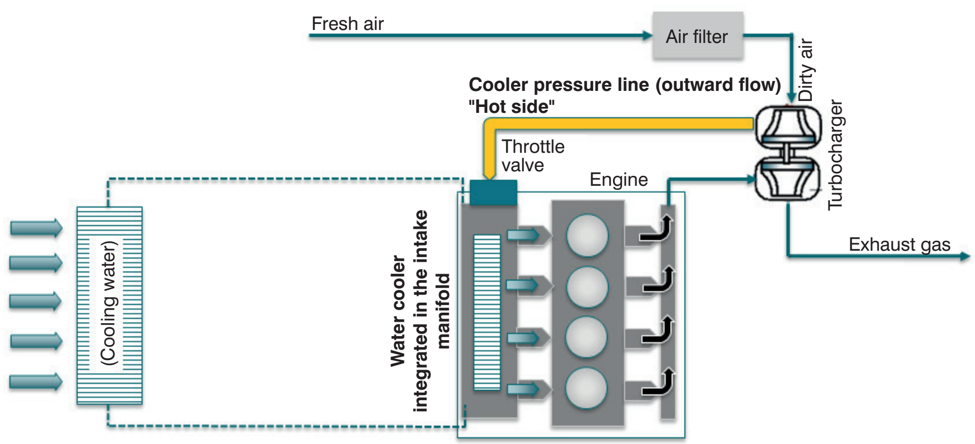
Indirect intercooling integrated in the intake manifold: Integrated air-water cooler

Here, cooling is performed using a cooler integrated in the intake manifold with water flowing through it. The cooler is permanently attached to the engine and integrated in the intake manifold here. The charge air lines transport the medium over short distances. There is no return line here.

Comparison with (direct) intercooling

In comparison with (direct) intercooling, indirect intercooling produces the following effects:

- \+ **Significantly reduced drop in charge air pressure due to shorter distances**
- \+ **Improved engine dynamics thanks to a lower volume of charge air**
- \+ **Increased dynamic cooling capacity**
- \+ **Improved engine efficiency thanks to increased charge air density**
- – **Increased cooling costs due to the need for an additional water cooling system**



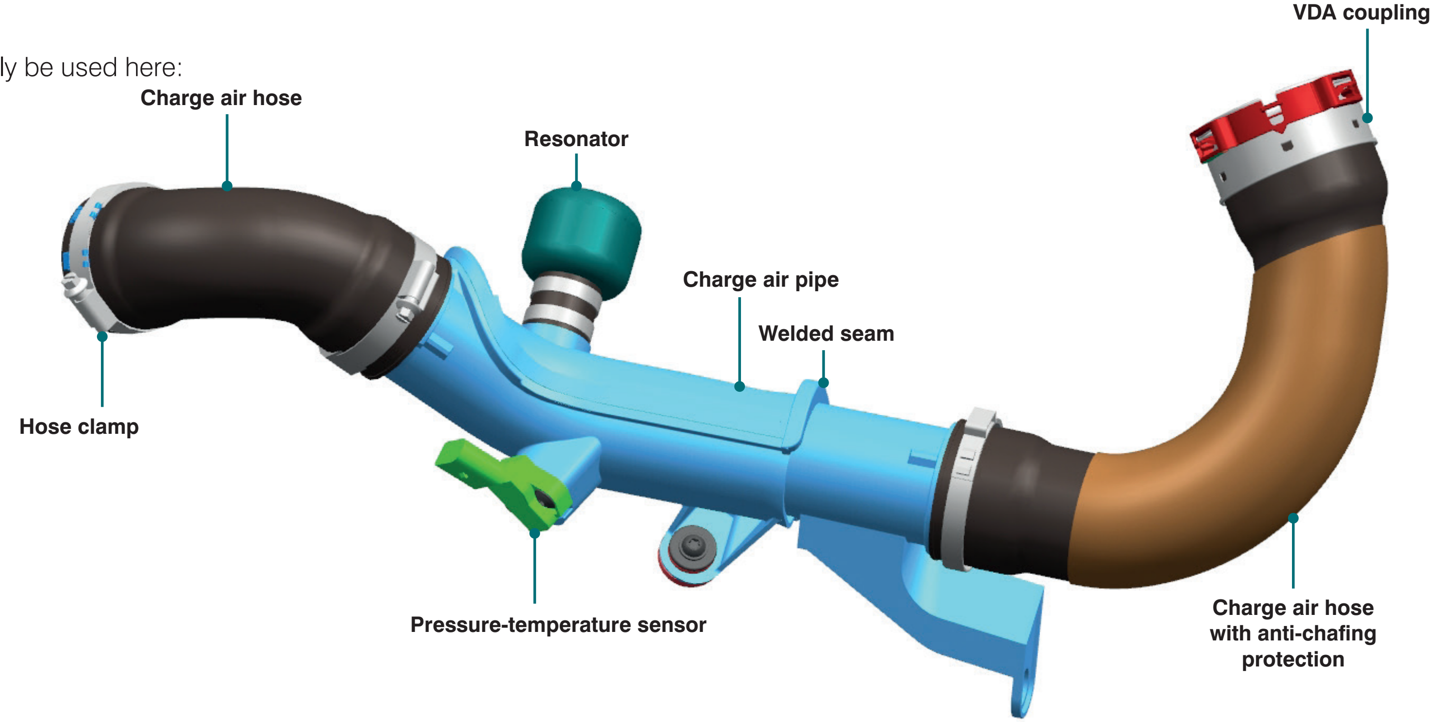
3. A typical charge air duct

The image shows an example of a charge air duct with potential fittings, as well as a twopiece charge air pipe and two connected pressure hoses.

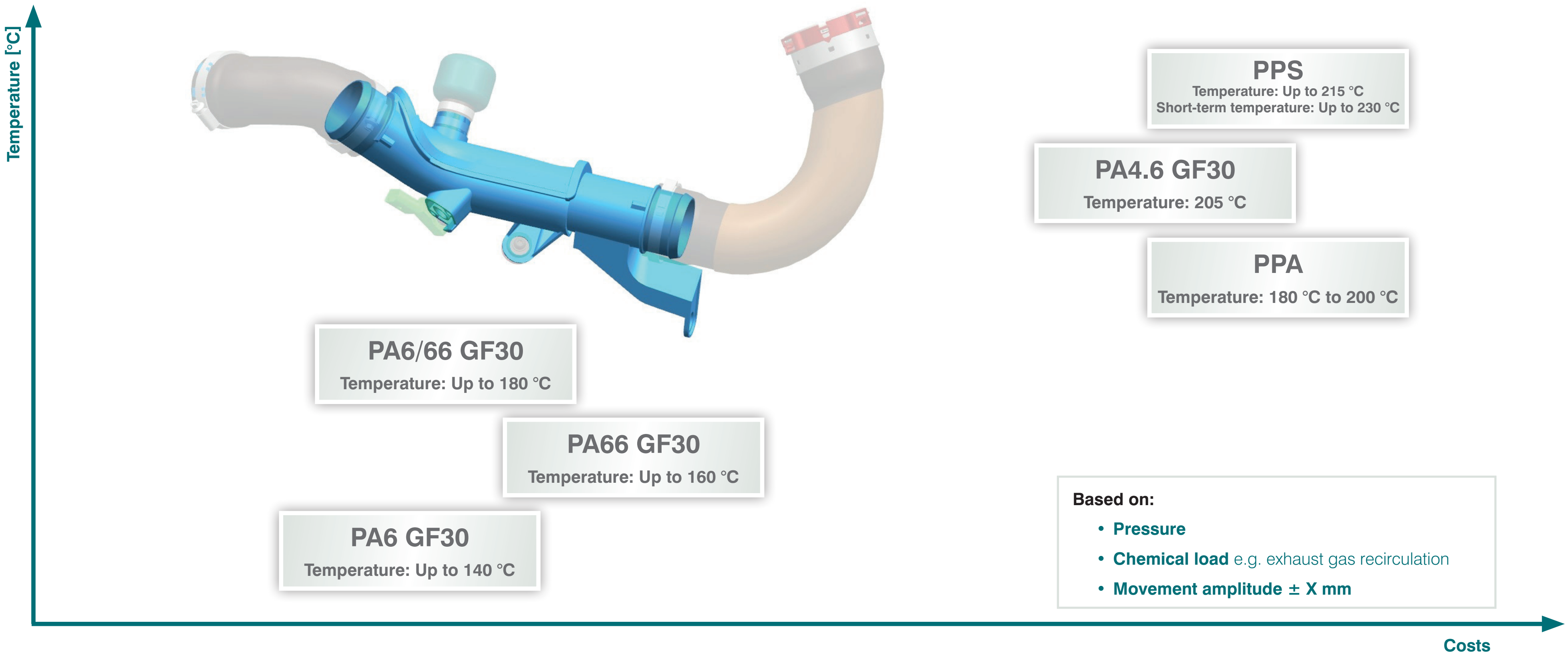
The plastic pipe is generally manufactured as a injection moulded or blow-moulded part. When using the injection moulded version, it is often necessary to design the plastic pipe as a multiple-piece unit for manufacturing reasons. The parts are then welded together.

The following welding processes can potentially be used here:

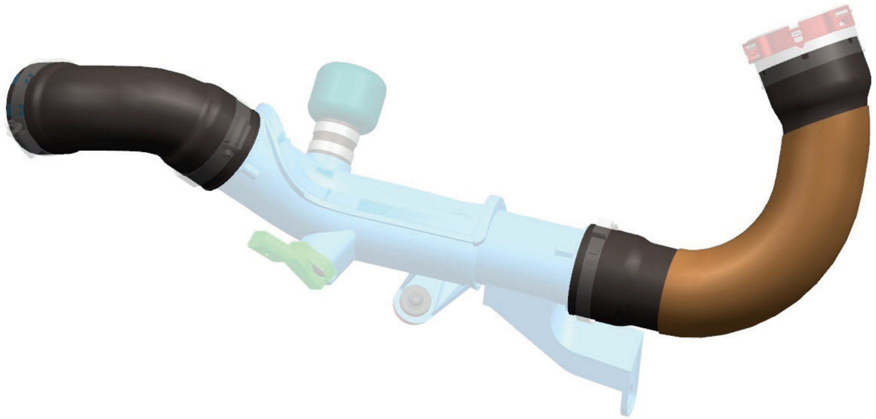
- Infrared welding
- Vibration welding
- Hot gas welding
- Hot plate welding



Requirements of materials (Veritas solutions) in the plastics product range



Requirements of materials (Veritas solutions) in the elastomer range of products



Temperature [°C]

HT/HP

Layer sequence: FKM in line with DIN ISO 1629 GEN 7
MVQ
m-AR
MVQ

Constant temp.: 230 °C
Short-term peak temp.: 250 °C

HT/HP

FKM in line with DIN ISO 1629
MVQ
POD/m-AR
MVQ

200 °C
temp.: 230 °C

HT ACM 185

Layer sequence: ACM
POD/m-AR
ACM

185 °C
temp.: 200 °C

AEM Classic

Layer sequence: AEM
p-AR
AEM

Constant temp.: 160 °C
Short-term peak temp.: 180 °C

ACM Alternative

Layer sequence: ACM
p-AR
ACM

Constant temp.: 150 °C
Short-term peak temp.: 170 °C

ECO Classic

Layer sequence: ECO
p-AR
ECO

Constant temp.: 125 °C
Short-term peak temp.: 150 °C

CM LT

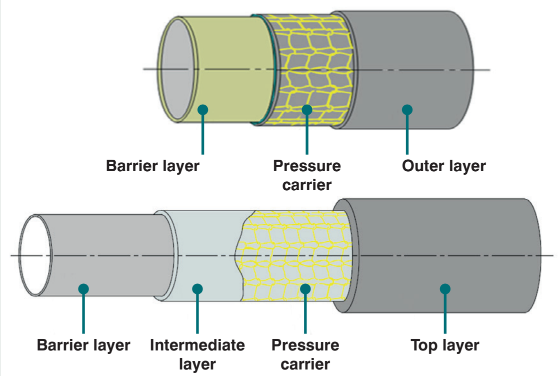
Layer sequence: CM
DT
CM

Constant temp.: 120 °C
Short-term peak temp.: 135 °C

CR LT

CR
DT
CR

110 °C
Short-term peak temp.: 125 °C



PC = Pressure carrier

Costs

Innovative connection technologies (Veritas solutions)

Design: Veritas AG

The development stages of Veritas connections correspond to the increasing charge air pressures associated with boosted engine performance. With its "Vecoflan®" coupling, including the accompanying hose connection, Veritas offers a connection technology designed specifically for pressures up to 4.5 bar and temperatures up to 250 °C. Installation of the line is also much easier, as it can simply be slid into position from the side. The slide-in unit is secured using a secondary lock.

Selection of typical charge air lines from Veritas' series production.

4. Emissions legislation for passenger vehicles

For several years, there have essentially been four pieces of legislation, various versions of which are applied in all emerging and industrial nations.

CARB legislation > California, similar limits apply in New York, Massachusetts, Connecticut, Vermont, Rhode Island, Maine and New Jersey

EPA legislation > Rest of USA

EU legislation

Japanese legislation

The following table shows the binding laws and their entry into force worldwide.

Tab. 1: Emissions legislation

		2013	2014	2015	2016	2017	2018	2019	2020
Europe	Czech Republic	Euro 5	Euro 6						
	France	Euro 5	Euro 6						
	Germany	Euro 5	Euro 6						
	Hungary	Euro 5	Euro 6						
	Italy	Euro 5	Euro 6						
	Poland	Euro 5	Euro 6						
	Russia	Euro 4			Euro 5				
	Slovakia	Euro 5	Euro 6						
	Turkey	Euro 5			Euro 6				
	Great Britain	Euro 5	Euro 6						
China	Beijing	Euro 5							
	China	Euro 4		Euro 5					
	Taiwan	Euro 5							
Japan/Korea	Japan	Japan ´09							
	South Korea	Euro 5	Euro 6						
Middle East/ Africa	Iran	Euro 2							
	South Africa	Euro 4							
North America	Canada	Tier II, Bin 4					Tier II, Bin 2		
	Mexico - petrol	Euro 4	Euro 5						
	USA	Tier II, Bin 4					Tier II, Bin 2		
	USA California	LEV III							
South America	Argentina	Euro 5							
	Brazil - LCV diesel	Euro 5						Euro 6	
	Brazil - petrol	Euro 5						Euro 6	
South Asia	Australia	Euro 4							
	India - metropolitan region	Euro 4							
	India - rest	Euro 3							
	Indonesia	Euro 4							
	Malaysia	Euro 3							
	Thailand	Euro 4							

LP EGR (low-pressure exhaust gas recirculation)

Technologies are being further refined and improved to comply with the emission limits. Exhaust gas recirculation (EGR) is an important technology in this regard.

The principle is based on feeding exhaust gas into the combustion chamber as a way of reducing nitrogen oxides (NO_x). When using LP EGR, the exhaust gas is fed back into the intake chamber by mixing in a portion of the fresh air intake via a pipe.

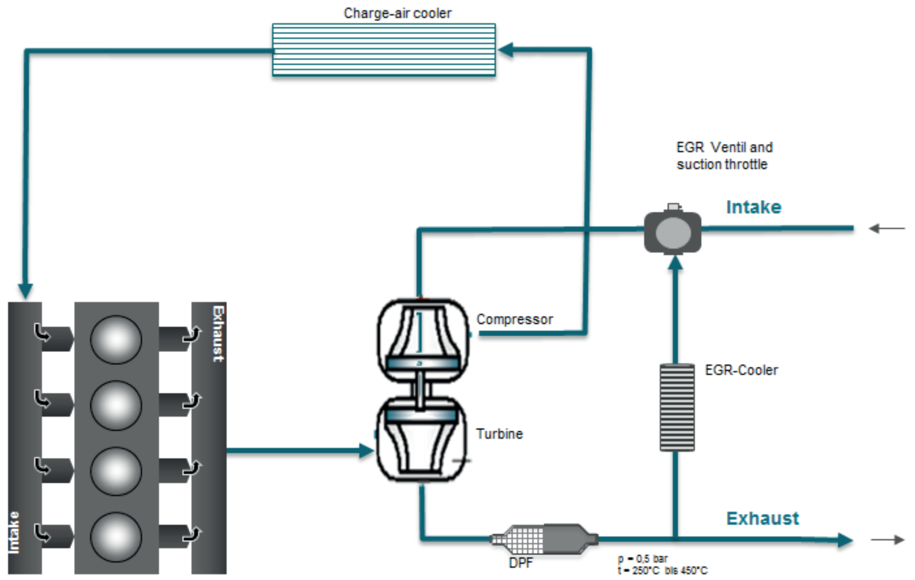
With diesel engines, it is one of the most important ways to reduce nitrogen emissions. Depending on the air/fuel mixture and driving profile, the condensate can contain a large volume of organic or aggressive acids.

However, this technology places strict requirements on the resistance of the materials used for the charge air ducts. Depending on the concentration, the medium can contain a high percentage of acid and have a pH value of less then 1. If the incorrect material is then selected, the plastic or elastomer hoses of the charge air lines can be directly damaged. This can ultimately lead to system failure.

Veritas offers the right solutions for charge air ducts, which fulfil the requirements of high material resistance to the acidic medium throughout their service life.

The composition of LP EGR condensate always varies and depends on the following factors:

- Engine performance and engine management
- Driving style (speed, rpm, cold starts, etc.)
- Design of the cooling system
- Composition of the fuel (S, H_2O, RME, etc.)



EGR: A complex, variable and aggressive mix (with a pH value below 1)

5. Simulation and testing

Current and future requirements

Higher charge air pressures lead to higher temperatures. Temperatures of up to 250 °C are possible using Veritas silicone hoses. Since silicone hoses are comparably expensive, efforts are being made to use new types of plastic materials for a large proportion of the charge air duct. At the same time, the materials must offer greater resistance, particularly against aggressive media such as the EGR condensate already mentioned.

Further research and development work is required in order to meet all of these requirements.

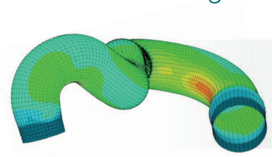
Ever stricter requirements also require new and more extensive testing. The scope and costs of meeting testing requirements are also increasing for OEMs and system suppliers as a result of this. The trend here is to shift responsibility for the tests to the system supplier.

After all, system suppliers boast comprehensive knowledge of materials, component design and simulation, as well as an excellent understanding of systems.

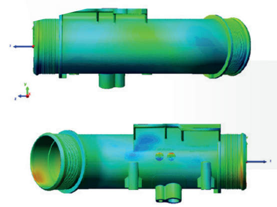
To give you an idea of what is being referred to here, the following pages list several tools for system design, simulation and testing, as well as the extensive testing equipment of Veritas AG required to perform the charge air duct tests.

Simulation and testing

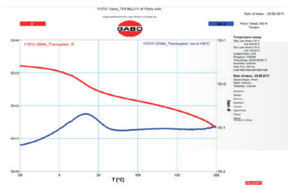
From the first design stage to the series production product



CAD and simulation



Measuring technology



Materials testing

Function testing

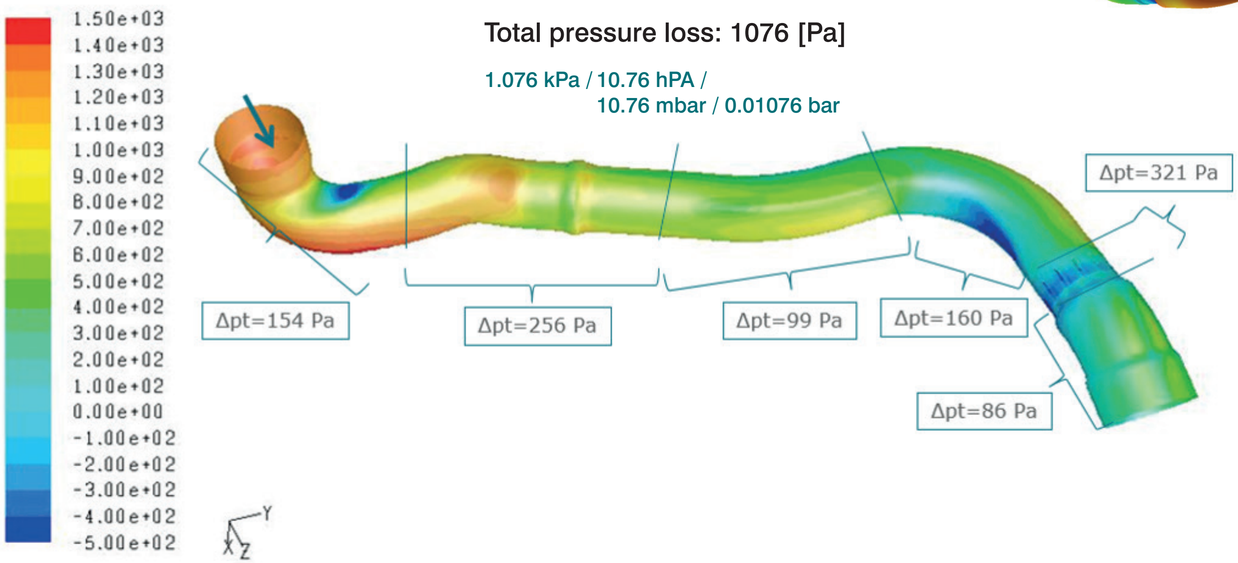
Computational fluid dynamics (CFD)

The example shown here is a pressure loss calculation for a charge air line.

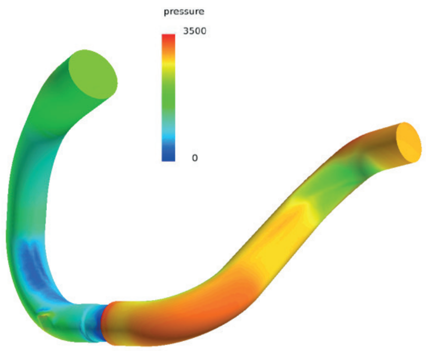
Pressure drops are unavoidable due to the path traced by the line, which can only be adjusted slightly due to the conditions of the installation space. It is therefore important to detect and subsequently eliminate the pressure losses while the project is still in the development phase.

Total pressure loss: 1076 [Pa]

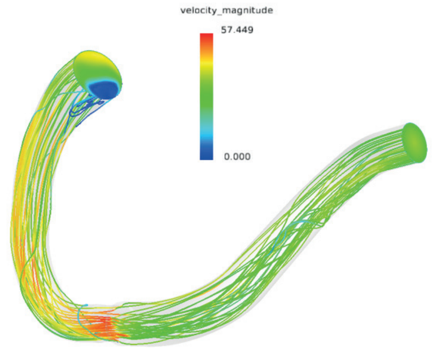
1.076 kPa / 10.76 hPA / 10.76 mbar / 0.01076 bar



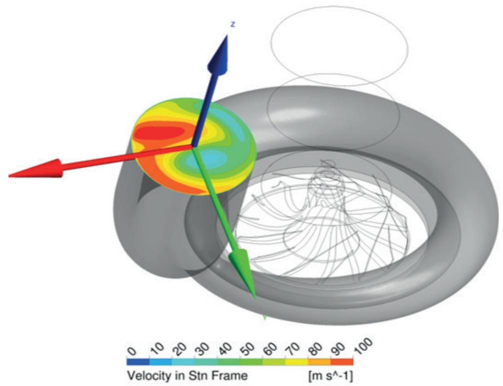
Static pressure at pipe wall



Speed distribution flow lines



Swirling inflow

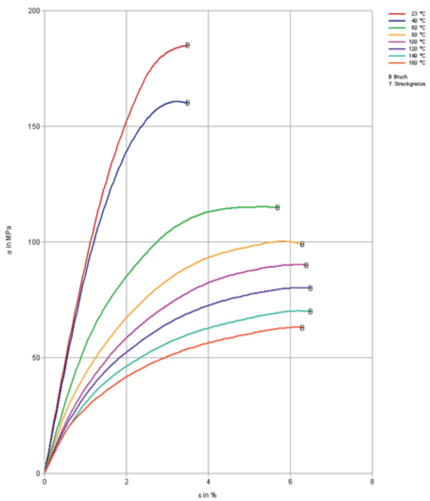


Numerical structure calculation

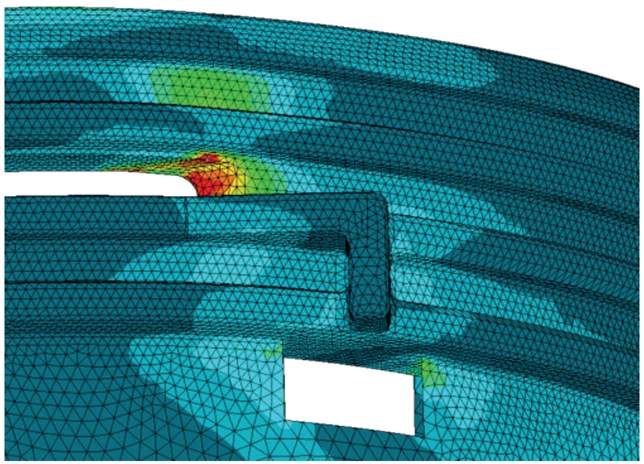
Computer-assisted numerical process for calculations: Finite element method (FEM)

The strength calculation of a quick release coupling is shown here as an example.

The connection elements of charge air ducts are subjected to special pulse-based component loads in the form of pressure and temperature influences. Calculating the mechanical load allows complex material behaviour and non-linear stress-strain relationships to be presented and the components therefore optimised.



Structure calculation



Component failure in the area of a clamping bracket

Tests

During the development phase, comprehensive tests are to be performed on the charge air system to secure proper functionality of all components throughout the entire life cycle. The tests represent the life cycle (time-lapsed). The test requirements are the result of customer requirements (works standards and requirements specifications). Loads take the form of temperature changes, pressure changes and three-dimensional movements, which are generally applied in combination.

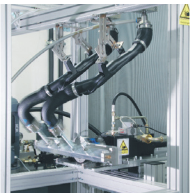
Overview of testing options at Veritas AG

Pulse test bench with temperature control for the medium and the chamber, as well as a rotation and buckling unit

Four large-scale test benches for bithermal charge air testing, three of which are equipped with a multi-axial movement unit and/or vibration excitement, ambient temperature of -40 °C to +220 °C, medium temperature from Rt to 300 °C, pressure up to 4 bar

Pulse test bench with chamber temperature control

Thirteen test benches for unithermal charge air testing, temperature range from Rt to 300 °C, pressure up to 15 bar

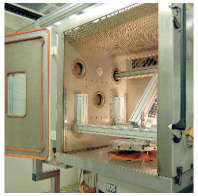


Pulse test bench with movement unit at RT

Pressure range from 0.1 bar to 15 bar, air test medium, movement distance: ± 50 mm, force up to 5 kN, frequency up to 200 Hz

Burst pressure test bench

For pressures up to 1000 bar, test medium = water



Temperature change test bench with shaker

Temperature unit with electrodynamic shaker, chamber volume of 1000 litres, chamber temperature from -70 °C to +180 °C, pressure up to 15 bar, vibration amplitude +/- 25.6 mm, frequency from 5 Hz to 3000 Hz, max. acceleration 60 g

CT test bench

Computer tomograph for measuring parts and non-destructive component testing

Salt-spray mist chamber for corrosion testing

Chamber volume of 1000 litres, NaCl solution medium, relative humidity from 10% to 95%
Chamber temperature from Rt to 60 °C, medium temperature from Rt to 75 °C

Acoustic measurements

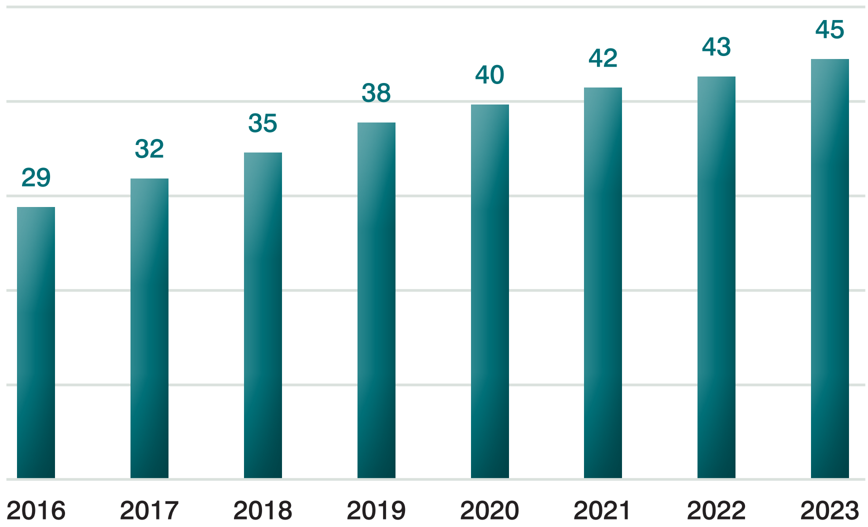
6. Outlook

The proportion of vehicles fitted with turbocharged engines is on the rise worldwide and continuing to gain ground on vehicles with naturally aspirated engines. Indeed, around 55% of all engines are expected to be employ some form of boosting by 2023. The market for charge air ducts therefore remains promising.
(Source: IHS)

Increasingly stricter vehicle emissions legislation is leading to higher requirements in terms of pressure, temperature and material resistance. The concepts of downsizing/rightsizing are motivating many manufacturers to produce smaller or optimised engines. The performance of these models is boosted by employing higher charge air pressure, which in turn leads to higher temperatures.

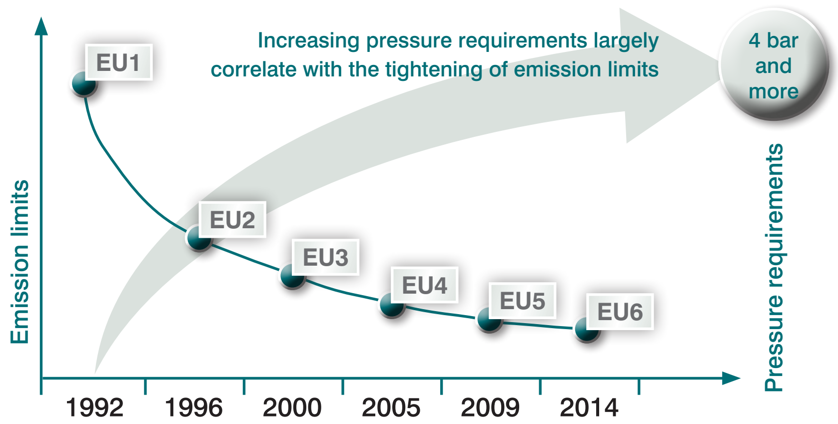
This development process is continuous and there is currently no physical limit in sight. Charge air pressures of up to 4 bar are already in development for passenger vehicles.

Number of boosted engines worldwide by 2023 (in millions)



Emission limits only achievable with boost systems

- Higher pressures
- Higher temperatures
- Downsizing/rightsizing



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