Keeping cool in future

Due to new alternative drivetrain designs for the vehicles of today and tomorrow, the entire basis of vehicle interior climate control is changing. Porsche Engineering is therefore ensuring that an integrated thermal management system is being developed now.

Some factors that influence the climate of the vehicle interior

Physical factors

- Air temperature
- Relative humidity
- Thermal stratification, vertical/horizontal
- Thermal radiation
- Air circulation
- Air quality
- Atmospheric electricity
- Acoustics
- Visual factors
- Number of passengers
- Seasonal changes to important physical factors

Physiology

- Physical constitution
- Sex
- Age
- Ethnic factors
- Food intake

Subjective factors

- Clothing
- Level of activity
- Level of acclimatization
- Daily/annual rhythm

"Comfort is the absence of disturbing factors"

Comfortable vehicle climate

Customers today expect a comfortable temperature in the interior of their vehicles – regardless of the conditions prevailing outside. Multi-zone climate control units in the front and back, provide the option to create a comfortable climate for each passenger, as is the case, for example, with the Porsche Panamera's state-of-the-art optional Four-Zone Climate Control.

A moderate interior climate, or "comfort" in the vehicle, can be basically reduced to the "absence of disturbing factors". The factors influencing this sense of comfort can be subjective as well as physical or physiological.

Along with creating and maintaining a comfortable vehicle interior climate through cooling and/or heating it, climate control must also fulfill legislative and safety requirements. This includes de-icing the windshield and windows within a defined time (for example, when cold-starting in the winter) and keeping the windows free from condensation.

It is also important to remember that the driver's reaction capabilities and concentration in difficult situations will be better the more comfortable he or she feels. This means that the temperature must be right from head to toe (what is known as stratification: "a cool head and warm

Panamera: fuel consumption (in l/100 km) combined 12.5-6.3; CO_2 emissions 293-159 g/km feet"). The air distribution, cleanliness and humidity must also be exactly right.

How a conventional climate control system works

Basically there are three main operating modes for the climate control system in a vehicle:

- **Pure heating mode:** quickly heating the cold interior of the vehicle in winter and de-icing the windshield when temperatures outside are low.

- **Combination mode:** automatic control of the vehicle climate ("car climate 22 degrees Celsius"/71.6 degrees Fahrenheit). Additional fresh air is first dehumidified and is then brought to the right temperature, to keep the windshield and windows free from condensation. This combined mode is the most common one for climate control systems in Central Europe, due to the climate conditions there.

- **Pure cooling mode:** quickly cooling the warm vehicle interior of the vehicle in summer, when temperatures outside are high.

A conventional vehicle climate control system design consists of the following components in addition to the actual climate control unit: a refrigeration circuit (provision of cold air) and a cooling circuit (provision of warm air), air ducts with outlet vents, a climate control operating unit and a climate control device (with its corresponding electrical parts such as a cable harness and sensors, for example).

The optional Four-Zone Climate Control in the Porsche Panamera enables individual, targeted climate control

The climate control unit measures the conditions outside as well as the current conditions in the vehicle interior and compares them with the target requirements. Thus, the climate control system can achieve the required climate using the three modes. Targeted individual climate control can be achieved in this way, which the two-zone automatic climate control system of the new Porsche 911 is capable of, for example.

These are the basic customer requirements and expectations for future climate control systems, regardless of the drive unit design of the vehicle.

Factors that influence vehicle climate control system designs

Climate control in vehicles is influenced by many different factors. These include the size of the passenger space, the design of the dashboard, the size and angle of the windshield, the thermal mass that needs to be climate controlled, the exterior aerodynamics and thermal management in the vehicle. All of these factors are taken into account and checked in the early stages of vehicle development, before the climate control system is designed, as their effects can vary widely depending on the vehicle in question.

How a conventional refrigeration circuit works

The most important parts of a climate control system are the refrigeration and cooling circuits. While the refrigeration circuit provides the energy to cool down the vehicle, the cooling circuit for the combustion engine collects the energy for heating up the vehicle interior.

Refrigerant sucked in by the compressor circulates in the refrigeration circuit. This circuit is divided into two sections: a high-pressure and a low-pressure section. The refrigerant, in the form of a gas, is heated in the compressor by being compressed and then channeled through the condenser under high pressure. There, heat is absorbed from the hot gaseous refrigerant, leading to a liquefaction of the gas.

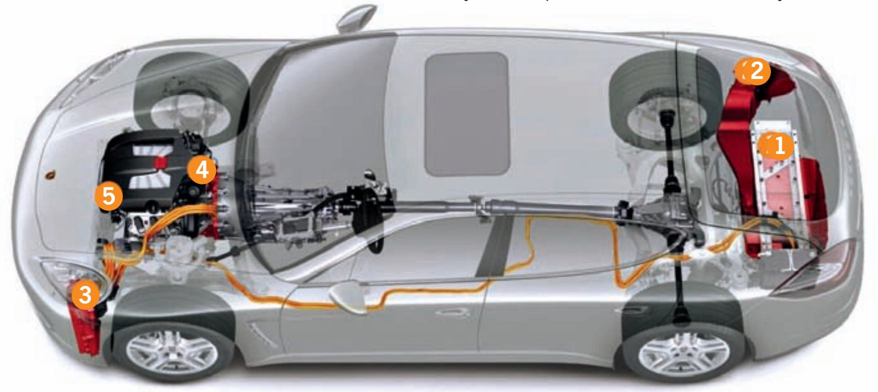
911 (Type 991): fuel consumption (in l/100 km) combined 9.7-8.2; CO_2 emissions 229-194 g/km

Then the refrigerant enters the drier/collector. In order to protect the refrigeration circuit from damage, impurities and water are separated from the refrigerant in the drier. The refrigerant is then passed from the drier to the expansion valve and enters the evaporator in a mostly liquid form. There it is vaporized by absorbing heat. Because it has absorbed heat from the surrounding environment, the air is cooled and dehumidified. The moisture created by dehumidifying the air is taken away via tubes. On very humid days, this moisture can appear in the form of a puddle under the vehicle. In the low-pressure section, the gaseous refrigerant is sucked back into the compressor and the cycle begins all over again.

Future challenges

In conventional drive unit designs sufficient „free“ energy for a comfortable climate inside the vehicle is available in form of „waste heat“ from the combustion engine. With alternative drive unit designs such as those in electric vehicles, however, the energy for heating the vehicle must be additionally generated. The efficiency of the individual electrical components is significantly higher in electric vehicles than in combustion engines. The missing energy in the form of heat that must be electrically generated in vehicles with electric vehicle drive units means that there is less energy available to propel the vehicle. The challenge therefore consists of maintaining a comfortable climate in the vehicle interior with as little energy as possible, in order to affect the vehicle's driving range as little as possible.

Hybrid components in the Panamera S Hybrid



1. **High-voltage nickel metal hydride battery**
2. **Air supply duct**
3. **Power electronics**
4. **Hybrid module**
5. **Supercharged 3.0-liter V6 engine**

Hybridization

Vehicles with hybrid drive units have a conventional combustion engine supported by an electric motor. Electric power is stored in a battery, which also must be kept cool. In the Panamera S Hybrid, the high-voltage nickel metal hydride battery is cooled by air. The challenge for the climate control system in a vehicle with a hybrid drive is the additional cooling required for the electrical components such as the battery, power electronics and the electric motor. As hybrid drives also usually have a start/stop function and can drive a certain distance on electric power alone, the climate control system must be designed so that it can operate without a combustion engine.

This means that the refrigeration and cooling circuit components, such as the compressor, must be powered electrically and can no longer be mechanically linked to the combustion engine, in order to ensure that the climate control system still functions when the vehicle has stopped at traffic lights, for example. This is made possible by special evaporators, which can store the cooling energy for a certain period (storage evaporators), and by high-voltage PTCs for electrical heating. Another major challenge for climate control and thermal management system design is ensuring that the drivetrain heats up quickly in order to reduce fuel consumption and emissions.

Electric vehicles

Electric vehicles – like the Porsche Boxster E research vehicle – use batteries that require a temperature range of between 20 and 30 degrees Celsius (between 68 and 86 degrees Fahrenheit) in their drivetrains. This temperature range ensures that the batteries function properly and prevents them from “getting old” too quickly. This means that the batteries do not just need to be cooled down, but sometimes also warmed up, depending on ambient temperatures.

Cooling with air, which is currently the standard method in hybrid drives, is no longer sufficient and must be replaced with liquid cooling methods using appropriate refrigerants or coolants. Climate control and thermal management are therefore becoming more complex and require new thinking.

The aim of the thinking behind the new designs at Porsche Engineering is to reduce the amount of heating required in the vehicle. There is potential in improved insulation, which will result in the loss of less heat via the body and the windows, and the reduction of the thermal mass to be heated in the vehicle's interior.

Innovative solutions

Options for new climate control system design being considered strongly at Porsche Engineering are the use of auxiliary heating systems (such as heat pumps, electric auxiliary heaters, fuel-powered auxiliary heaters) and targeted climate control according to the number of passengers in the vehicle. Other areas being focused on are the use of thermal storage systems, the preheating or precooling of the vehicle interior while the vehicle is being charged at the electrical power outlet, or the use of direct and surface heating devices in the seats and the steering wheel.

The cooling agents and cooling and heating methods are selected by engineers in the earliest stages of the design process. For this purpose, Porsche Engineering has developed its own thermal simulation tool, which was validated by tests. This can be used to work out and define the optimum climate control and thermal management system design at an early stage of vehicle development, using previously identified performance data, cooling and heating needs, and driving profile requirements.

Batteries like those in the Boxster E research vehicle need to be warmed up as well as cooled down, depending on ambient temperatures

Conclusion: challenges and solutions

Climate control and thermal management play a very important role when designing hybrid and electric vehicles, as the increasing electrification of vehicles leads to a decrease in the number of available sources of heat. As a result, today's standard method of reusing the (free) engine waste heat is becoming increasingly difficult or even impossible.

The more effective use of heated or cooled air in the vehicle interior, better insulation and further modifications in the vehicle contribute to reducing energy consumption for the heating and cooling of the vehicle interior. The same is true for the inclusion of new components in climate control and thermal management system design. Along with cooling the batteries in order to increase their lifespan, heating the batteries is also becoming more important.

Porsche Engineering is developing solutions for these challenges based on comprehensive electromobility experience from internal and external engineering projects, as well as thermal management expertise from classic sports car design. Using all the tools available to them, from simulation and calculation tools to component testing on test stands and the testing of entire vehicles in the climate wind tunnel and on the test track, engineers at Porsche Engineering are creating the climate control and thermal management system designs of the future.

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Panamera S Hybrid: fuel consumption (in l/100 km) urban 7.6-7.4 · extra-urban 6.8-6.6 · combined 7.1-6.8, CO_2 emissions 167-159 g/km