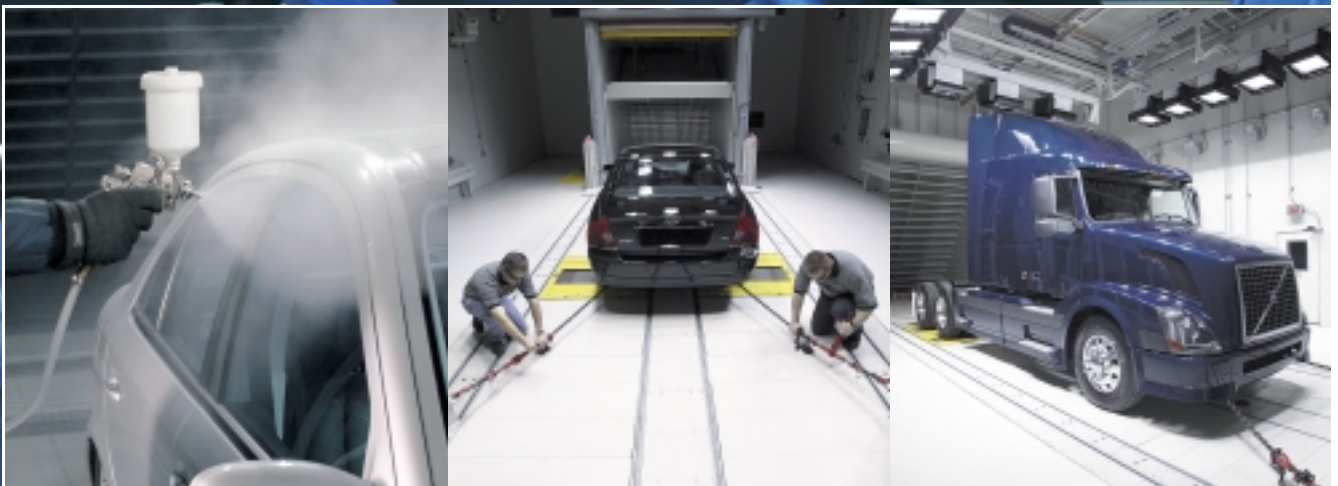




We bring the road into the laboratory

**Research and
Development in the
Climatic Wind Tunnels
in Stuttgart and Troy**

BEHR



The Behr climatic wind tunnels in Stuttgart, Germany, and Troy, USA, are capable of realistic measurements in all vehicle models: from compact cars to trucks.

Setting a new standard for realistic measurements

As the leading international direct supplier of automobile climate control and engine cooling, Behr offers a comprehensive range of research and development services. These services are customized for each customer, make and model, to provide the best possible technical and economic solution in each case.

Our employees work with the latest test equipment to develop products that meet the increasing demands of the market. The Behr climatic wind tunnels play a special role here, making realistic measurement and testing conditions possible. They provide a reliable basis for a smooth technology transfer process, quality management, cost reductions and time savings, all in the customer's interest.

Development history of Behr wind tunnels

1936: Manfred Behr, son of the company founder, decides to build his own wind tunnel.

1937: The first blower-operated wind tunnel for testing cooling water and oil circulation in all vehicle types, without the need for road tests, goes into operation.

1957: Behr builds Europe's first adjustable climatic wind tunnel, for the development of vehicle heating and cooling systems.

1972: Enlargement of testing facilities to create a development center unmatched anywhere in Europe. Replacement of the 1937 blower tunnel with tunnel 2, and commissioning of the third wind tunnel.

1999: Start of construction on the large climatic wind tunnel in Stuttgart (KWK).

2000: Climatic wind tunnel goes into operation, on schedule, at Behr headquarters in Stuttgart-Feuerbach.

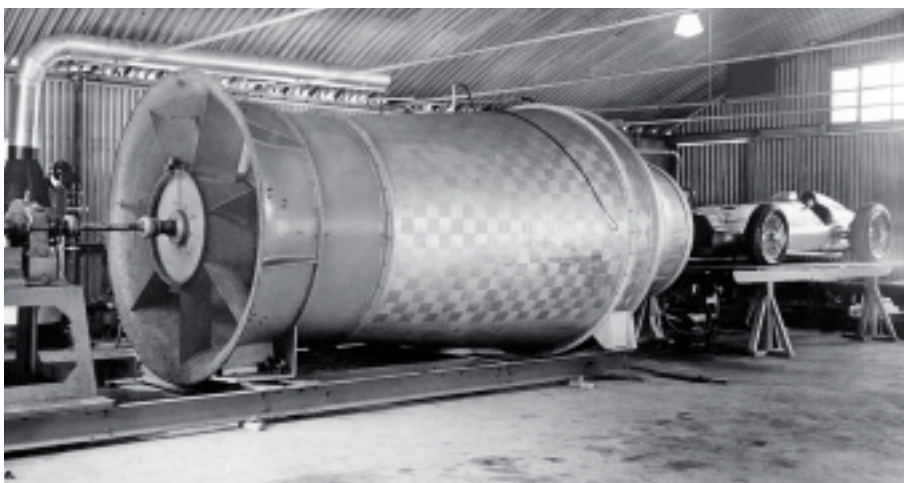
2002: Start of construction on the Troy Wind Tunnel (TWT) at Behr America in Troy, Michigan/USA.

2004: The TWT goes into operation.

The road environment in the laboratory – state of the art

Our modern climatic wind tunnels set new standards for the simulation of environmental and driving conditions. For example, the specified values for uniformity of temperature distribution and speed at the nozzle outlet are achieved, while all dynamic driving cycles can be run and the noise level in the test section is well below the level previously regarded as normal for wind tunnels. This provides ideal conditions for using a climatic wind tunnel to run the acoustic tests in the vehicle interior.

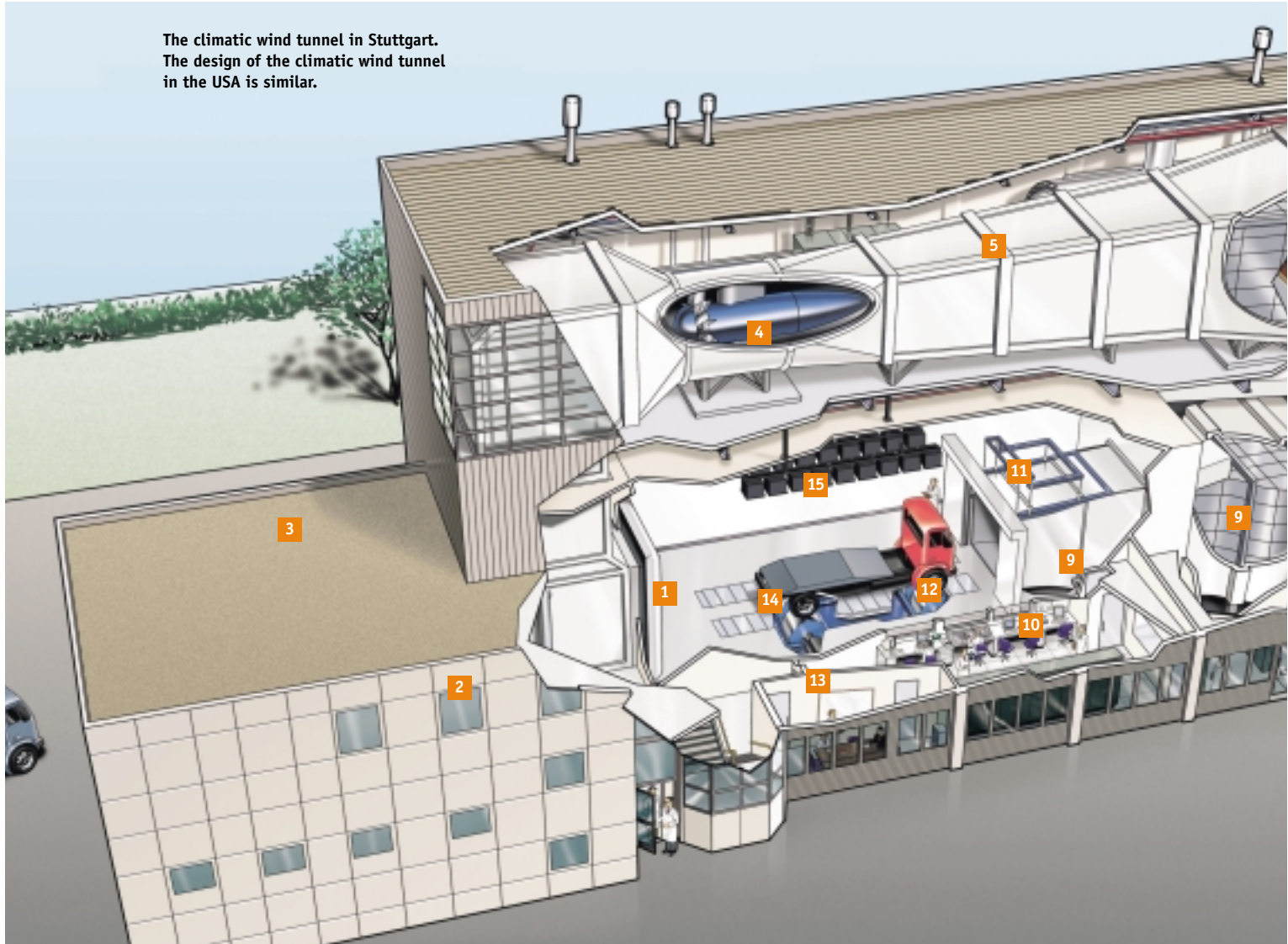
Behr has literally brought the road into the laboratory. In addition to definitions of the usual speed and climatic values, it is now also possible to simulate as required solar irradiation from all directions. In addition, as further confirmation of the pioneering concept and flawless technical implementation of the climatic wind tunnels, the flow quality approaches the level of aero-acoustic wind tunnels.



The first Behr wind tunnel went into operation in 1937.

A new dimension in research and development

The climatic wind tunnel in Stuttgart.
The design of the climatic wind tunnel
in the USA is similar.



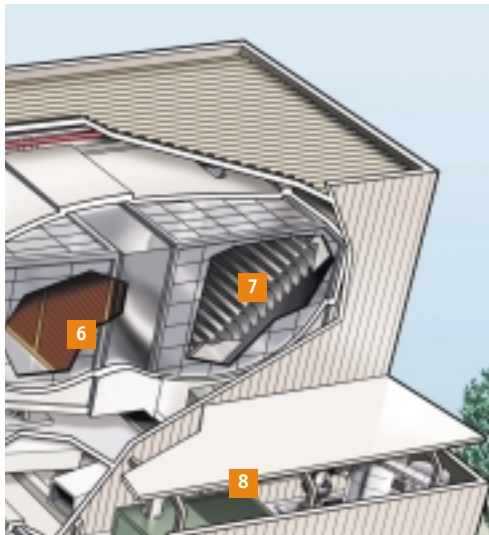
- | | | |
|--|-----------------------------|--|
| 1 Collector | 6 Heat exchanger (33 sq m) | 11 Adjustable nozzle |
| 2 Working areas, offices | 7 Turning vanes | 12 Roller dynamometer |
| 3 Soak room, transfer hall and vehicle preparation | 8 Technical roof | 13 Meeting room |
| 4 Fan (315 kW) | 9 Contraction ratio (5.5:1) | 14 Open test section for all vehicle types and classes |
| 5 Diffuser | 10 Control room | 15 Solar simulation |

The main function of a climatic wind tunnel is to check the air conditioning system of a vehicle, optimize the control algorithms and achieve the best possible coordination between the individual components of the A/C and engine

cooling system. With this in mind, and having the additional option of running cooling capacity measurements at peak load in a wind tunnel specifically for this purpose, the climatic wind tunnel was designed on a “no compromise” basis. With a maximum speed of 130 km/h it allows measurements for automobile climate control and for partial loadings in the engine cooling system. With a maximum speed of 200 km/h and higher roller loads, the climatic wind tunnel in Troy also covers the sector for full-load measurements for engine cooling.

realistic driving situations, a very wide range of combinations and sequences of temperature, air humidity, solar irradiation and road load provide for extremely finely tuned settings. This means that the characteristic parameters of the cooling circuit can be run and replicated as required.

All the required tests are run in a generously-dimensioned open test section, which is able to accommodate all vehicle sizes, right up to trucks. The chamber temperature can be set with a maximum deviation of ± 0.5 K, from minus 30°C to plus 50°C. The air humidity can be set with the same level of precision; a tolerance of ± 0.5 K for any dew point between 0°C and 95% relative humidity ranks among the top values in the industry today.



Real situations replicated as required

The climatic wind tunnels meet every challenge – every conceivable set of

Design and technology

Equipment features:

- Open test section for passenger cars, vans and heavy trucks
- All drive systems (2 rollers, for front, rear and four-wheel drive)
- Roller dynamometer with adjustable axles
- Adjustable nozzles for different vehicle types
- Solarium with sun position and full solar spectrum
- Temperature pre-conditioning area for passenger cars and vans
- Tunnel design for acoustic measurements in vehicle interior

Driving programs:

- Simulation of test drives
- ECE (fuel consumption, thermal management)

Environmental conditions:

Simulation of day profiles (sun position, climate)

Performance features

Vehicle dimensions (max.):

KWK Stuttgart

10.0 x 2.65 x 5.0 m (L x W x H)

TWT Troy

8.8 x 2.6 x 4.35 m (L x W x H)

Wind speed (max.):

Passenger cars: 130 km/h, at 6 sq m of nozzle area
SUV/vans: 100 km/h, at 8 sq m of nozzle area
Trucks 80 km/h, at 10 sq m of nozzle area

Passenger cars: 200 km/h, at 6 sq of nozzle area
SUV/vans: 160 km/h, at 8 sq m of nozzle area
Trucks 120 km/h, at 10 sq m of nozzle area

Temperature ranges:

- 30 to + 50°C in climatic wind tunnel
- 40 to + 50°C in soak room
(cooling time < 180 min from + 50 to - 30°C)

- 30 to + 50°C in climatic wind tunnel
- 40 to + 50°C in soak room
(cooling time < 180 min from + 50 to - 30°C)

Humidity range:

0°C dew point to 95% rel. humidity

0°C dew point to 95% rel. humidity

Solarium:

350 to 1,200 W/sq m intensity

350 to 1,200 W/sq m intensity

Braking power of roller dynamometer (max.):

150 kW/axle from 30 km/h

300 kW/axle from 35 km/h

Drive power (max.):

> 100 kW

> 250 kW from 35 km/h

Speed deviation (max.):

0.5%

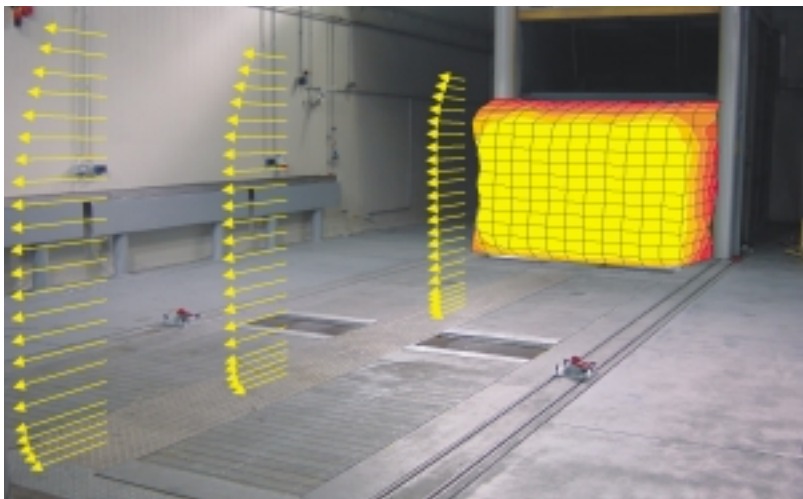
0.5%

Background noise:

< 70 dB(A) at 50 km/h

< 65 dB(A) at 50 km/h

Versatility and efficiency combined



A speed deviation of < 0.5% and temperature deviation of < 0.5 K is maintained over almost the entire nozzle outlet area. This flow quality remains virtually constant downstream.

In the Behr climatic wind tunnels the vehicle wheels are positioned on two pairs of rollers, each with braking capacity of 150 kW (Stuttgart) or 300 kW (Troy) engine power; the specified axle distance is set to within millimeters. The two dynamometers guarantee realistic simulation of the underfloor flow, perfectly reproducing the aerodynamics of a road driving situation.

Hi-tech for light and heat

For analysis of cabin heating by the sun, the climatic wind tunnels have a

versatile solarium, providing for adjustment of the radiation intensity between 350 W/sq m and 1,200 W/sq m, with exact replication of the sunlight's spectral distribution. To allow reproduction of any irradiation angle and sun position at any time of day, the solarium lamps are mounted on movable frames. Shutter systems and filters are used to replicate the short-term shade conditions caused by cloud or driving in a tunnel.

Flow quality far above average

The flows through the vehicle interior are largely dictated by the pressure conditions around the entire vehicle, which means that the flow quality is particularly important. Whereas in earlier wind tunnels an opening of 6 sq m was

regarded as generous for vehicle tests, in the Behr climatic wind tunnels, featuring a flexible nozzle top section, the nozzle exit surface can be set not only to 6 sq m, but to 8 sq m for vans, or even 10 sq m for trucks. In addition to outstanding flow quality, the uniformity of flow speed ($\pm 0.5\%$) and temperature distribution (± 0.5 K) also meet the most demanding requirements.

Low sound level

For identification of the acoustic emissions from the A/C system penetrating into the vehicle interior and evaluation of those emissions, it is essential that the sound level be kept as low as possible. This is achieved in the Behr climatic tunnels by the rigorous selection of individual components, which are then carefully matched to achieve optimum system performance.



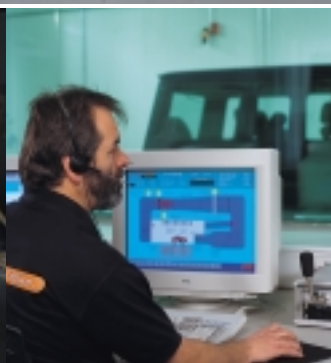
Cooling in the soak room



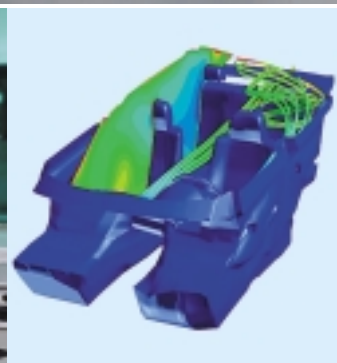
Vehicle preparation



Climate simulation. e.g. icing up



Data acquisition and analysis



Computer simulation of vehicle interior



Heat up. Cool down.

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