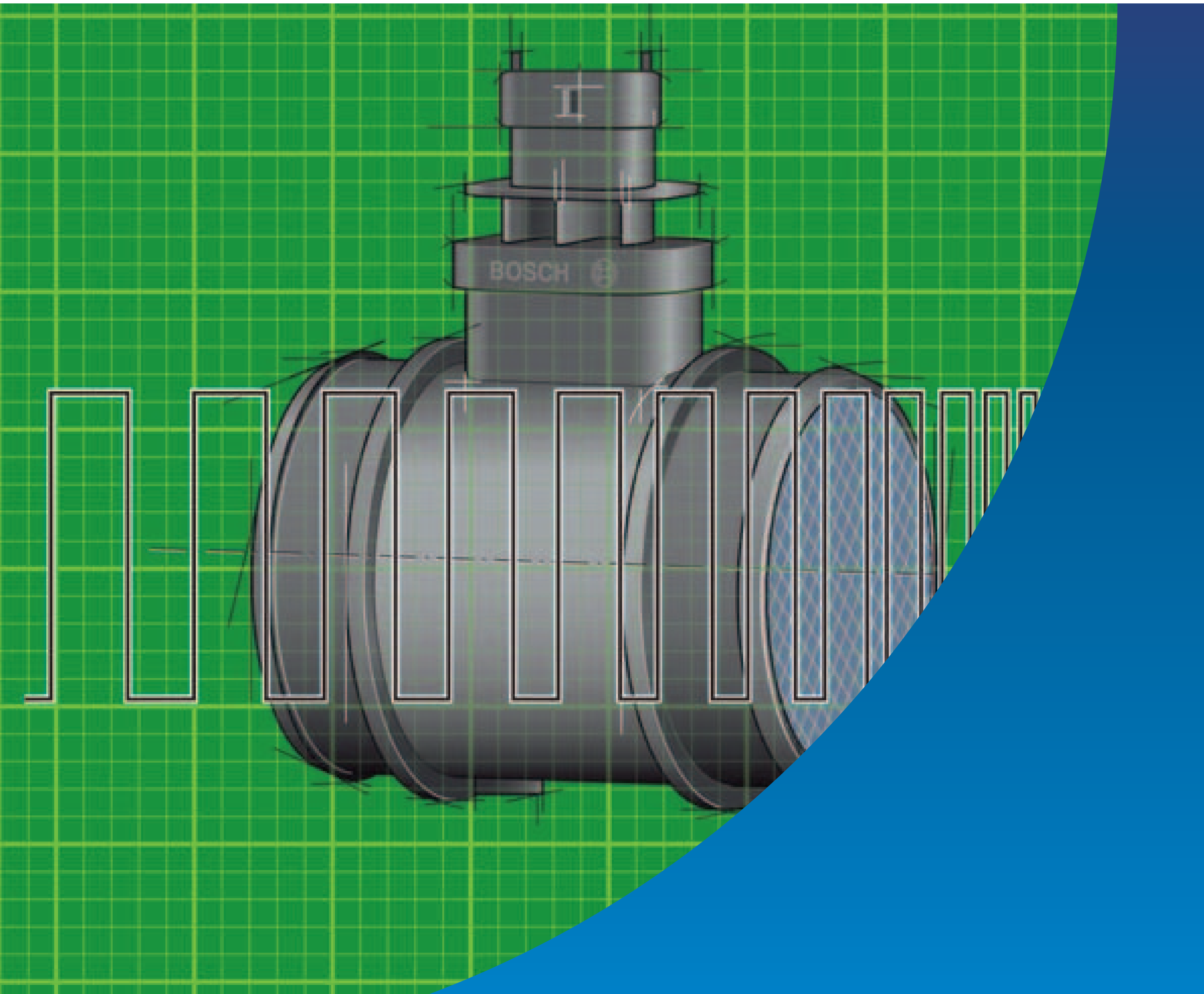
Service Training

Self-study Programme 358

Hot-film Air-mass Meter HFM 6

Design and Function



Due to the further development of standards and laws for exhaust emissions in vehicles, components with improved measuring accuracy are constantly needed. Therefore a new generation of hot-film air-mass meters are now being used for engine management.

Simply converting the exhaust gases after combustion is not enough to meet these laws and standards, instead they have to be kept as low as possible by means of efficient combustion.

Furthermore modern engines deliver an increasing amount of power with the same or lower fuel consumption.

In addition to other measures, the exact measurement of the intake air by the air-mass meter also helps meet all of these requirements.

This self-study programme explains the basics of measuring intake air mass, familiarises you with the hot-film air-mass meter HFM 6 and helps you understand how it works.

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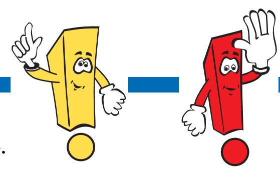
NEW



Warning Note

The self-study programme shows the design and function of new developments.
The contents will not be updated.

For current testing, adjustment and repair instructions, refer to the relevant service literature.

Contents

Basics of Air-mass Measurement

Temperature and air pressure

Many people immediately think about the medium around us when they hear the word "air". That is air under normal atmospheric pressure and at comfortable temperatures.
But as we know, the temperatures and also the air pressure change constantly.

Temperatures and air pressure vary extremely across the world depending on the location.
(Temperature and air pressure decrease as the altitude rises.)

Influence of altitude on air temperature and pressure

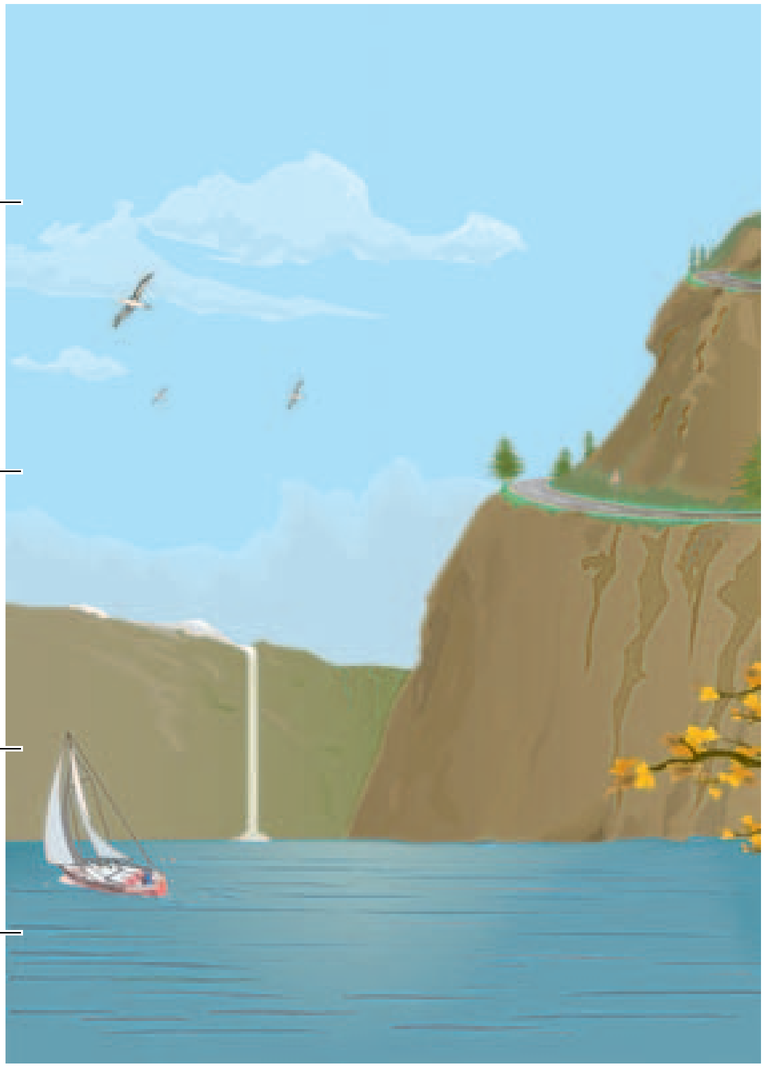
For example:

Altitude: 1000 metres
Air pressure: 898 hPa (0.898 bar)
Temperature: 13.5°C

Altitude: 500 metres
Air pressure: 954 hPa (0.954 bar)
Temperature: 16.75°C

Altitude: 100 metres
Air pressure: 1001 hPa (1.001 bar)
Temperature: 19.35°C

Altitude: 0 metres
Air pressure: 1013 hPa (1.013 bar)
Temperature: 20°C



S358_002

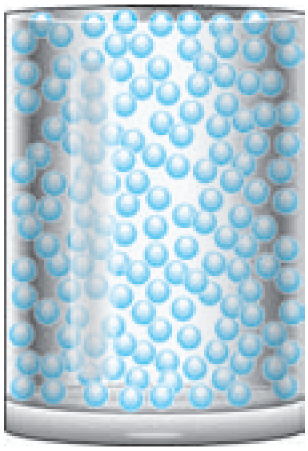
Effect of temperature and air pressure on the air mass

At the same volume, the air mass changes with the temperature and the air pressure.

Low air pressure, high temperature

A cylindrical container with an area of 1 m^2 and a height of 1m contains 1 m^3 air.

The air pressure is low and the temperature of the air is high.
The air density is low due to the low pressure and the high temperature.
(There is a low air mass in the container.)
The air mass in the container is low.



S358_003

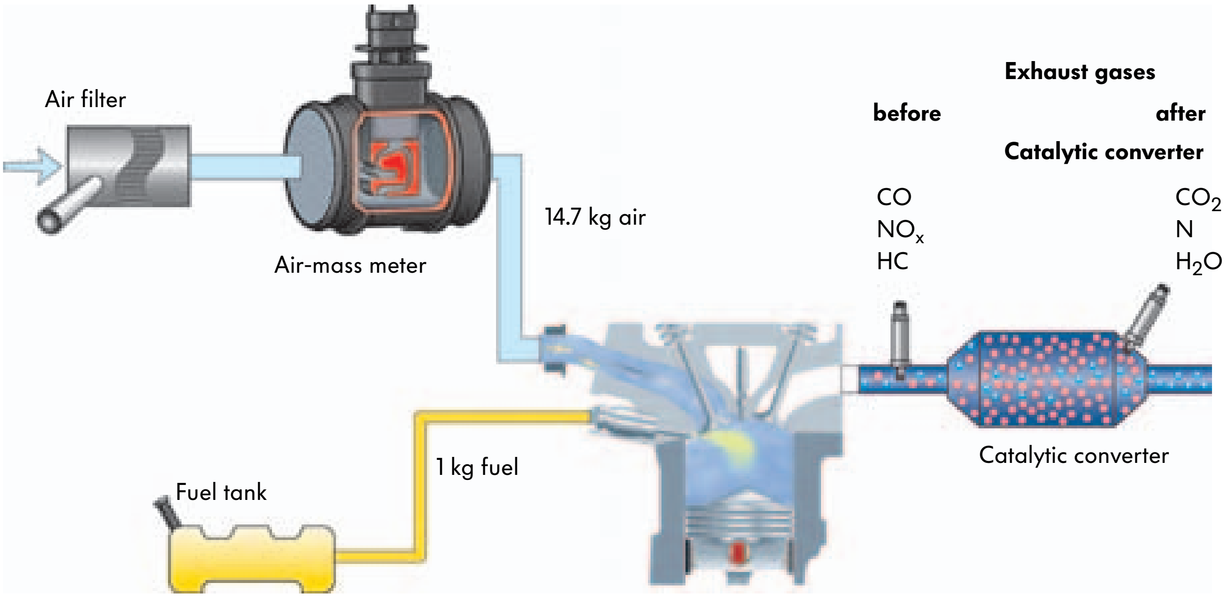
High air pressure, low temperature

In the same-sized container, the air is at a high pressure and low temperature.
The air density is considerably higher due to the high pressure and the low temperature.
(There is a considerably higher air mass in the container.)
The air mass in the container is considerably higher.

S358_004

Air-fuel ratio

Path of air



Path of fuel

S358_005

Combustion engines require 14.7 kg of air for the ideal combustion of 1 kg fuel. In engineering, this ratio of fuel to air is called the stoichiometric ratio.

The engine control unit requires exact information on the intake air mass in all operating situations so it can set the correct ratio of fuel to air.

In stoichiometric operation, the air-fuel ratio has the Lambda value 1.
It is only in stoichiometric operation that harmful substances can be almost completely removed from the exhaust gas by the catalytic converter.

Rich air-fuel ratio

When there is a rich air-fuel ratio (Lambda < 1), the exhaust gas will contain too much carbon monoxide (CO) and too many unburned hydrocarbons (HC).

For example: $\frac{1.2\text{ kg fuel}}{14.7\text{ kg air}}$

Lean air-fuel ratio

When there is a lean air-fuel ratio (Lambda >1), the exhaust gas will contain too much nitrogen oxide (NO_X).

For example: $\frac{0.8\text{ kg fuel}}{14.7\text{ kg air}}$

The exact measurement of the intake air mass thus contributes to the air-fuel ratio being kept in the Lambda 1 range and to reducing or preventing harmful substances in the exhaust gas.

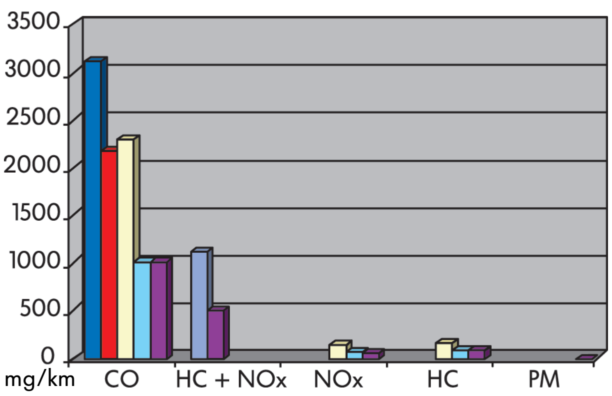
Emissions guidelines

The hot-film air-mass meter helps meet the increasingly stricter emissions guidelines in Europe and the United States thanks to its reduced measuring tolerances compared with the previous models.

By measuring the exact air mass taken in, the mixture formation is optimised and the treatment of the exhaust gases by catalytic converters is enhanced.

Development of emissions values using Europe as an example

Petrol engines

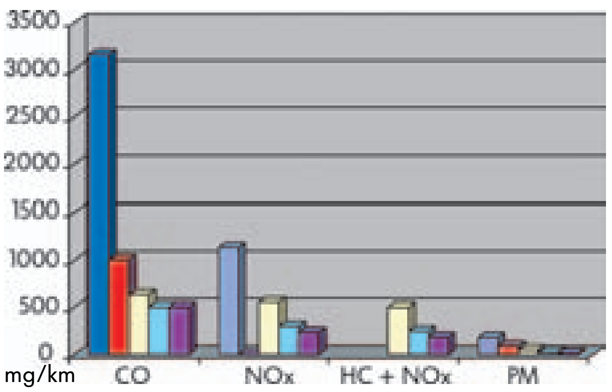


S358_010

Standard	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5**
Valid from	1/7/92	1/1/96	1/1/00	1/1/05	1/9/09
CO	3160	2200	2300	1000	1000
HC + NOx	1130	500			
NOx			150	80	60
HC			200	100	100
PM				5*	5*

* Vehicles with direct injection
** Values according to previous information
See page 19 for explanation of chemical symbols

Diesel engines



S358_011

Standard	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5**
Valid from	1/7/92	1/1/96	1/1/00	1/1/05	1/9/09
CO	3160	1000	640	500	500
HC + NOx	1130	700/ 900*	560	300	230
NOx			500	250	180
PM	180	80/100*	50	25	5

* Vehicles with direct injection
** Values according to previous information
See page 19 for explanation of chemical symbols

Legend

EURO 1	From 1992 also EEC stage 1 (European EconomicCommunity)
EURO 2	From 1996 also EEC stage 2 (European EconomicCommunity)
EURO 3	from 2000
EURO 4	from 2005
EURO 5	from 2009

Hot-film Air-mass Meter HFM 6

Task

The hot-film air-mass meter HFM 6 is used to measure the intake air mass. The engine control unit calculates the exact intake air mass from its signal.

With petrol engines, the signals for calculating all load-dependent functions are used.

The load-dependent functions are:

- the ignition time,
- the injection time,
- the injection amount and
- the activated charcoal filter system.

With diesel engines, the signals are used to control:

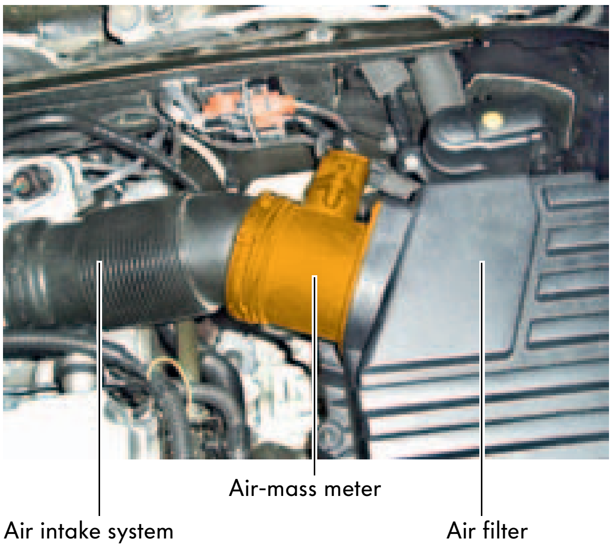
- the exhaust gas recirculation quantity and
- the injection time.

The following engines are already equipped with this:

- 3.2l V6 FSI engine
- 3.6l V6 FSI engine
- 2.5l R5 TDI engine

Location

The hot-film air-mass meter is fitted between the air filter and the throttle valve in the engine air intake system.



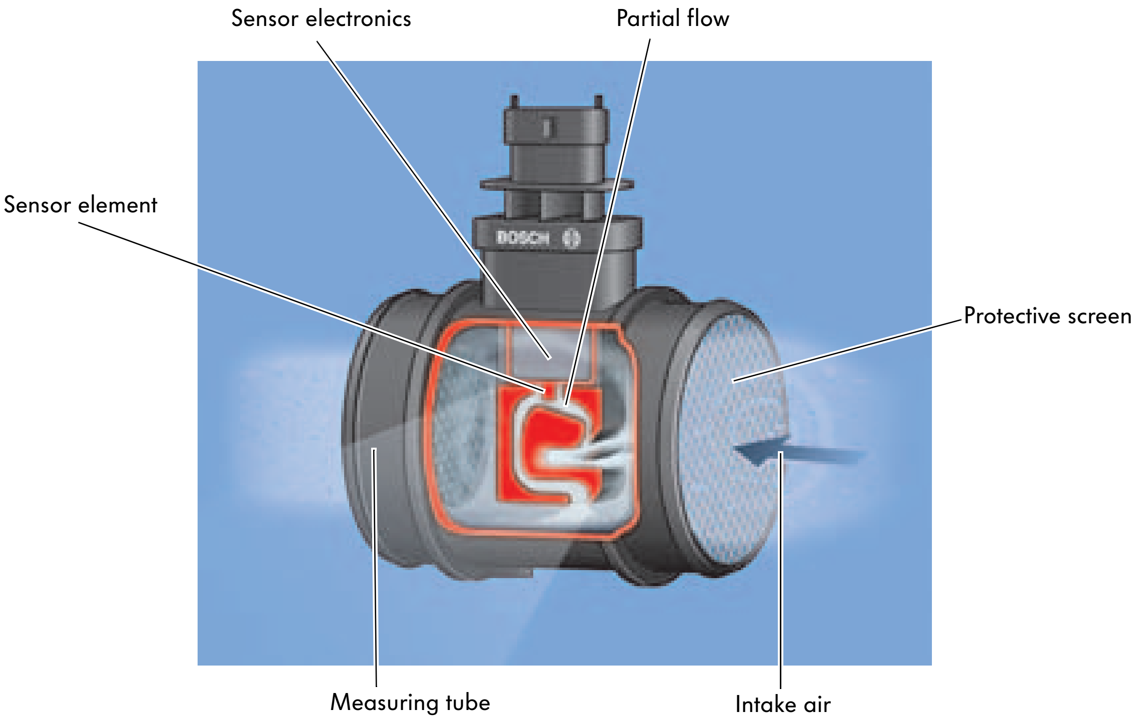
S358_016

Design

The hot-film air-mass meter HFM 6 consists of:

- the measuring tube and
- the sensor electronics with sensor element.

The air mass is measured in a partial flow (bypass). Thanks to its special design, the air-mass meter can measure the intake and recirculated air mass.



S358_006

If dirt particles, engine oil vapour and humidity reach the sensor element, the measuring result will be incorrect. For this reason, particular attention was paid to ways of stopping these impurities reaching the sensor electronics when the measuring tube and the protective screen were designed.

Sensor Element

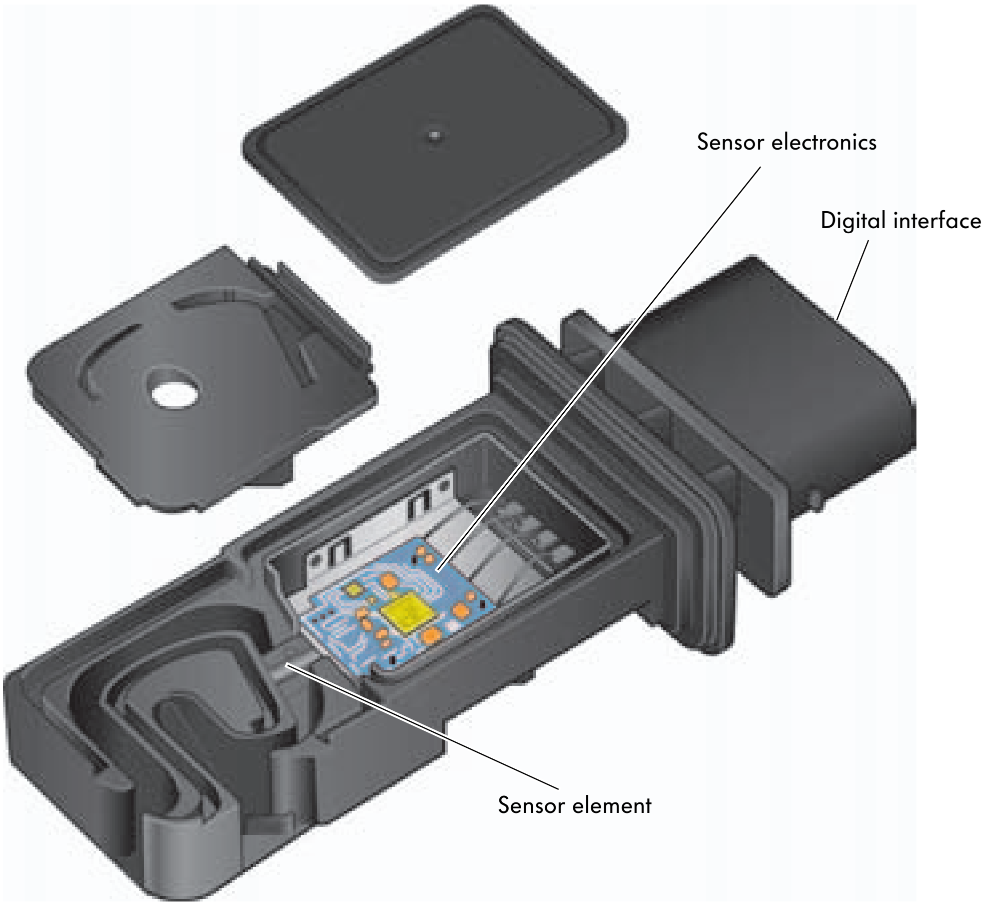
Design

The new air-mass meter uses a thermal measuring system like its predecessor.

It is made up of the following main components:

- the micromechanical sensor element with return flow detection and an intake air temperature sensor,
- a sensor system that includes digital signal processing
- and a digital interface.

Compared with previous air-mass meters, the evaluation of the signal in the engine control unit is more precise and stable in the new generation thanks to the digital interface.



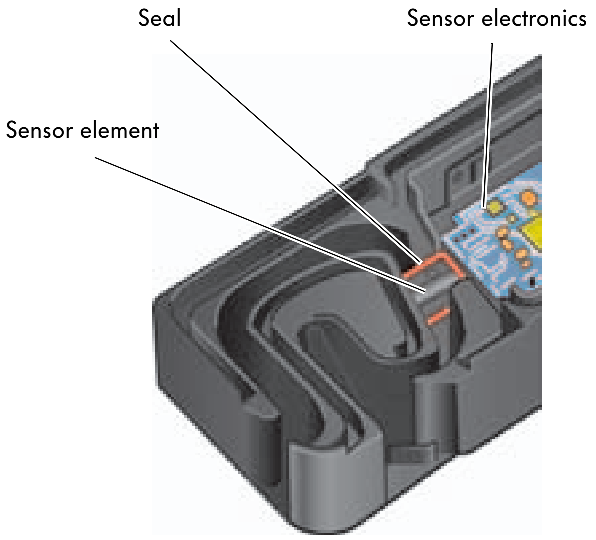
S358_001

Digital signal processing

In contrast to the previous models, the air-mass meter HFM 6 transmits a digital signal to the engine control unit. Up to now the engine control unit received an analogue signal in which the signal became innacurate as the components aged due to the transfer resistance.

Bypass channel

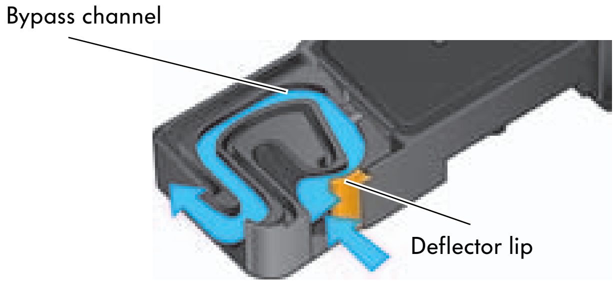
The bypass channel is flow-optimised compared with the previous model HFM 5.
The partial flow required for air-mass measurement is drawn into the bypass channel behind the deflector lip.



S358_013

Sensor stability

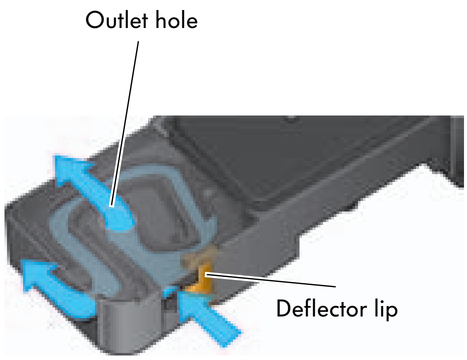
The bypass channel is separated completely from the sensor electronics by adhesives and seals for the sensor element. Furthermore the sensor element material has been reinforced.
This modification increases the robustness of the sensor.



S358_008

How it works:

The design of the deflector lip causes a vacuum to form behind it.
This vacuum causes the partial air flow required to measure the air mass to be drawn into the bypass channel. The slow dirt particles cannot follow this fast movement and are fed back to the intake air via the outlet hole.
The dirt particles can therefore not falsify measurements and cannot damage the sensor element.



S358_012

Sensor Element

Measuring procedure

The sensor element is next to the sensor electronics. The sensor element protrudes into the partial air flow to measure the air mass.

The sensor element consists of:

- a heating resistor,
- two thermistors R1 and R2 and
- an intake air temperature sensor.

How it works:

The sensor element is heated in the middle to 120 °Celsius above the intake air temperature by the heating resistor.

Functional example:

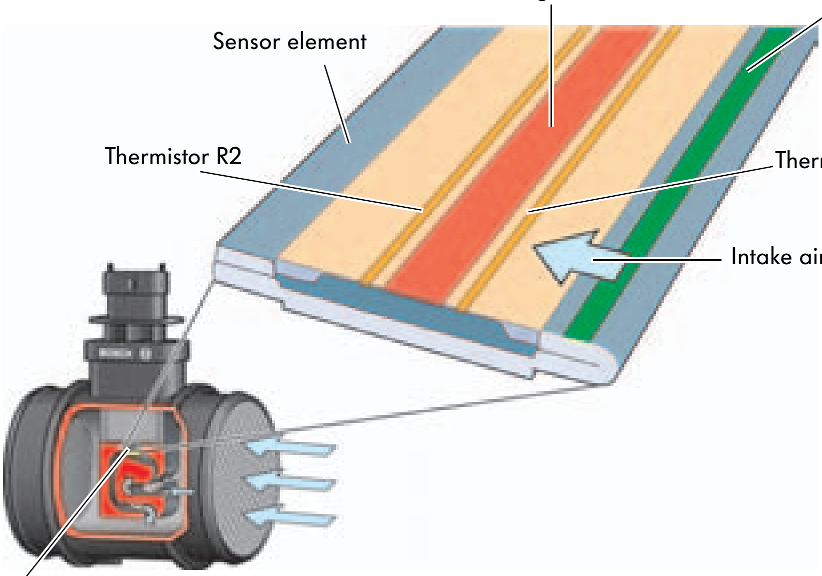
Intake air temperature 30°C
Heating resistor is heated to 120°C
Measured temperature 120°C + 30°C = 150°C

Due to the distance from the heating resistor, the temperature of the sensor element decreases towards the edge.

Measuring example:

Intake air temperature:	30 °C
Temperature at sensor element edge:	30°C
Heating resistor:	150°C
Temperature at R1 and R2 without intake air flow:	90°C
Temperature at R1 with intake air flow:	50°C
Temperature at R2 with intake air flow:	stays at approx. 90°C

Due to the temperature difference at R1 and R2, the electronic module recognises the intake air mass and the flow direction of the air.



S358_007

Return flow detection

When the inlet valves are closed, the intake air bounces off them and flows back to the air-mass meter. If this is not recognised as return flow, the measured result will be incorrect.

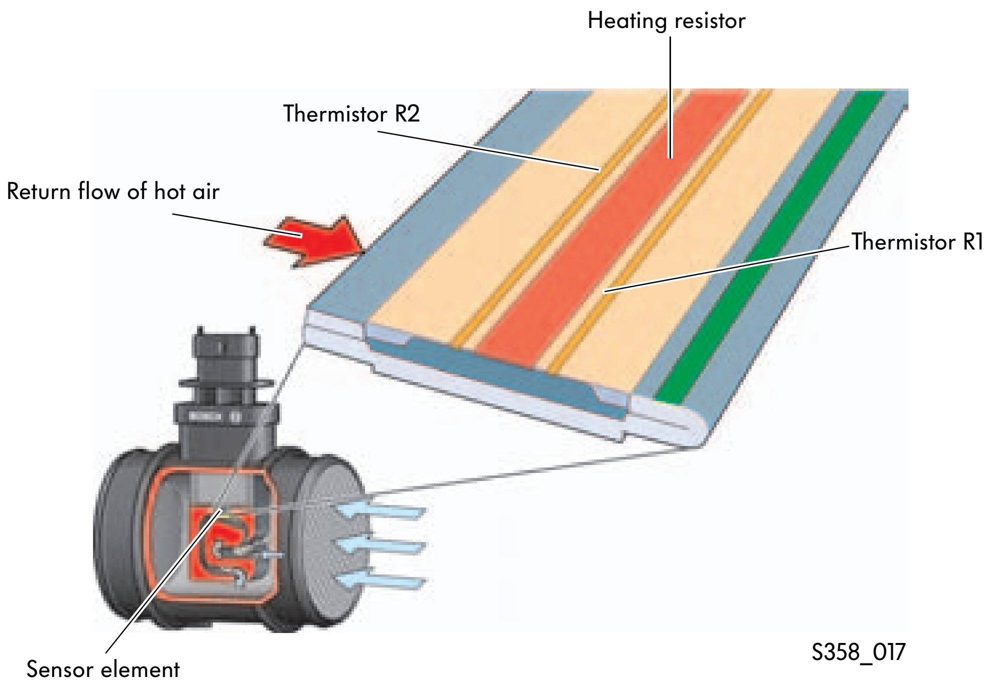
How it works:

The return flow air reaches the sensor element and first flows via thermistor R2, then via the heating resistor and via thermistor R1.

For example:

Intake air temperature:	30°C
Heating resistor:	150°C
Temperature at R2:	50°C
Temperature at R1:	90°C

Due to the temperature difference at R1 and R2, the electronic module recognises the air-mass return flow and the flow direction of the air.



S358_017

Sensor Element

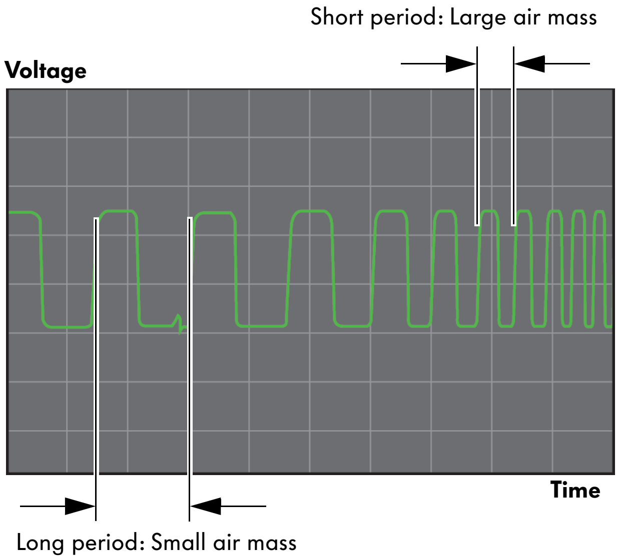
Transfer of air-mass signal to the engine control unit

The air-mass meter transmits a digital signal for the measured air mass to the engine control unit in the form of a frequency. The engine control unit can recognise the measured air mass from the period length.

Advantage:

The digital messages are less susceptible to interference than analogue wire connections.

Frequency signal



S358_018

Signal use

Petrol engine

The intake air mass is required by the engine control unit for exact calculation of the load-dependent functions.

Diesel engine

The measured values are required by the engine control unit to calculate the exhaust gas recirculation quantity and the injection quantity.

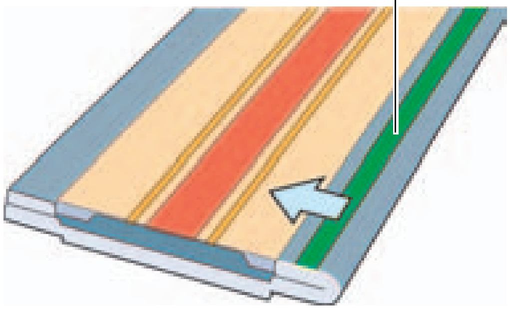
Effects of signal failure

Petrol engine and diesel engine

If the air-mass meter fails, the engine control unit will use a substitute air-mass model that is stored in the engine control unit for this case.

Intake air temperature sensor for sensor element

The intake air temperature sensor is on the sensor element. It measures the current intake air temperature.



S358_009

Signal use

The intake air temperature sensor is used to evaluate the temperature inside the air-mass meter.

Notes:

The engine management system has its own separate sensor to recognise the intake air temperature.

The 3.2l V6 FSI engine and the 3.6l V6 FSI engine use the intake air temperature sensor G42 to recognise the intake air temperature.

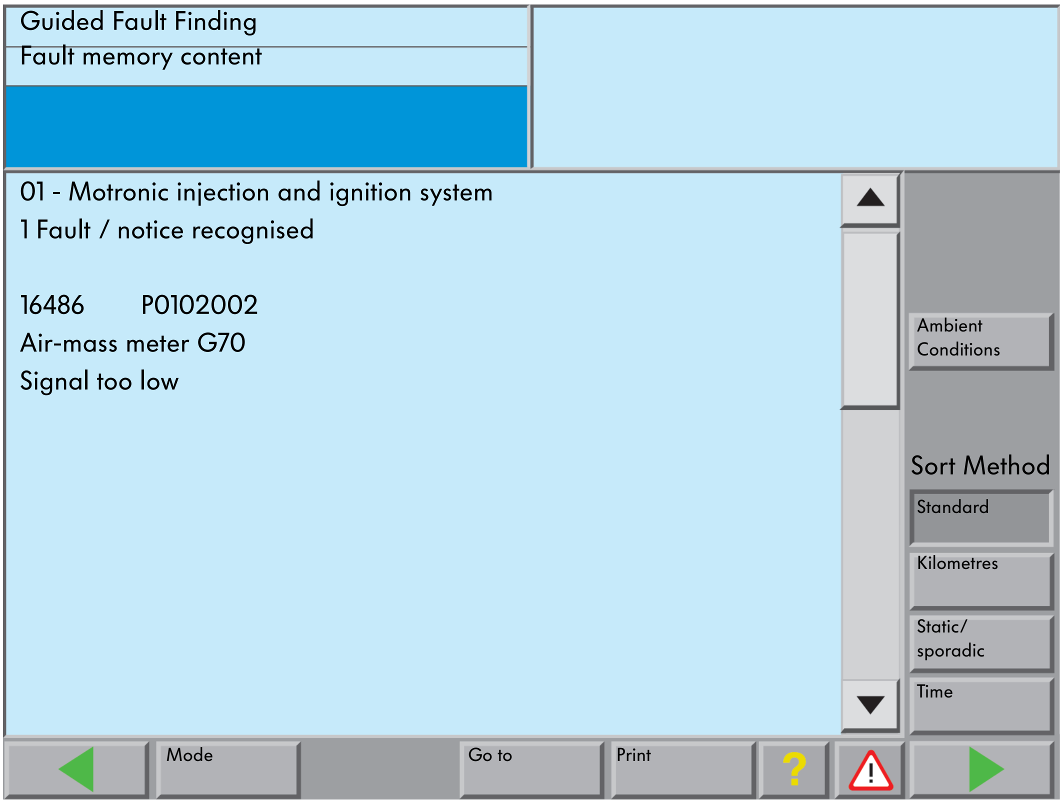
The 2.5l R5 TDI engine uses the intake air temperature sensor G42 to recognise the intake air temperature. It is in one component together with the charge air pressure sensor G31.

Diagnosis

Fault memory

The function of the air-mass meter is monitored by a fault memory in the engine control unit J623.

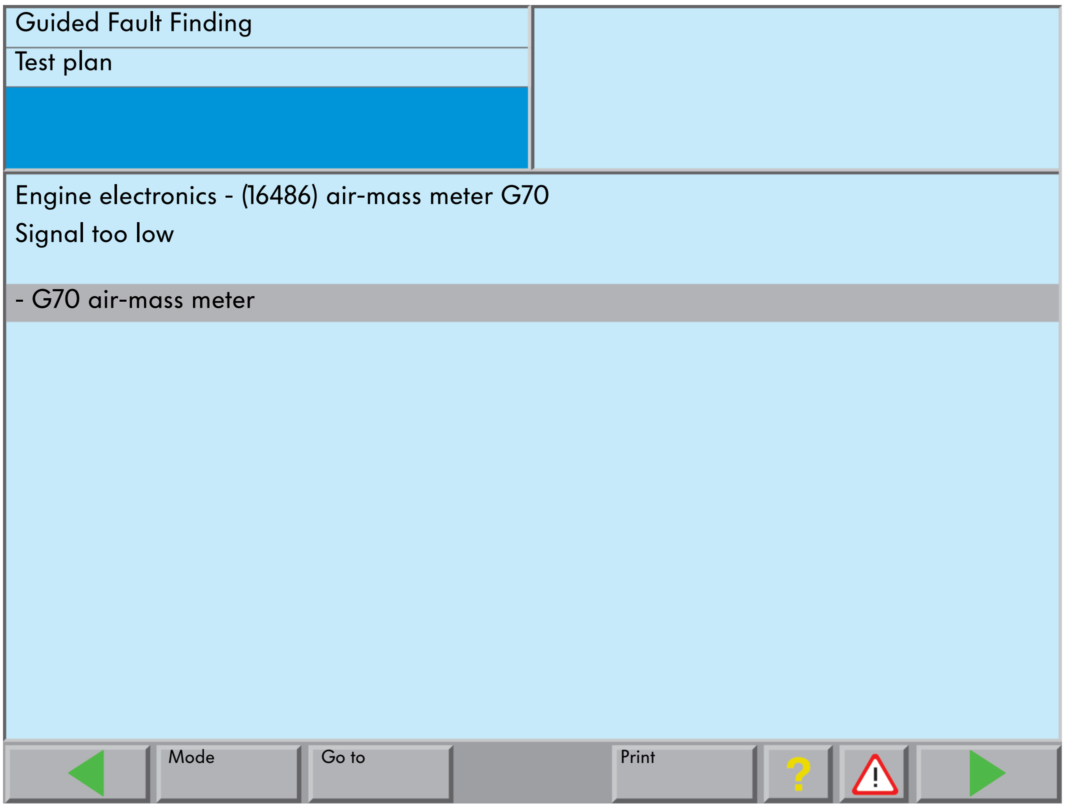
If a fault occurs during operation, an entry will be made in the fault memory.



S358_014

Test plan

A system test plan is called up depending on the entry in the fault memory. The individual steps for diagnosis are described in this test plan.



S358_015

The air-mass meter is maintenance-free.
The necessary repair measures for faults are listed in the Guided Fault Finding.

Test Yourself

1. Which statement about air density is correct?

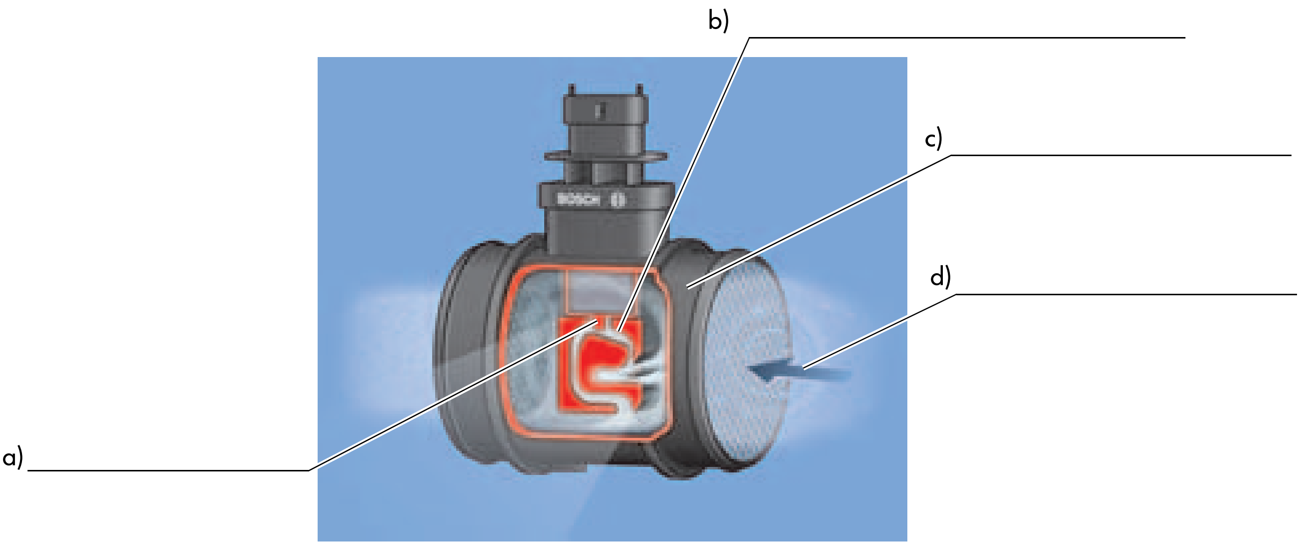
- ☐ a) A low air density corresponds with a low air mass.
- ☐ b) A high air density corresponds with a high air mass.
- ☐ c) A low air density corresponds with a high air mass.
- ☐ d) The air density and air mass are not related to each other.

2. Which statement is correct?

A combustion engine requires the following for the optimum combustion of 1kg fuel:

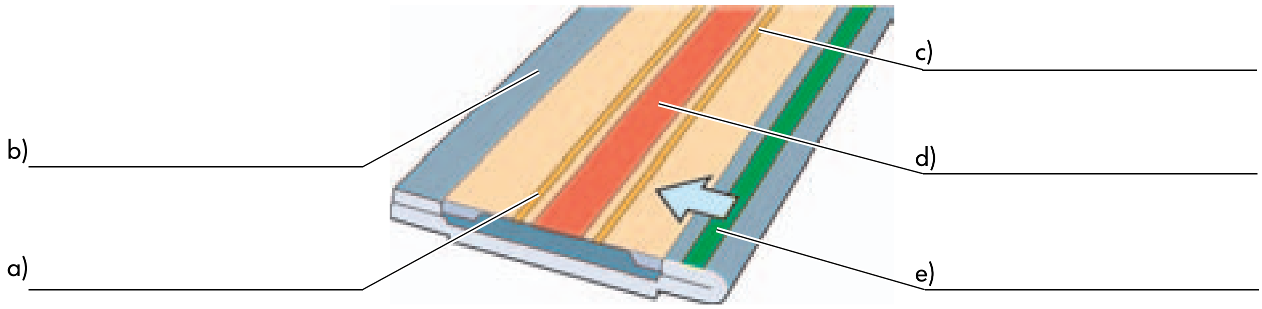
- ☐ a) 1 kg air
- ☐ b) 7.4 kg air
- ☐ c) 14.7 kg air
- ☐ d) 17.4 kg air

3. Name the components.



S358_006

4. Name the components.



S358_009

5. Which components does the air-mass meter use to detect a return flow of air?

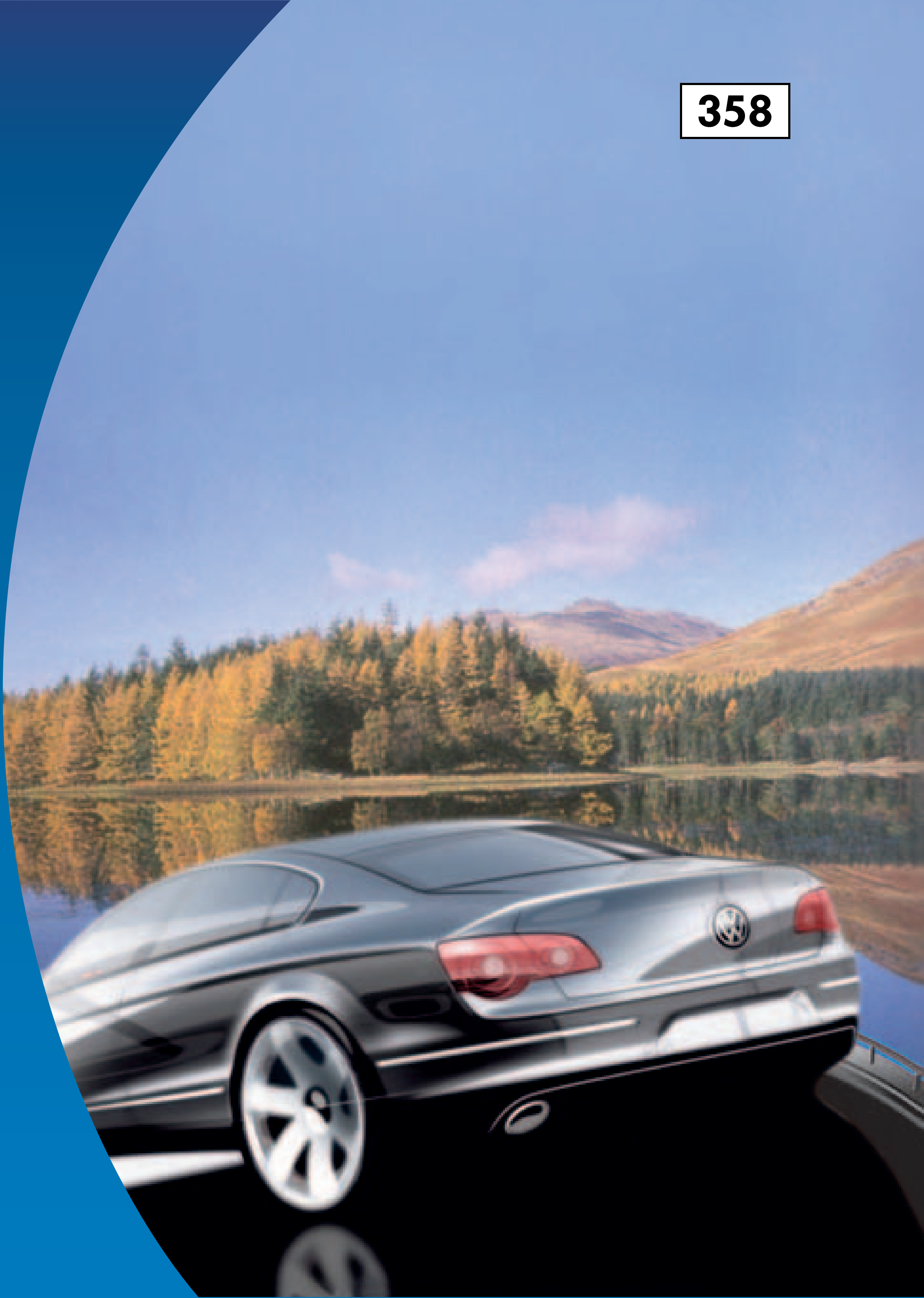
- ☐ a) Thermistor R2
- ☐ b) The heating resistor
- ☐ c) The intake air temperature sensor G42
- ☐ d) Thermistor R1

Glossary

Explanation of chemical abbreviations

- CO carbon monoxide
- HC hydrocarbons
- NOx nitrogen oxide
- PM particles

Answers:
1 a, b; 2 c; 3 a: Sensor element, b: Partial air flow c: Measuring tube d: Intake air;
4 a: Thermistor R2, b: Sensor element, c: Thermistor R1, d: Heating resistor,
e: Intake air temperature sensor; 5 a, d



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