All About Spark Plugs

Technical Information No. 02

FEDERAL-MOGUL MOTORPARTS

Perfection built in BERU®

Contents

Starting characteristics, service life, performance, fuel consumption, and exhaust performance – these critical engine parameters are all influenced by the spark plug. The functional part of the spark plug is concealed within the engine's combustion chamber; only a part of the insulator and connector are visible from outside.

During operation, spark plugs have to deliver outstanding performance: in all situations they must produce a spark reliably, ensure correct cold starts, and prevent misfiring – even under extreme conditions – playing their part in ensuring optimum combustion with low emissions.

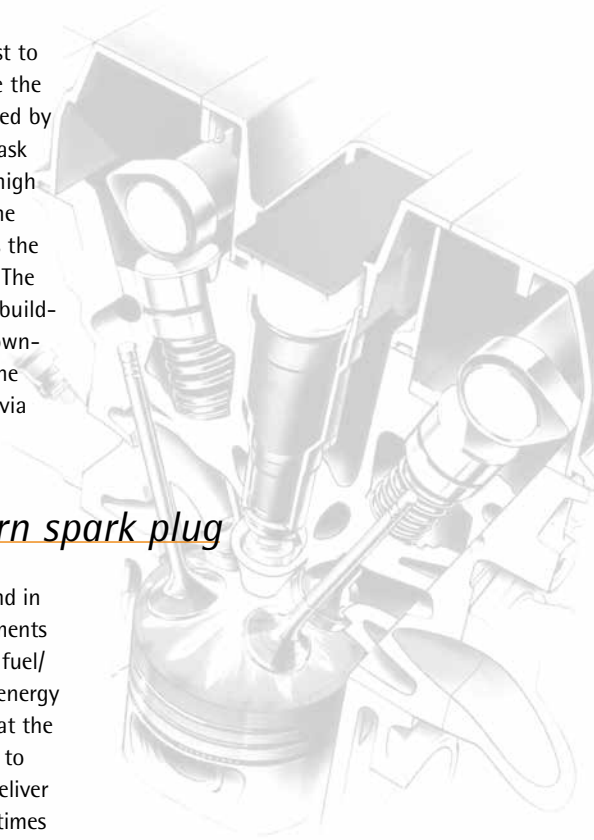
They have to cope with temperatures in the combustion chamber of up to 3,000 °C and pressures of up to 100 bar, not to mention ignition voltages of up to 40,000 volts, with transient power peaks of up to 300 A. Chemical influences also make high demands on quality. So this is extremely tough work , that the spark plug has to maintain for many thousands of kilometers.

BERU spark plugs are highly specialized, precision components, which have been developed to meet vehicle manufacturers' specifications and are produced on up to date production lines.

The spark ignition engine

The function of a spark plug

The ignition system on petrol-driven engines – in contrast to diesel engines – is external: during the compression cycle the combustion of the compressed fuel-air mixture is triggered by an electrical spark produced by the spark plug. It is the task of the spark plug to generate this spark. Created by the high voltage produced by the ignition coil, it leaps between the electrodes. A flame front spreads from the spark and fills the combustion chamber until the mixture has been burned. The heat released increases the temperature, there is a rapid build-up of pressure in the cylinder and the piston is forced downwards (Power stroke). The movement is transferred via the connecting rod to the crankshaft; this drives the vehicle via the clutch, the gears and the axles.



The spark from the spark plug triggers the combustion of the compressed fuel-air mixture during the compression cycle

The demands placed on a modern spark plug

In order for the engine to operate smoothly, powerfully and in an environmentally friendly manner, a number of requirements have to be met: the correct amount of perfectly balanced fuel/air mixture must be present in the cylinder, and the high-energy ignition spark must leap between the electrodes precisely at the predetermined moment. For this purpose spark plugs have to meet the highest performance requirements : they must deliver a powerful ignition spark between around 500 and 3,500 times a minute (in 4-stroke operation) - even during hours of driving at high revs or in stop-and-go traffic conditions. Even at -20 °C, they have to ensure a completely reliable ignition. High-tech spark plugs provide low-emission combustion and optimum fuel efficiency – without misfiring, which can cause unburnt fuel to get into the catalytic converter, and destroying it. A modern spark plug must meet the following requirements:

Electrical requirements

- Reliable high-voltage transmission, even at ignition voltages of up to 40,000 volts
- Good insulation capability, even at temperatures of 1,000 °C, prevention of arcing and flashover

Thermal requirements

- Resistance to thermal shock (hot exhaust gases – cold intake mixture)
- Good thermal conduction by insulator tip and electrodes

Mechanical requirements

- Pressure-tight and gas-tight sealing of the combustion chamber, resistance to oscillating pressures up to approx. 100 bar
- High mechanical strength for reliable installation

Electrochemical requirements

- Resistance to spark erosion, combustion gases and residues
- Prevention of build-up of deposits on the insulator

BERU spark plugs are designed and manufactured using high-quality materials to consistently meet these extreme requirements. Even at the engine development stage, BERU engineers work closely with the motor industry to ensure that the spark plugs are precisely adapted to specific conditions in the combustion chamber.

Spark plug design and types

Materials

BERU offers a wide range of spark plugs to ensure that the optimum spark plug is always available for the many different engine types and applications. Diverse materials are used for the center electrodes. Special nickel-based alloys and copper-core electrodes offer good thermal conductivity and high corrosion resistance. Silver has even higher thermal conductivity. Platinum and Iridium offer excellent resistance to erosion, so it extends the length of time between replacements. The design of the earthing electrode is just as important. Its geometry influences mixture accessibility, wear, heat dissipation and ignition voltage requirement, among other things. Titanium, platinum and iridium offer particularly long operating lives, for the same electrode gap.

Electrode gap

Ultra X Titan

Platinum central electrode

The shortest distance between the central and earth electrode(s) on the spark plug is called the electrode gap. This is what the ignition spark must jump across. The optimum electrode gap in any particular situation depends partly on the engine, and it is determined in close collaboration with the vehicle manufacturer. Maximum precision in maintaining the electrode gap is important since an incorrect gap can have a considerable detrimental effect on spark plug function and consequently on engine performance.

- If the electrode gap is too small this may cause misfiring, noisy idling and poor exhaust gas quality levels.
- If the electrode gap is too large, this may lead to misfiring.
- The co-ordinated spark positioning on multi-electrode plugs means the electrode gaps does not have to be adjusted (for example Ultra X Titan, air/glide spark technology).

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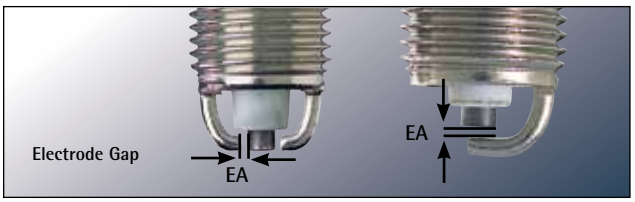


1 Connector for the spark plug (The illustration shows an SAE connector , older vehicles are fitted with connectors with M4 threads). Feeds the ignition voltage to the central electrode.

2 The steel pin (ignition pin) enclosed in a gas-tight fit within the conductive glass melt, forming a link with the central electrode.

3 The insulator is made of an aluminium oxide ceramic and insulates the central electrode against earth at up to 40,000 Volts. The insulator can be produced in a plain form or with profiles to prevent flashover.

4 Nickel-plated spark plug body forms a gas-tight connection with the insulator through a heat shrinkage method, which is why the shrinkage zone shows the blue oxydation colour. Thread serves to secure the spark plug in the engine block.

5 Captive outer sealing washer, for sealing and heat dissipation.

6 Electrical connection of spark pin and central electrode. On suppressed (R types) glass melt resistors. By means of appropriate additives the glass melt can be given a defined degree of resistance in order to ensure the required erosion resistance and suppression chracteristics.

7 The inner sealing ring forms the gas-tight junction between the insulator and the metallic body and provides heat conduction.

8 The center electrode consists of a copper core enclosed in nickel. Depending on the type, the central electrode can be in platinum or iridium.

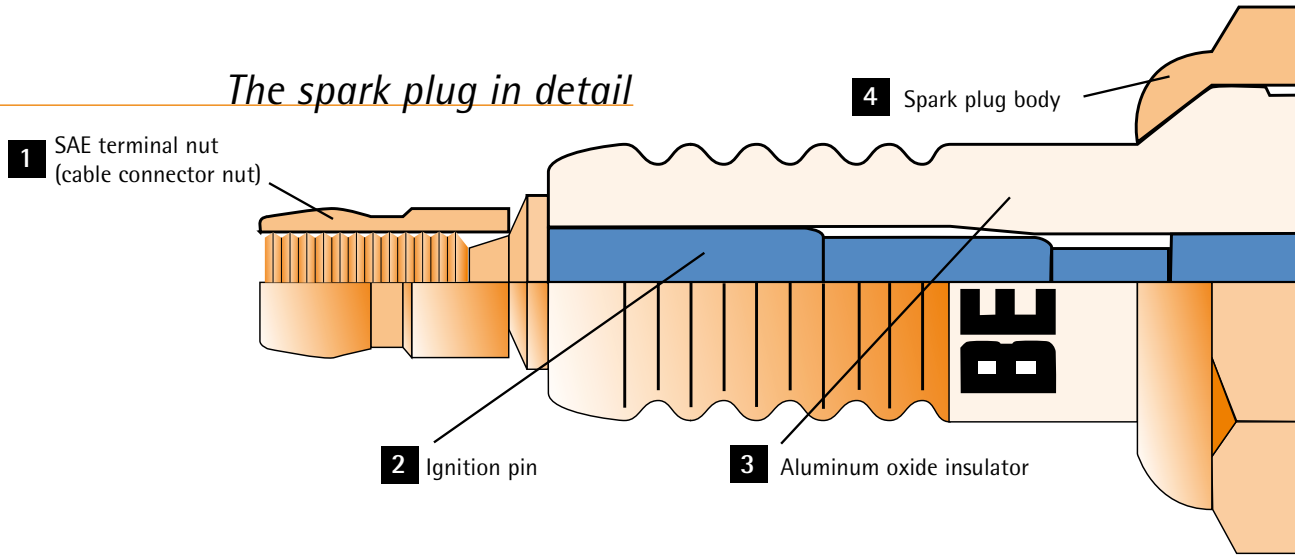
9 The insulator tip extends into the combustion chamber. It has a fundamental influence on the thermal rating.

10 The lead-in chamfer makes it easier to screw the spark plug into engine block.

11 The clearance volume influences self-cleaning action.

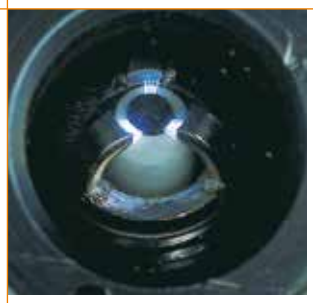
12 One or more earth electrode are welded onto the body of the spark plug, and with the central electrode form the spark path. Specially developed nickel-based alloys (or platinum or titanium reinforcements) increase the erosion resistance of the electrodes.

The spark plug in detail



Spark plug design and types

Spark position and Spark distance



Spark path

The innovative Poly-V design : 5 ignition points are targetted by the spark in a contuinually changing sequence – thus ensuring great reliability for the ignition and consequently fuel-saving combustion with an ignition performance that remains constant over long periods.

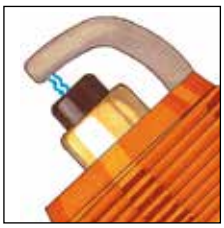
The function of the spark plug in the combustion chamber is influenced by three main factors: the spark position, the spark distance and the electrode gap for spark plugs using variable spark technology.

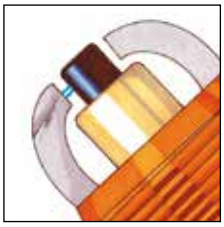
Spark position is the name given by engine developers to the spark path geometry , the extent to which the spark path extends into the combustion chamber.

With regard to the spark distance, a distinction is made between:

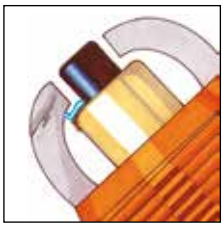
- The air spark distance which denotes the path the spark takes between central and earth electrode in order to ignite the fuel-air mixture in the combustion chamber.
- The variable spark distance which denotes the path which the spark takes if it first passes over the surface of the insulator tip before then jumping across to the earth electrode. Taking this path burns off harmful deposits and combustion residues.
- Air spark distance/variable spark distance: spark distances, that can pass via air and the insulator. By combining the mutually independent air spark and variable spark distances, electrode burn-off can be reduced, leading to a significantly increased service life for spark plugs.

Sparking air distance





Variable sparking distance

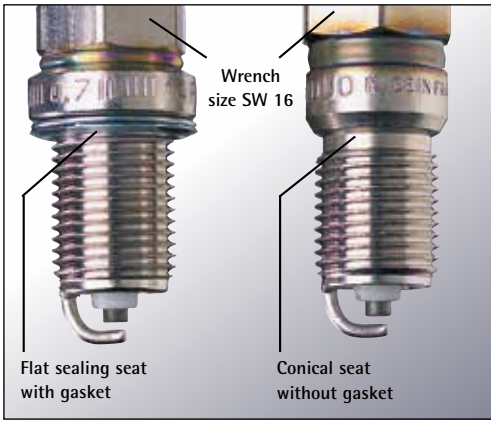


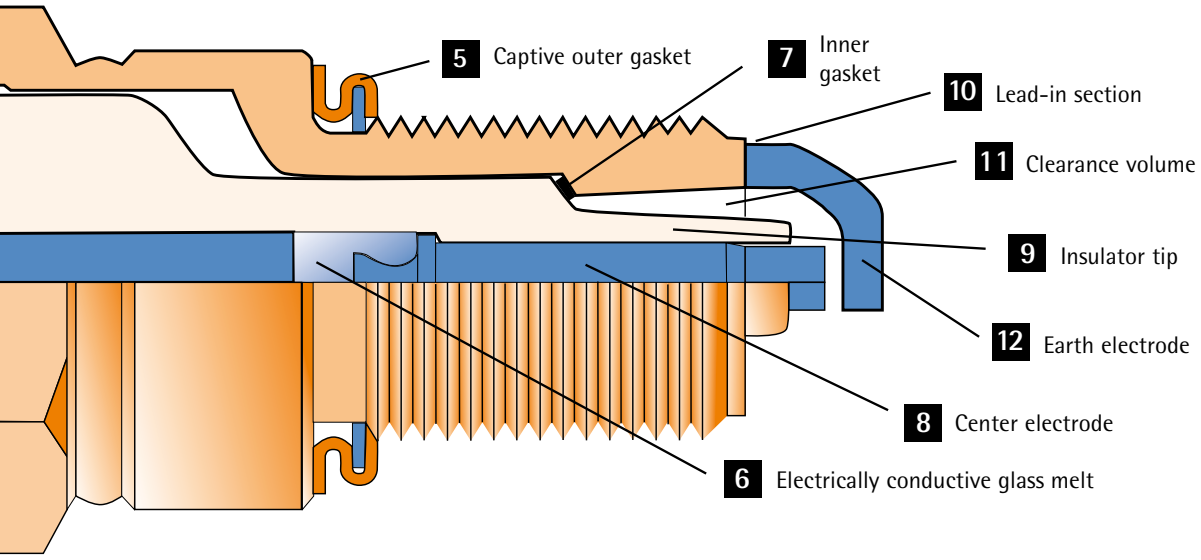
Seat sealing

The spark plug must be screwed into the cylinder head so that it is gas-tight. Depending on engine construction features , there are two different types of seal:

- Flat seat or level seat: a captive outer gasket acts as a seal around the plug body.
- Taper seat or conical seat: the conical surface of the plug body fits into a correspondingly shaped contact surface in the cylinder head to create a seal.

In restricted spaces (e.g. multi-valve engines), FineLine or BiHex spark plugs are commonly used, which require smaller wrench sizes and have more miniaturised dimensions.

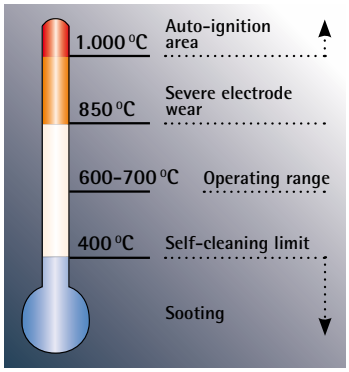




Thermal rating and thermal conduction

Thermal rating

The thermal rating is a measure of the thermal structure of a spark plug. It indicates the maximum thermal loading on the spark plug in equilibrium between heat absorption and heat dissipation.



It is vital to choose the correct thermal rating when selecting a spark plug:

- If the thermal rating characteristic is too high (for example thermal rating 9) the plug is unable to dissipate the resultant heat quickly enough. This leads to incandescent ignition; in other words it is not the ignition spark that ignites the mixture but the overheated plug.

- If the thermal rating characteristic is too low (for example thermal rating 5) then the free burning temperature required in the lower peformance range for self-cleaning the plug, is not reached. Result: misfiring, increased fuel consumption and higher exhaust emissions. (For pictures of faults, see Pages 8 and 9).

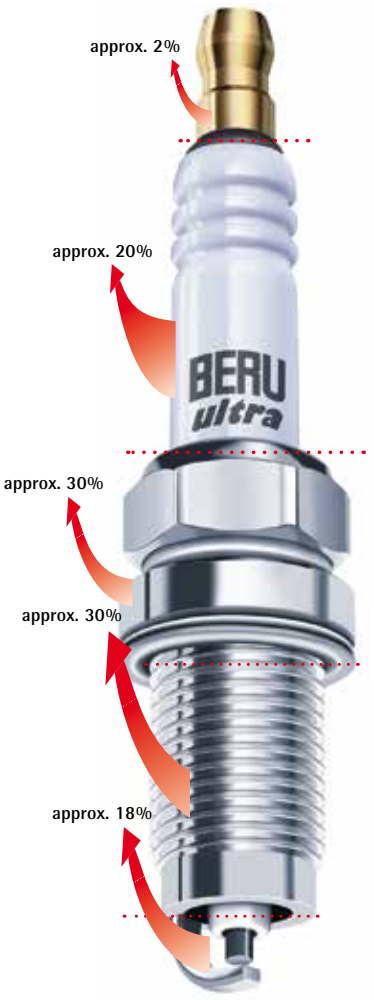
The influences on thermal rating

The higher the engine output, the higher in most cases is the combustion chamber temperature. The size of the insulator base has a critical influence on heat absorption; heat dissipation takes place through the insulator tip, via the center electrode and the inner gasket on the plug body to the cylinder head.

- Spark plugs with a long insulator tip absorb more heat. However, since they emit less heat on the long path to the plug body they are called hot plugs.

- Spark plugs with a small insulator tip absorb less heat. However, since they are able to emit a lot of heat on the short route to the plug body they are called cold spark plugs.

Heat conduction path of a spark plug



The thermal conduction

Cylinder temperatures of up to 3,000 °C are generated for short periods during the combustion process and these temperatures also cause the spark plugs themselves to heat up. The spark plugs give off around 80 per cent of this absorbed heat tot he surroundings through various methods of heat conduction (illustration). The vast majority of the heat is transferred from the plug thread directly to the cylinder head. The spark plug must therefore always be screwed in with the correct torque. Only about 20 per cent of the heat is absorbed and dissipated by the passing fuel-air mixture.

The use of composite electrodes , e.g. copper-cored Ni-electrodes,enables a considerable improvement in heat conduction. If the spark position is extremely far forward in the combustion chamber, the self-cleaning temperature is quickly reached - thanks to a special adjustment of the cross-section and the heat-absorbing surface of the insulator tip – and the upper cut-off temperature at the insulator is kept to below 900°C. This type of spark plug is therefore suitable for combustion chambers with both relatively low and very high temperatures.

BERU spark plug range

BERU Ultra X Titan. The range for X-treme demands.

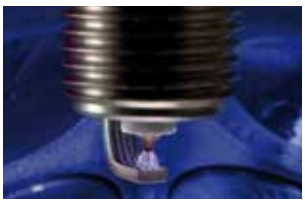
ULTRA X TITAN

15 types of spark plugs
90% market coverage
100% fit for the workshop
The successful Ultra X range is now called Ultra X Titan – and consists of a total of 15 spark plug types: 6 of the well established Ultra X spark plugs and 9 new ones. Together they make up the Ultra X Titan Series – offering you a market coverage of almost 90% !

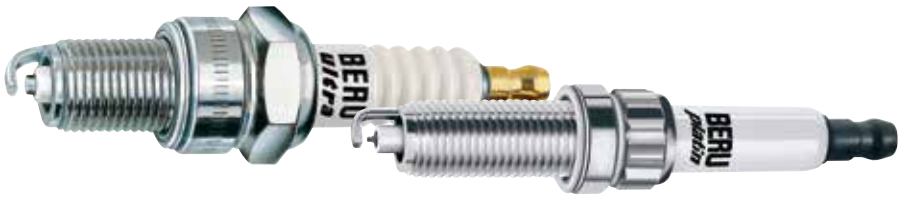
BERU Ultra X. Titan.

For more spark power at higher combustion chamber pressures – giving highly efficient combustion.

The higher the combustion chamber pressure, the greater must be the power of the spark. This is where the innovative spark plug BERU Ultra X Titan sets new standards : with its burn-off resistant nickel-titanium alloy and intelligently designed earthing electrodes – for increased ignition reliability and and a highly effective, and therefore fuel-saving cmbustion, with correspndingly low emmissions figures.



BERU Ultra – the car manufacturers' choice.



BERU Ultra.

Top-quality spark plugs in OEM quality – for the many different engine types and applications.

- Environment-friendly combustion: saves fuel and protects the catalytic converter
- Reliable ignition, even at low temperatures
- Long service life, good durability
- Proven materials: two-element center electrode with nickel-sheathed copper core

BERU Bi-Hex.

- Twelve millimeter technology with wrench size 14
- Reduced thread diameter
- Thread length 26,5 millimeters
- Reliable ignition via corona pre-discharge

„YOU CAN FIND SPARK PLUGS FOR GAS-FUELLED ENGINES IN TI 06“

Special spark plugs

The BERU range of spark plugs included special applications for:

1. Compact spark plugs for the particularly confined spaces on power saws or lawnmowers
2. Fully screened spark plugs with steel jacket where very stringent demands are placed on suppression, for example in official vehicles
3. Spark plugs for gas powered engines on gas driven vehicles and stationary engines for industrial and domestic use
4. Measurement spark plugs specially for test and trial engines

Workshop tips

Spark Plug Checks


1

A visual inspection of a spark plug can reveal a wide variety of damage patterns. Some of them are listed below, with a description of causes, effects and solutions:

NORMAL

Minimal electrode burn-off and a grayish white/grayish yellow to russet colored insulator base: Engine settings are OK, thermal rating is correct.


2

SOOT DEPOSITS

The insulator tip, electrode and plug are covered with velvety black soot.
Cause: Incorrect mixture setting (Injection unit). Mixture too rich. Air filter very dirty. Defective cold start system (injection). Defective temperature sensor. Used predominantly on short journeys. Thermal rating of plug too high. Defective lambda sensor.
Effect: Due to leakage currents, cold starting behaviour is poor and misfiring occurs.

Solution: Checking and if possible correction of mixture and start system. Also examine temperature sensor. Check air filter, use a spark plug with correct heat rating.


3

OILED-UP

Insulator tip, electrode and plug covered in black oil film.
Cause: Too much oil in combustion chamber. Oil level too high, heavily worn piston rings, cylinders and valve guides.Defective turbo charger.
Effect: Misfiring or even shorting of the spark plug, complete failure.

Solution: Overhaul engine, correct fuel-air mixture, fit new, original BERU spark plugs.


4

GLAZE FORMATION

Insulator tip shows signs of brownish yellow glazing which could also take on a greenish tint.
Cause: Additives in fuel and oil forming ash-like deposits.
Effect: During sudden full loading of engine, the glaze liquifies and becomes electrically conductive.

Solution: Check whole engine, fit new, original BERU spark plugs.


5

EXCESSIVE DEPOSITS

Heavy deposits of fuel and oil additives on the insulator tip and earth electrode. Slag type deposits (oil coke).
Cause: Additive residues , especially from the oil, which then settle in the combustion chamber and onto the plug.
Effect: Can lead to pre-ignition with loss of performance and engine damage.

Solution: Check engine. Fit new, original BERU spark plugs, possibly change the type of oil used.

Workshop tips

CENTRE ELECTRODE MELTED

Center electrode melted, end of insulator tip burnt.
Cause: Thermal overload due to "glow ignition" , combustion residues in chamber, defective valves, inadequate fuel quality, thermal rating of plug too high , tightening torque not observed.
Effect: Misfiring, drop in output (engine damage).

Solution: Check engine, ignition, mixture, tightening torque of the spark plugs. Fit new, original BERU spark plugs with the correct thermal value.

BROKEN INSULATOR TIP

Surface break up on the insulator nose.
Cause: Mechanical damage due to incorrect use. Initially often only discernible as a hairlike crack, sometimes caused by pinking. In extreme cases, deposits can from between the middle electrode and the insulator, causing the insulator to shatter. Pinking.
Effect: Misfire, spark "wonders", not guaranteeing ignition.

Solution: Fit new, original BERU spark plugs.

EXCESSIVE WEAR OF THE ELECTRODE

Centre or earth electrode shows visible signs of material loss.
Cause: Aggressive fuel or oil additives. Poor flow in the combustion chamber, possibly due to carbon build up. Pinking, overheating.
Effect: Misfire, especially during acceleration (ignition voltage no longer sufficient, with large electrode gap). Poor starting performance.

Solution: Fit new, original BERU spark plugs.

PARTLY MELTED ELECTRODES

Cauliflower-like deposits on the electrode , possible deposits of materials not originating from the spark plug.
Cause: Thermal overload due to "glow ignition, combustion residues in chamber, defective valves, inadequate fuel quality, possibly too high heat rating, spark plugs were not tightened as prescribed.
Effect: Prior to total engine failure (engine damage) , efficiency will drop.

Solution: Check engine, ignition and mixture; check tightening torque of the spark plugs. Fit new, original BERU spark plugs with correct heat rating.

EMBRITTLEMENT OF SPARK PLUG CONNECTOR

Cause: Thermal overload, old connectors.
Effect: Misfiring.

Solution: Fit new, original BERU connectors and spark plugs, grease spark plug connector with BERU special grease (see p. 11).

Workshop tips

Faults and wear

Overload, poor fuel, wrong choice of spark plug, and stop-and-go traffic conditions are just a few of the factors that can lead to spark plug faults. Here is a short checklist to help you identify the fault:

Symptom	Cause	Possible consequences
Spark erosion, corrosion	Thermal overload Wrong or poor fuel Incorrect thermal value	Melted electrodes Incandescent ignition Misfiring (due to larger electrode gap)
Incandescent ignition	Residues in combustion chamber Faulty valves Plugs with incorrect thermal value Fuel with insufficient octane count	Piston damage Valve damage Spark plug damage
Knocking	Fuel with insufficient octane count Wrong ignition timing Excessive compression	Uncontrolled rise in pressure and temperature can lead to piston and spark plug damage
Misfiring	Faulty, old, leaking spark plug connector	Spark-over to insulator; Damage of the catalytic converter

Spark plug installation

As spark plugs are designed for specific engines, the correct plug must always be used. Plugs with the incorrect thermal rating, electrode gap or thread length can lead to reduced engine performance or even damage the engine and/or catalytic converter. Installing and removing them carefully is also imperative.

- When removing them, make sure that no dirt gets into the combustion chamber. First loosen the plug by a few turns, then clean the plug shaft using compressed air or a brush, before screwing the plug out completely.
- Apply a thin film of BERU special grease to the spark plug insulator.
  ZKF01 - 0 890 300 029 with 10g contents
  ZKF02 - 0 890 300 045 with 50g contents.
- When installing plugs, make sure that the plug thread and cylinder head bore are clean. With BERU spark plugs, a nickel coating on the plug body avoids the need for lubrication. Be sure to use the correct tightening torque (see table).
- Warning: If you drop a spark plug, do not use it. Even invisible damage can lead to misfiring and may even damage the catalytic converter.
- Check spark plug connectors for wear. If you see signs of embrittlement or hairline cracks, replace the connectors.

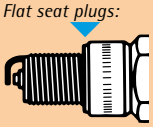
Workshop tips

IMPORTANT : WHEN INSTALLING PLUGS, IT IS ESSENTIAL TO USE THE CORRECT TIGHTENING TORQUE.

If extreme burn-off or melting occurs on the center electrode, despite using the specified tightening torque, the cause is almost certainly due to an uncontrolled combustion process (e.g. incandescent ignition or high-speed knocking). Possible causes: wrong heat rating , discharge valve clearance too small, wrong ignition timing , unsuitable fuel quality, deposits in the combustion chamber, or too lean a fuel mix.

Torque in Nm, thread must not be greased

Flat seat plugs:



Plug thread	Cylinder head	
	Cast iron	*Light alloy*
M 10x1	10–15 Nm	10–15 Nm
M 12x1,25	15–25 Nm	15–25 Nm
M 14x1,25	20–35 Nm	20–30 Nm
M 18x1,5	30–45 Nm	20–35 Nm

Conical seat plugs:

M 14x1,25	15–25 Nm	10–20 Nm
M 18x1,5	15–30 Nm	15–23 Nm

BERU assembly aids

For easy and reliable spark plug replacement without jamming the wrench or cracking the insulator, we recommend the use of special tools.

BERU SPARK PLUG ASSEMBLY AID ZMH001

The mechanic's extended arm

THE PROBLEM In the engine compartment, space is painfully tight. When screwing the spark plug in or out, the mechanic can injure or burn his hand on the engine – or drop and damage the spark plug.

THE SOLUTION The BERU spark plug assembly aid, made of rubber, acts as the "mechanic's extended arm": it holds the spark plug securely, so that it can be screwed in and out carefully after loosening or before tightening.

Article Name	BERU short code	BERU order number
Spark plug assembly aid	ZMH001	0 890 000 001

BERU SPARK PLUG ASSEMBLY AID ZMH002

Reliable spark plug replacement without tilting

THE PROBLEM The relatively large opening in the spark plug shaft means that when fitting or removing spark plugs using an extension, there is a risk of tilting the wrench, causing the spark plug insulator to crack. The consequence: misfiring due to sparks jumping across the cracked insulator can destroy the catalytic converter.

THE SOLUTION Simply insert the BERU assembly tool, suitable for almost all vehicle models, into the 3/8" spark plug extension and push it into the spark plug shaft. The wrench will now remain parallel to the shaft and cannot be tilted.

Article Name	BERU short code	BERU order number
Spark plug assembly aid	ZMH002	0 890 000 002

BERU SPECIAL GREASE ZKF001/ZKF002

To prevent the spark plug connector from fusing to the spark plug neck and damaging the sealing lips, we recommend greasing the spark plug insulator with BERU special grease. This also increases resistance to spark-over.

Article Name	BERU short code	BERU order number
BERU Special grease, Tube 10 g	ZKF001	0 890 300 029
BERU Special grease, Tube 50 g	ZKF002	0 890 300 045

1

2

3

1 | Signs of high voltage spark-overs

2, 3 | BERU Spark Plug Connector Grease: When smeared into the connector before screwing in the spark plug, the greease protects from embrittlement , and consequently from high voltage spark-overs (ZKF001 0 890 300 029 / 10 g ZKF002 0 890 300 045 / 50 g)

Future

The future of the spark plug

In the development of modern petrol engines, the technology trends are going towards modified combustion processes and high-charged, smaller engine units (downsizing). BERU engineers are developing the optimal spark plugs for this purpose in close co-ordination with the international automobile manufacturers.

Less fuel consumption, lower emissions, more driving enjoyment: these simple watchwords summarize the current technical trends in the development of spark ignition engines.
Total and partial variability in the valve drive through phasers or valve stroke control, as well as direct injection with wall, air or jet-driven injection represent the current start of the art. The newest generations of injection systems with piezo-controlled injectors extends the range for de-throttled, lean engine operation, and should thus ensure the required reductions in petrol consumption and emissions.

In close co-operation with international automotive manufacturers BERU engineers are developing innovative spark plug concepts for modern spark ignition engines.

This all results in new demands on the spark plugs:

- smaller construction dimensions
- specifically positioned body electrodes (earth electrodes)
- more accurate spark positions, and
- higher dielectric and mechanical strength in spark plug ceramics.

High demands placed on the new generations of spark plugs

With the new direct injection systems, there is less room available fort he spark plug within the cylinder head in spark ignition engines. This is turn makes it necessary to have a lengthened fitting thread and/or a modified spark plug geometry. M12 spark plugs are being increasingly used, although in comparison to the traditional M14 spark plugs, they must manage to work with a reduced ceramic wall thickness. Demands in the opposite direction – smaller wall thicknesses on the insulator and increased voltage requirements – make it necessary to achieve new developments in materials, geometry and processes.

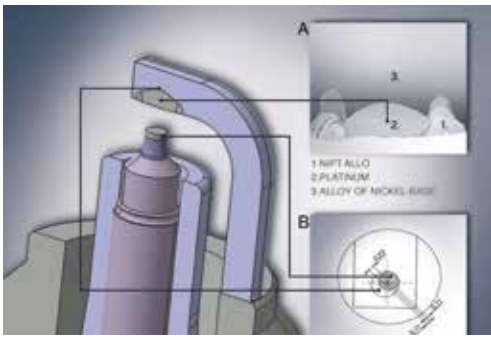
Improvement of ceramics properties

As an insulator material for passenger car spark plugs, an aluminium oxide based ceramic has proved dependable, since this material fulfils the electrical and mechanical requirements regarding dielectric strength, even at temperatures of up to 1,000 °C. The main factor that determines the properties of the present ceramics is residual porosity. In order to obtain a considerable reduction in this, and consequently to improve even further the dielectric strength and the mechanical strength of the spark plugs, the development engineers for the BERU have, amongst other things, undertaken modifications to the ceramic additives.

Future

New Spark plug geometries for even longer life

The automotive manufacturers currently require a target operating life for spark plugs of 60,000 to 120,000 kilometres. Simultaneously, the increase in the requirement for electric potential due to wear on the spark plug spark gap must be kept as low as possible. This means that it is necessary to develop novel electrode geometries, materials and processes. For spark plugs with nickel alloy-based electrodes, the wear mechanism is determined to a large extent by oxidation. This results in a requirement for nickel alloys that have a stable, durable oxide layer. In the case of spark plugs with electrodes coated with oxidation-stabilized precious metals, e.g. platinum or iridium, it must above all be ensured that there is a permanent attachment of the precious metal onto the nickel-based spark plug electrodes.

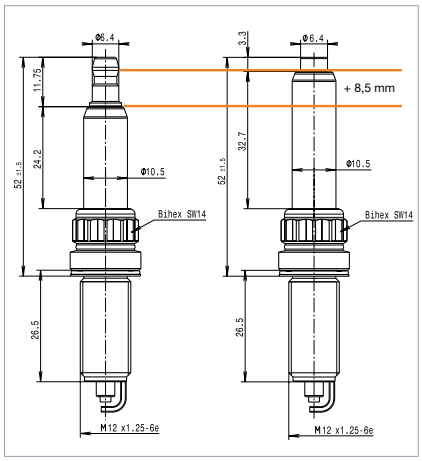


The nickel-based electrodes in BERU High-end spark plugs are coated with an oxidation-stabilized precious metal such as platinum. Thanks to a special laser welding process, BERU produces an extremely long-lasting bond between the two materials. (A).
A coverage of the precious metal surfaces at the centre and body electrodes of at least 92% (B) enables extremely high operating performance.

New high-voltage connector for increased flashover resistance

Downsizing is a key technology for reducing fuel consumption and emissions. This new technology confronts the ignition systems designer with new challenges, because downsized engines have less installation space available and work at higher combustion chamber pressures and higher ignition voltages, which drastically increases the danger of high voltage flashovers at the spark plug.
In order to provide increased flashover resistance, BERU has developed a new high-voltage connector, which – for the same spark plug dimensions – offers a greater insulating surface, thanks to an 8.5mm longer insulator neck, thus increasing the flashover resistance by up to 9000 volts. It is not only the added insulation surface that provides more protection against insulation breakdown and flashovers, but a new type of contact method. Instead of an external contact point (as in SAE or M4) contact occurs on the inside via a pressure spring. This novel, conically converging pressure spring connector is designed in such a way that the front end is securely enclosed by the bowl-shaped recess of the ignition pin in the spark plug (giving it its name " high-voltage bowl connector"). This prevents the build-up of excessive voltage fields – and, in spite of the increased ignition performance, the flashover resistance is visibly improved.

Greater flashover resisitance in spite of higher ignition voltage: thanks to the longer insulator neck, the greater overlap, the recessed pressure spring and the new contact technology.



- For the same overall dimensions, a larger insulating surface was obtained by lengthening the insulator.
- An increase in voltage overload protection in air of 8,000-9,000V
- Operating range up to 40,000V

High-frequency ignition technology: the solution for the future

In contrast to traditional engine ignition systems, in which combustion is initiated by heat, this patented high-frequency ignition technology generates a high-energy electrostatic field inside the combustion chamber. This leads to a considerable improvement in the effectiveness and speed of combustion, and even extremely lean fuel-air mixtures ignite reliably. For additional improvement in engine performance, the system provides electronic regulation for various parameters in the combustion cycle, further reducing emissions, improving efficiency and increasing engine performance. High-frequency ignition has the potential to revolutionize ignition technology. By industrialising this technology, BERU has strengthened its competence in ignition technology and can take up the position as world leader. BERU believes that high-frequency ignition will go into series production within a few years.

With the new high-frequency ignition, BERU intends to revolutionize the ignition technology for petrol engines.

Future

The latest measurement and applications systems

The development of spark plugs specific to individual engines necessitates a close collaboration between the automotive manufacturer and the spark plug manufacturer. The preconditions for this are optimum technical possibilities for establishing:

- the appropriate heat rating
- the electrode temperatures
- the required ignition voltage
- the required form of ignition voltage
- the optimum cold-starting performance of the spark plugs.

For all these areas, BERU has developed a special measuring technology, which is also available in the form of a mobile applications system. The investigation into cold-starting properties of the spark plugs can be carried out within the vehicle on a movable test bed inside a cold room at the Ludwigsburg Research and Development Centre, in accordance with a pre-established test cycle.

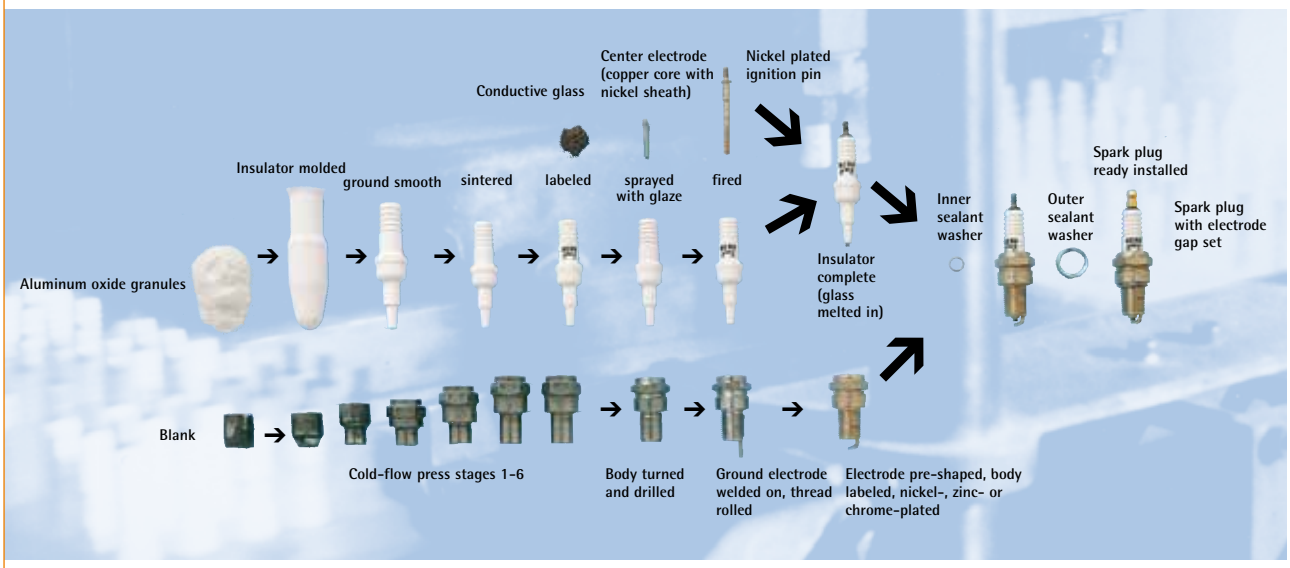
Cold-starting properties of the spark plugs are tested on the two-axis mobile testing stand in BERU's Ludwigsburg Research and Development Centre.

Spark Plug Production

From blank to precision component

Original BERU spark plugs are manufactured in our own factories on computer-controlled production lines – from preparation of the ceramic materials for insulator production from high-grade aluminum oxide, to fitting of the outer gasket.

Testing insulators at 40,000 volts: BERU spark plugs have to demonstrate their reliability on the test rigs before being accepted for starting up in series production.



Spark Plug Production

The BERU endurance tests

Whether in stop-and-go traffic or marathon motorway trips, whether in the bitter cold or the burning heat of the sun – a BERU spark plug must always continue to function. In order to fulfil these high quality demands, BERU spark plugs are subjected to a variety of tests during their development and after production.

Highest quality standards

In order to compete at an international level, quality is paramount. All BERU plants are certified to international quality standards such as DIN ISO 9001:2000. In Germany, the plants also meet the requirements of ISO/TS16949 and DIN EN ISO 14001. The certificates are renewed at regular intervals and always correspond to the latest standards.

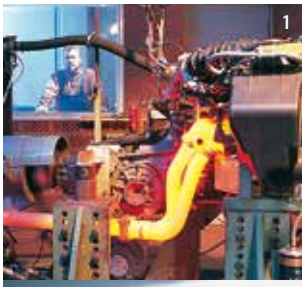
Around ten percent of all BERU employees are involved in quality assurance. One of the principles behind BERU's quality philosophy is production control rather than product inspection. That's because quality has to be built in, not inspected in. BERU relies on qualified employees and the latest, computer-controlled processes. This is the only way to ensure that the specifications promised to the customer are reliably reproduced in every spark plug. Yet quality assurance starts with the selection of suppliers and materials: reliable partners and premium raw materials are fundamental to uncompromising quality.

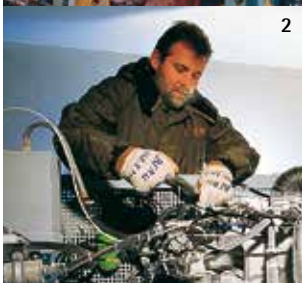
Spark plugs are wearing parts which must be replaced regularly. Otherwise there is a danger of incomplete combustion. This in turn leads to a strong increase in fuel consumption and pollutant production. In addition, due to misfiring, unburnt fuel gets into the catalytic converter, burns there and heats up the catalyser support. If misfiring occurs more frequently, then the catalytic converter may be completely destroyed – and pollutant production can increase by up to ten-fold: this means that it would not pass the legally prescribed exhaust gas check.

As a general rule, independently of annual mileage, spark plugs should be replaced within the period recommended by the manufacturer – in order to maintain engine performance and to protect the catalytic converter.

BERU services

Today BERU is one of the world's leading suppliers of electrical components to the automotive industry. As a medium-sized company, BERU is flexible and quick to respond to customers' needs. Around 150 developers and designers are constantly working on optimizing existing products and developing new ones - in close association with customers from the car and engine manufacturing sectors. Special applications, specially tailored to BERU's partners, ensure that vehicle manufacturers can rely on products that exactly match their needs. That is why BERU is increasingly offering complete system solutions instead of individual components.





1 | Service life test – test bench

2 | A view inside the Cold Chamber in the BERU Research and Development Center Testing the cold start response in the refrigeration unit at -30 °C.

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