All about Spark Plugs

Technical Information No. 2

Perfektion eingebaut

Perfektion eingebaut

Perfection built in

BERU

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A few words of introduction

Virtually all motor vehicles today are powered by an internal combustion engine. Central importance is attached to the spark plug in external ignition, petrol-driven engines. This inconspicuous element influences the engine's starting ability, performance, consumption and exhaust emission levels. The critical part which determines the correct functioning is concealed inside the engine combustion chamber, only the insulating body and connector are externally visible.

Beru spark plugs are highly-specialised precision parts which are developed to meet customer standards and manufactured with the help of modern systems. They have to withstand extreme loads; the heat of summer, the cold of winter, high voltage and the influences of the combustion chamber such as pressure, temperatures in excess of 3,000 °C and the corrosive effects of hot gas. And they must not fail any of the most stringent tests carried out by the international automobile industry or the vehicle driver in day-to-day use. How Beru spark plugs achieve this will be explained below.

Beru spark plugs – top quality products for pollution-free driving.

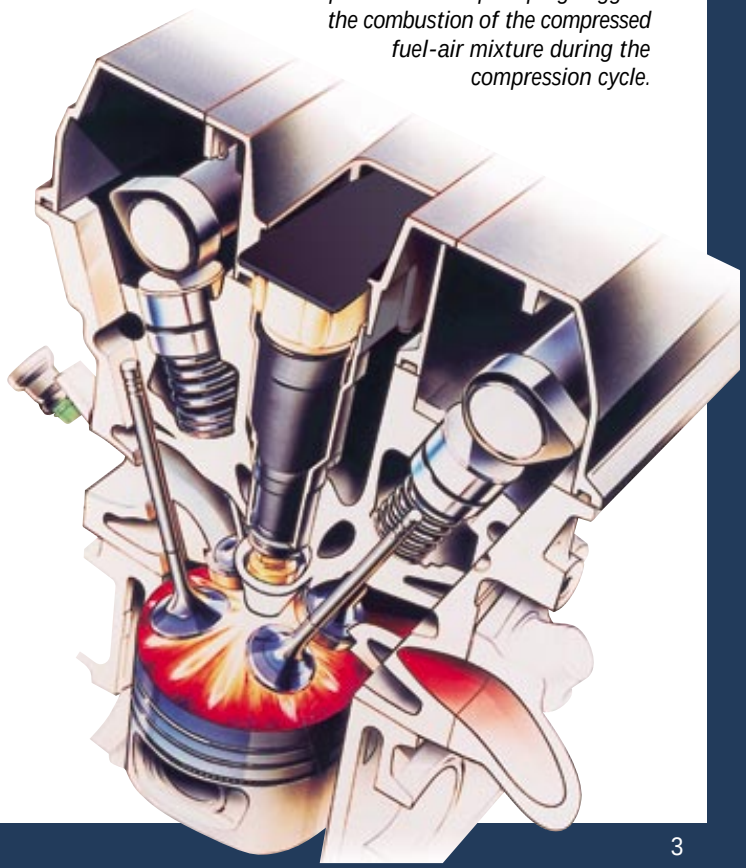
The function of a spark plug

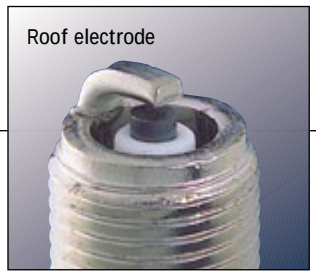
The igniting spark. The ignition system on petrol-driven engines – by contrast to diesel engines – is external: during the compression cycle the combustion of the compressed fuel-air mixture is triggered by an electrical spark which is produced by the spark plug. This is created via a correspondingly high voltage generated by the ignition coil or ignition transformer. At a precisely predefined point the spark leaps between the central and earth electrodes. A flame emanating from the spark fills the entire 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. The movement is transferred via the connecting rod to the crankshaft; this drives the vehicle via the gears and the axles.

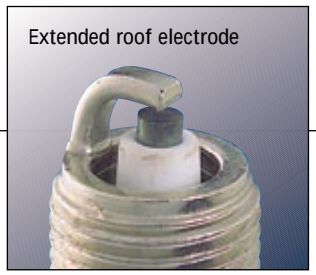
The demands on spark plugs

Reliability under extreme conditions. The engine only operates smoothly when the spark plugs function properly. This means the mixture burns without leaving any residues and, as a result, on the one hand the energy created being utilised to optimum effect and secondly the exhaust gasses containing as few pollutants as possible. A spark plug must deliver a powerful ignition spark between around 500 and 3,500 times a minute. The ultimate extremes are cold starting in Winter, hours at maximum performance in Summer and stop-and-go traffic conditions. The spark plugs must be able to cope with temperature fluctuations of 3,000 °C caused by the operational conditions and differences in pressure of over 50 bar, within fractions of a second. Only top quality products like the spark plugs manufactured by Beru using the best materials available on computer-controlled systems are able to continually withstand these extremely demanding requirements.

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





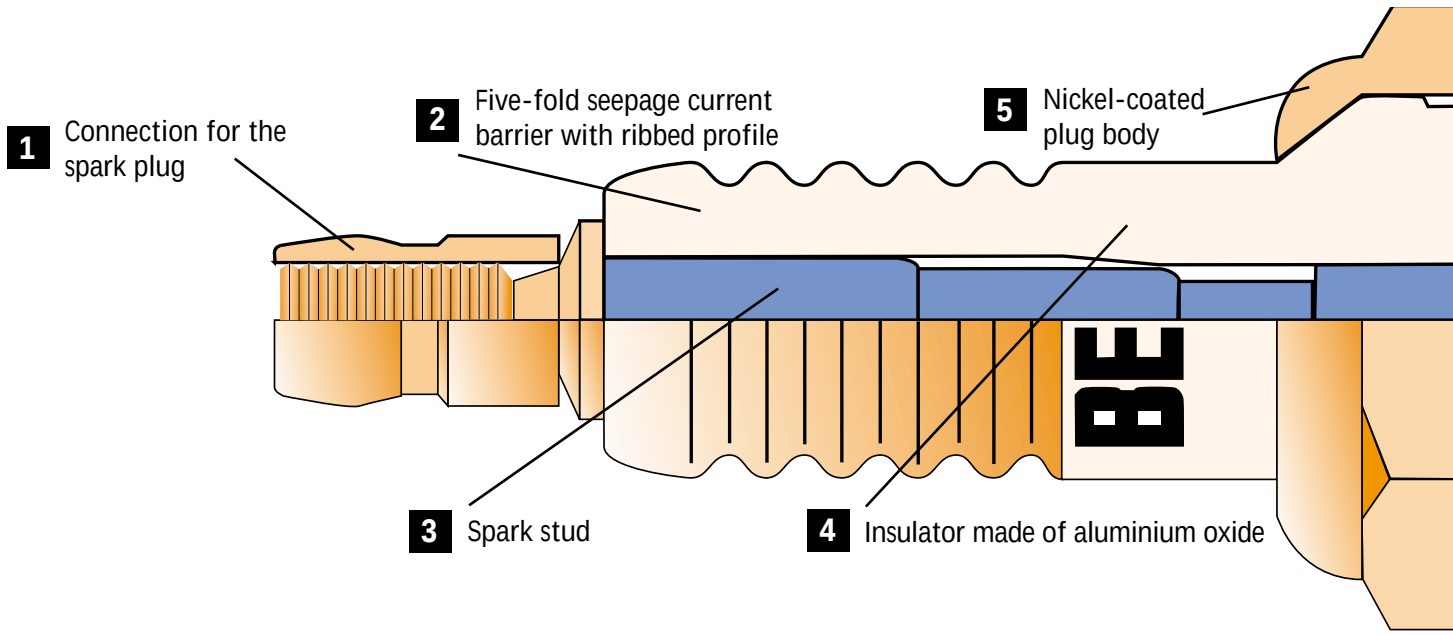


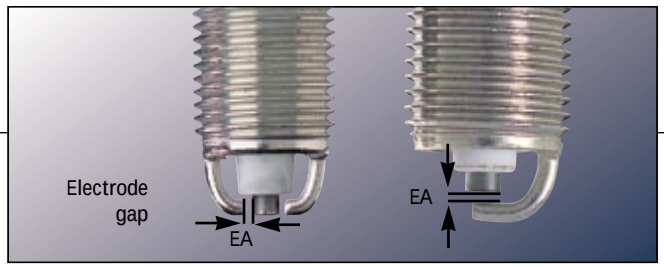
The materials used in spark plugs

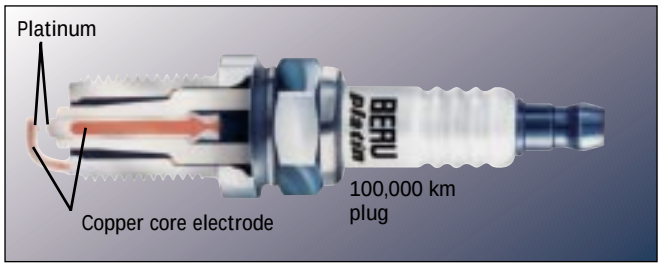
The secret of the electrodes. Beru offers a whole range of spark plugs to ensure that the optimum spark plugs are always available to meet the wide range of varying engines and purposes of use. In this context, Beru uses very differing materials for the central electrodes. The particular features of special nickel-based alloys as well as copper core electrodes are their good heat conduction and high corrosion resistance. Silver has an even higher heat conduction capability. Platinum offers optimum burn-off resistance and consequently extends the length of time before replacements are needed. In conjunction with the automobile industry, Beru has developed a "100,000 kilometre spark plug" for engines on which access to the spark plugs is very difficult. The design of the earth electrode is just as important. Its geometry influences, amongst other things, the mixture accessibility, wear and tear, heat dissipation and required ignition voltage. Its design can vary to a considerable extent depending upon the shape of the combustion chamber. Multi-electrode concepts offer the ideal spark path depending upon engine operating condition (e.g. airborne sparks, glide sparks, combination of air/glide sparks).

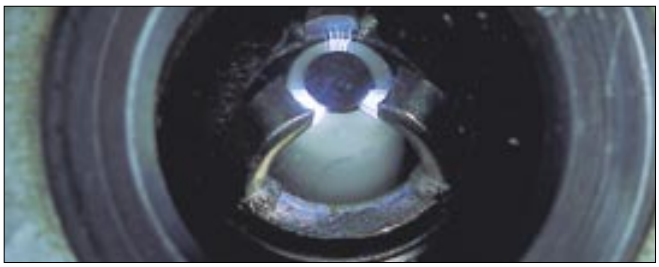
The spark plug in detail

1 Connection for the spark plug (4 mm thread, SAE screw connection or SAE fixed (mono-block)). Transfers the ignition voltage to the central electrode.
2 Prevents seepage currents through extended path.
3 Gas-tight steel pin enclosed in the conductive glass melt, forming a link with the central electrode.
4 Ceramic body insulates the central electrode against earth up to 40,000 Volts.
5 Nickel-coated plug body forms gas-tight connection with the insulator through the heat shrinkage method. Thread used to secure the spark plug in the engine block.
6 Electrical connection of spark pin and central electrode. On suppressed (R types) glass melt resistors.
7 Permanent outer sealing washer, for sealing and heat dissipation.
8 Seals insulator in the plug body and used for heat conduction.
9 Enables the spark to pass to the earth electrode.
10 The part of the insulator which protrudes into the combustion chamber.
11 Enables spark plug to be screwed into engine block.
12 Influences self-cleaning action and thermal value tolerance.
13 Nickel-based alloy additives increase the durability of the earth electrode.









Spark path

Normal spark position: Primarily on older engine types

Extended spark position: Standard in modern engines

The electrode gap

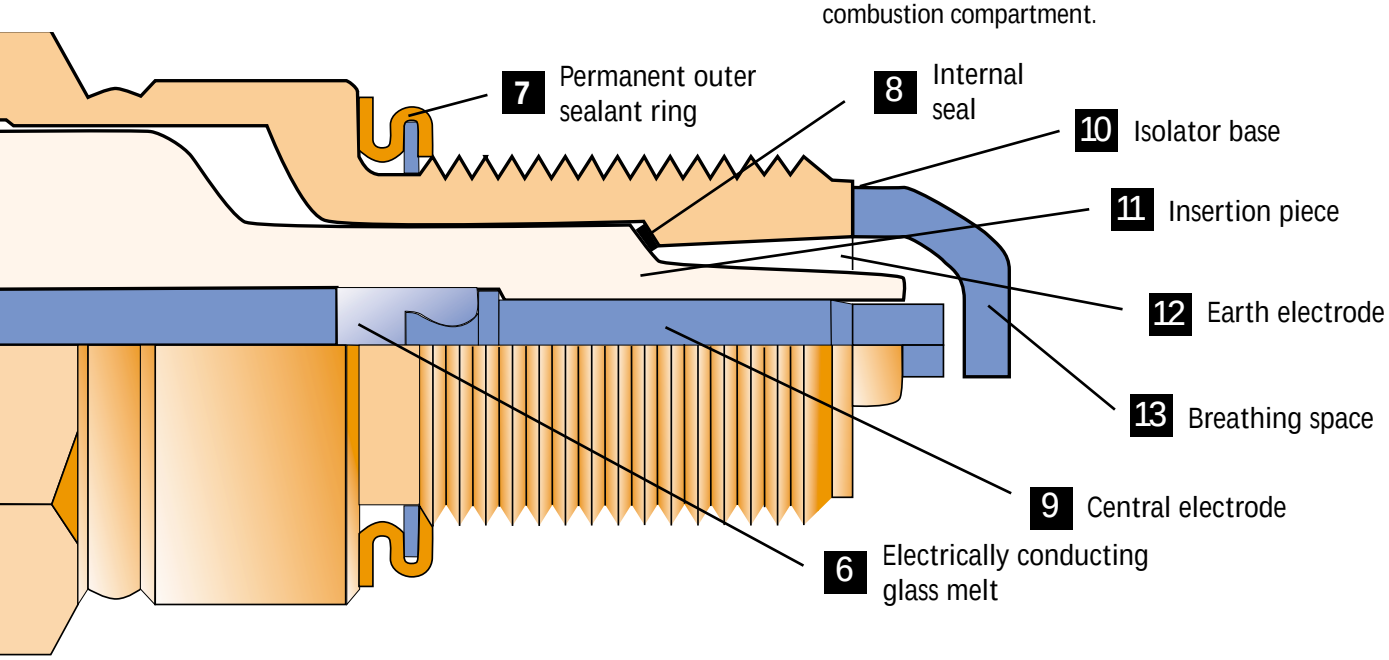
The gap is what counts. The shortest distance between the central and earth electrode(s) on the spark plug is called the electrode gap. The ignition spark must jump this gap. The vehicle manufacturer specifies the relevant optimum electrode gap – depending upon the engine. Maximum precision in maintaining the electrode gap is important since an incorrect gap can have a considerable detrimental effect on the functioning of the spark plug and consequently the engine performance.

- If the electrode gap is too small this may cause misfiring, noisy action and poor exhaust levels.
- If the electrode gap is too large then a higher ignition voltage is required to enable the spark to jump the gap: this may lead to misfiring.
- The co-ordinated spark positioning on multi-electrode plugs means the electrode gap does not have to be adjusted (for example Ultra X, air/glide spark technology).

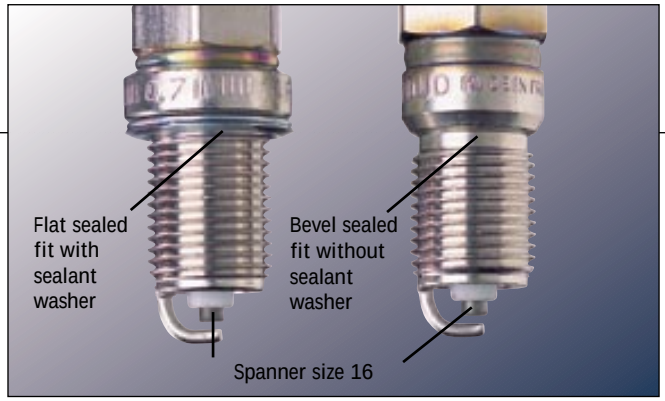
The crucial spark

The short spark path. The function of the spark plug in the combustion chamber is influenced by two main factors: the spark distance and the spark position. 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 glide 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. Spark position is the name given to the pattern of the spark path in the combustion chamber. Depending upon the electrode and insulator fit, the spark ignites the mixture at a different position in the combustion compartment.



The **sealed fit/Special spark plugs**

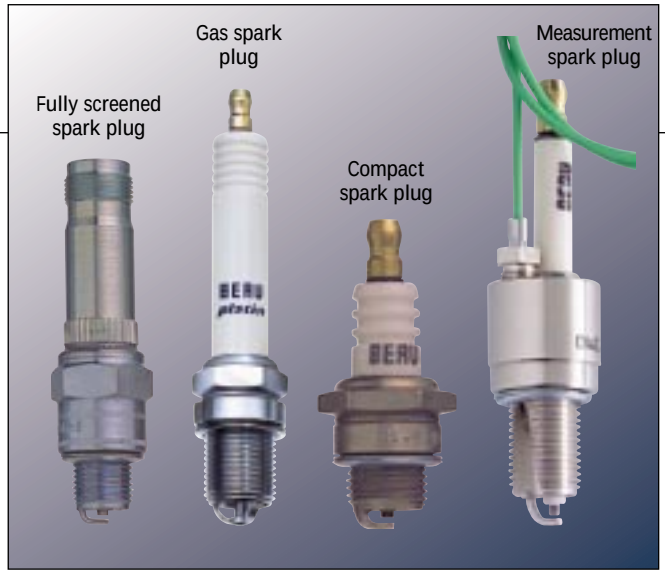


The sealed fit

All round seal. The spark plug must be screwed into the cylinder head so that it is gas-tight. Depending upon the engine design a distinction is made in this context between two different types of seal:

- Flat sealed fit or level sealed fit is the name given to the type on which a permanent outer sealant washer on the spark plug body has the task of providing the seal.
- Bevel sealed fit or conical sealed fit is the name of the design on which the conical-shaped surface of the spark plug body provides the seal in a correspondingly shaped cylinder head contact surface.

Spark plugs with a flat sealed fit and small spanner size are frequently used in particular where the installation conditions restrict the available space, as often applies in multi-valve engines. Use is also frequently made of bevel sealed fit spark plugs which have smaller external dimensions due to their compact design. (Fine Line).



Special spark plugs

For every occasion. Beru manufactures special spark plugs for a wide range of applications:

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

BERU type description

Thread — 14

10	M 10 x 1
12	M 12 x 1,25
14	M 14 x 1,25
18	M 18 x 1,5

Version — F

B	screened, watertight, burn-off resistance, ignition circuit 7 mm
C	as per B, but ignition circuit 5 mm
F	flat sealed fit
G	glide spark plug
K	bevel sealed fit
R	suppression resistance 5 k Ohm/10 k Ohm
S	spark plugs for small engines, flat sealed fit
T	as per S, but with bevel sealed fit
Z	spark plugs for two-stroke engines
GH	glide spark plugs with auxiliary spark distance

Thermal value statistic — 7

new	old
13	25
12	50
11	75
10	100
9	125
8	145
7	175
6	200
5	225
4	250
3	275
2	300
09	325
08	350
07	375
06	400

X	Special labels
01	
02	
03	
04	
05	

Thread length and spark position — D

A	12.7 mm normal spark position
B	11.2 mm extended spark position* 2.7 mm extended spark position
C	19.0 mm normal spark position
D	17.5 mm extended spark position* 19.0 mm extended spark position
E	9.5 mm extended spark position
F	9.5 mm extended spark position
K	19.0 mm extended spark position
L	19.0 mm extremely extended spark position
Z	26.5 mm extended spark position

* Spark plug with bevel sealed fit

Electrode version — T

A	triangular earth electrode
T	with multi-hole plug electrodes
D	2 earth electrodes
Q	4 earth electrodes

Electrode material — U

U	Beru ultra NiCu
S	Silver
P	Platinum

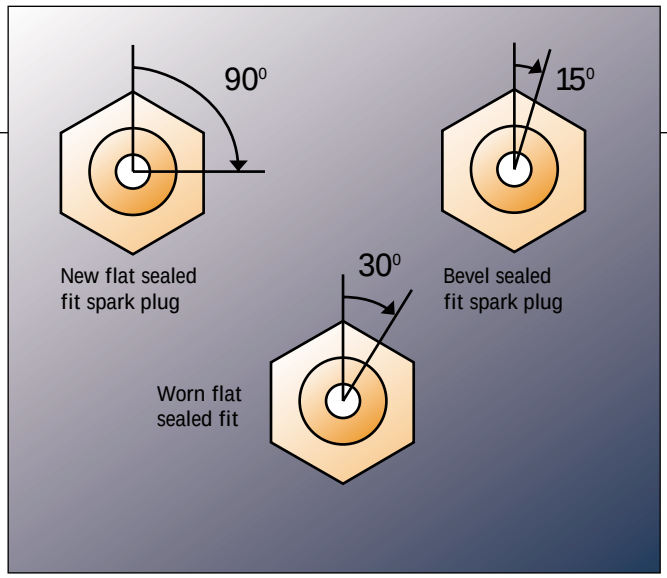
Other features — O

O	variation from the basic version (e.g. stronger central electrode)
R	with burn-off resistance
V	electrode gap 1.3 mm
X	electrode gap 1.0 mm or 1.1 mm
2	twin material earth electrode
4	extended insulation base

Ultra X

Heat ranges Ultra X spark plugs

Type	Thread lenght	Thermal value
UXK 79	Conical-shaped seal fit, spanner size 16	125-175
UXK 56	Conical-shaped seal fit, spanner size 16	200-225
UXF 79	Flat sealed fit, spanner size 16	125-175
UXF 56	Flat sealed fit, spanner size 16	200-225
UX 79	Flat sealed fit, spanner size 21	125-175
UX 56	Flat sealed fit, spanner size 21	200-225



Installing without torque wrench

Tightening torque in Nm (thread must not be greased)		
Plug thread	Cylinder head	
	Cast iron	Light metal
Flat sealed fit plugs:		
M 12 x 1,25	15-25	12-20
M 14 x 1,25	20-35	15-30
M 18 x 1,5	30-45	20-35
Bevel sealed fit plugs:		
M 14 x 1,25	15-25	12-20
M 18 x 1,5	15-30	15-25

Installing with torque wrench

Fitting the spark plugs

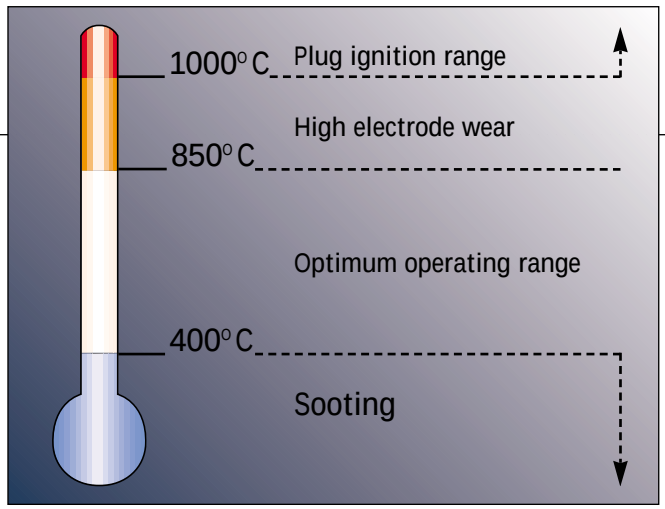
The right type. Since spark plugs are designed for specific engines the correct plugs must always be used. Plugs with the wrong thermal value, electrode gap or wrong thread length will always lead to reduced engine performance, often damage to the engine and/or catalytic converter. It is also imperative that they be installed and removed carefully.

- When removing, care must be taken to ensure that no dirt falls into the combustion chamber. The plug should therefore first be loosened by a few turns, the plug shaft cleaned using compressed air or a paintbrush, then the plug unscrewed completely.
- Plug thread and cylinder head bore should be clean when installing plugs. A nickel coating on Beru plugs avoids the need for lubrication. Check to ensure the correct torque (see table).

Beru manufactures spark plugs for an extremely wide range of applications.

Beru information material

Indispensable reference guide. The Beru Spark and Heater Plug Catalogue (Order No. 5 000 004 001), the Beru Manual of Vehicle Electrics (Order No. 5 000 002 004) and the Tecdoc CD are available for making the correct choice of plugs. These provide information on which plugs suit which vehicles and which other manufacturers spark plugs can be replaced by with Beru plugs. Another practical aid is the electrode feeler gauge (Order No. 0 800 100 001) which allows you to easily check and adjust the electrode gap. The rubber plug holder is available for plugs with difficult access (Order No. 0 890 000 001). This holds the plug firmly, provides finger-tip feel for screwing and unscrewing and prevents injuries to the hand as well as damage to sensitive spark plug and cylinder head threads.



Temperature on the insulator

Beru installation aids

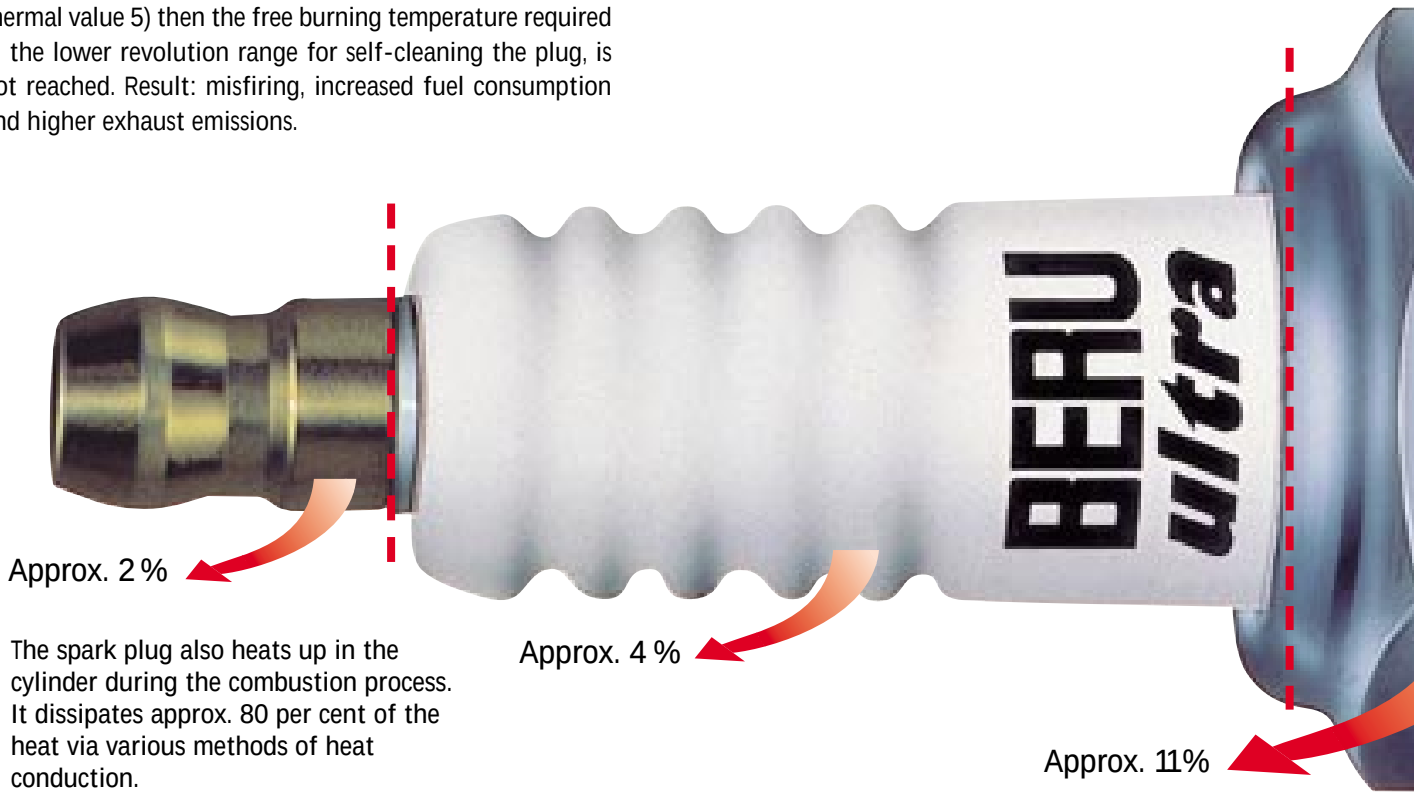
The thermal value

Characteristics. The term "thermal value" describes the thermal load capacity of a spark plug. This must also be co-ordinated with the relevant engine. The thermal value indicates to what extent the heat absorbed by the plug can be given off to the cylinder head. The thermal value must be adhered to precisely when selecting a plug:

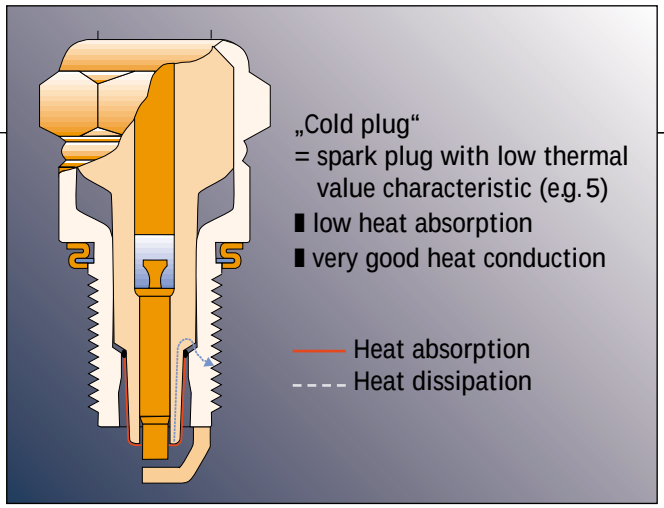
- If the thermal value characteristic is too high (for example thermal value 9) the plug is unable to dissipate the resultant heat quickly enough. This leads to incandescent ignition; in other words it is not the ignition spark that ignites the mixture but the overheated plug.
- If the thermal value characteristic is too low (for example thermal value 5) then the free burning temperature required in the lower revolution range for self-cleaning the plug, is not reached. Result: misfiring, increased fuel consumption and higher exhaust emissions.

The thermal conduction

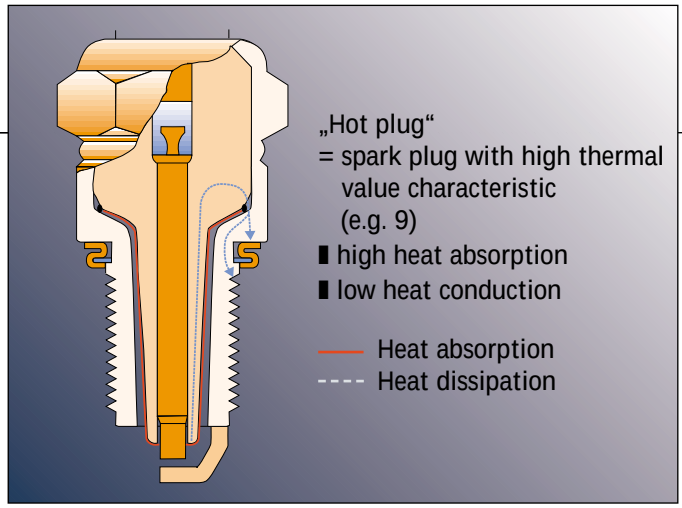
A hot item. Cylinder temperatures of more than 3000 °C are generated during the combustion process and these temperatures also cause the spark plugs themselves to get very hot. The spark plugs give off around 80 per cent of this absorbed heat through various methods of heat conduction (illustration).
The vast majority of the heat is transferred from the plug thread directly to the cylinder head. The passing fuel-air mixture only absorbs and dissipates around 20 per cent of the heat.



The spark plug also heats up in the cylinder during the combustion process. It dissipates approx. 80 per cent of the heat via various methods of heat conduction.



Cold spark plug



Hot spark plug

The influences on the thermal value

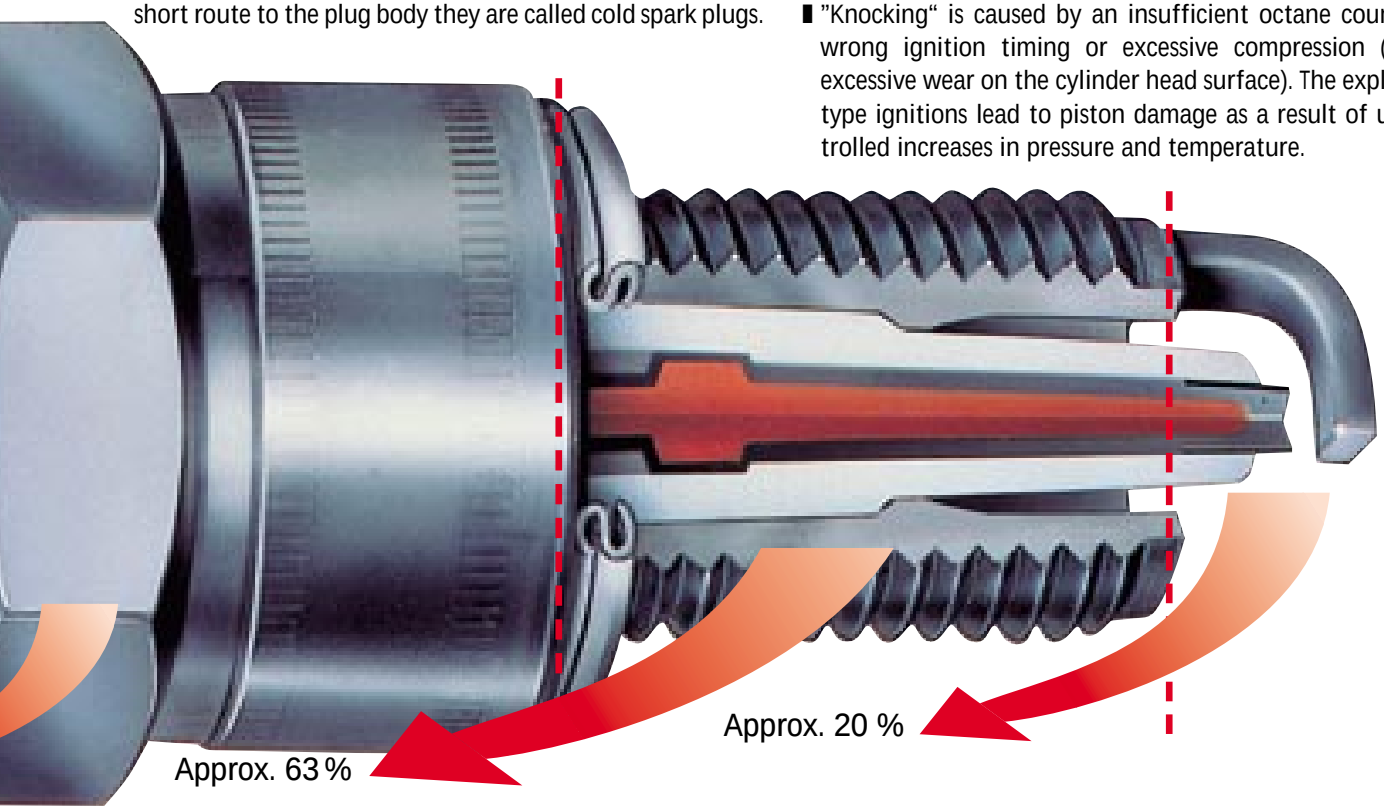
The size of the insulator base is important. The higher the engine performance the higher in most cases the combustion chamber temperature as well. The spark plug selected must be co-ordinated to suit this requirement. The size of the insulator base to a considerable extent determines the heat absorption at which the heat conduction takes place from the insulator base, via the central electrode and the inner seal on the plug body.

- Spark plugs with a long insulator base 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 base 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.

Malfunctions

Potential faults. There are a number of influences which can cause an engine ”to go on strike”: for example overload, poor fuel, wrong choice of plugs or stop-and-go traffic.

- Spark erosion and corrosion are created by thermal overload, the wrong type of or poor fuel as well as the wrong thermal value. The consequences of these are melted electrodes, incandescent ignition and, because of the larger electrode gap, misfiring.
- Incandescent ignition caused by residues in the combustion chamber, faulty valves, plugs with the wrong thermal value or fuel with an insufficient octane count, can cause piston damage.
- ”Knocking“ is caused by an insufficient octane count, the wrong ignition timing or excessive compression (cause: excessive wear on the cylinder head surface). The explosion-type ignitions lead to piston damage as a result of uncontrolled increases in pressure and temperature.



Spark Plug Appearances

Excessive lead

The insulator base has a brownish-yellow or greenish glaze in places.
Cause: Lead additives in the fuel cause deposits.
Effect: At increased load the coating becomes electrically conducting, leading to misfiring. Possible damage to the catalytic converter.
Solution: Change fuel; replace spark plugs since these cannot be effectively cleaned.

Deposits

The insulator tip, electrode and plug are covered with velvet-like black soot.
Cause: Incorrect mixture setting. Mixture too rich. Air filter blocked, defective cold start system (injection). High proportion of short journey use. Thermal value of plug too high.
Effect: Due to leakage currents, cold starting behaviour is poor and misfiring occurs. This can result in unburned fuel reaching the catalytic converter and causing demage.
Solution: Correction of mixture and cold start system. Check air filter.

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.
Effect: Misfiring or even shorting of the spark plug, complete failure.
Solution: Overhaul engine, correct fuel-oil mixture, fit new, original Beru spark plugs.

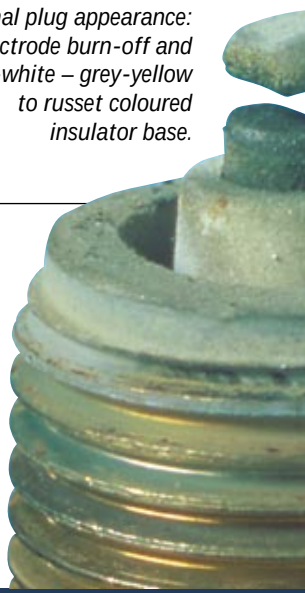
Glaze formation

Insulator tip shows signs of brownish yellow glazing which could also appear to be green in colour.
Cause: Additives in fuel and oil forming ash-like deposits.
Effect: Under excessively sudden full engine load, the glaze liquifies and becomes electrically conductive.
Solution: Adjust fuel system exactly, fit new, original Beru spark plugs.

Excessive deposits

Heavy deposits of fuel and oil additives on the insulator tip and earth electrode. Slag type deposits.
Cause: Alloy deposits, especially resulting from oil build-up, which then settle in the combustion chamber and on the plug.
Effect: Can lead to pre-ignition with loss of performance and engine damage.
Solution: Check engine tuning. Fit new, original Beru spark plugs, possibly change the type of oil used.

Normal plug appearance: minimal electrode burn-off and a grey-white – grey-yellow to russet coloured insulator base.



Overheated

Centre electrode melted. Blistered, sponge like and soft insulator tip.
Cause: Thermal overload due to "glow ignition" e.g. because of ignition timing set too early, combustible residue in chamber (coked-up), defective valves, damaged distributor, too weak a fuel mixture and thermal value of plug too low, tightening torque not observed.
Effect: Misfire, 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 hair-like 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.

Extreme overheating

Cauliflower-like deposits on the electrode leading to further deposits on the plug and other parts of the combustion chamber.
Cause: Thermal overload due to "glow ignition", e.g. through ignition timing set to early, combustible residue in chamber (choked-up), defective valves, damaged distributor, too weak a fuel mixture, spark plugs incorrectly tightened.
Effect: Prior to engine failure, efficiency (output) will drop.
Solution: Check engine, ignition and mixture; check tightening torque of the spark plugs. Fit new, original Beru spark plugs.

Our Tip for the Toughest Requirements: Beru Ultra X

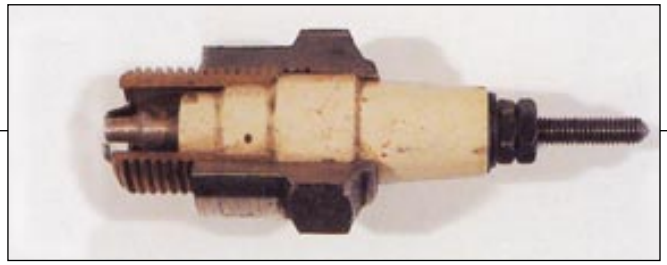
The air/surface discharge spark plug with nickel sheathed copper core and 4 earth electrodes, arranged in pairs in the shape of an X, provides highly dependable ignition: the spark has a total of 6 different possible ways of igniting the air-fuel mixture!

The development of the spark plug

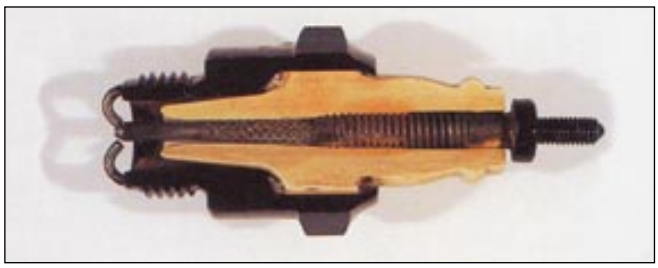
Long history. The history of spark plug development goes back further than that of the automobile: in 1860 Jean Joseph Etienne Lenoir patented the invention of the spark plug for his gas-powered engine. The new era of spark plug design began after the turn of the century with the battery-less, high-voltage magnetic ignition invented by Gottlob Honold. The battery ignition version, still used as standard today, only arrived on the scene during the 20's.

The insulating bodies of the first spark plugs were made of porcelain. Although it looked good the material was not sufficiently resistant. It would break even if over-tightened. Trials with other materials such as steatite, zirconium, sintered corrundum or mica finally led to the moulded insulation body made of aluminium oxide granulate which is still currently in use today. The shape of the electrode and choice of material have also undergone numerous changes. Today, the dominant materials are chromium nickel alloys, silver and platinum.

Advertising from the 20's



Soapstone plug (1920)



Two-pole steatite sports plug (circa 1930)

Beru history

Starting with the Ruprecht plug. In 1912 the 29 year old inventor Albert Ruprecht, from Swabia, was granted the patent for his "Ruprecht plug". Its main advance was that it was gas-sealed against compression pressure. With the patent in his pocket Ruprecht set up his own company: Beru. The new plugs operated so reliably that Beru rapidly expanded and soon became one of the leading manufacturers of spark plugs.

Numerous other patents and the expansion of the production range to include other components made Beru the expert in vehicle electrics. Whereas in the beginning the focal point of the interest was primarily on operating safety and reliability of the plugs, today, in line with the growing environmental consciousness, the attention is increasingly being focused on the optimum mixture combustion. This is the only way to ensure optimum fuel consumption and minimal emission levels at the same time.

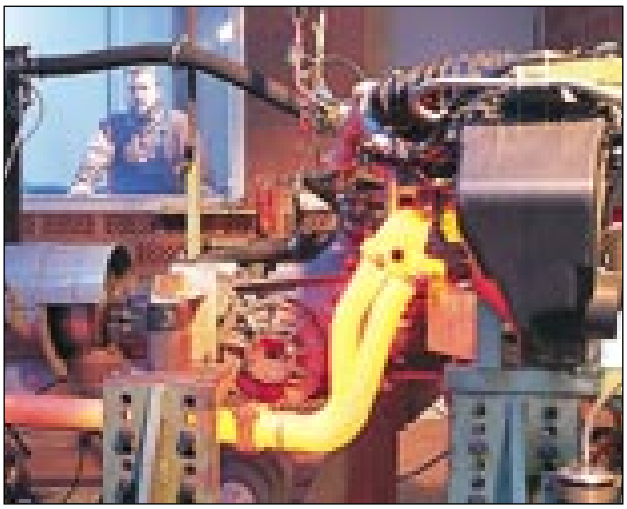
Testing an insulator at 40,000 Volts.

Special applications for Beru partners

The Beru hardness test

For bending and breaking. There is no compromise for spark plugs in the everyday life of the car. Whether in stop-and-go traffic or long motorway trips, whether in the bitter cold or the burning heat of the sun – a Beru spark plug must always continue to function. And yet even the best Beru product is subject to natural wear and tear. That is why the vehicle manufacturers stipulate specific intervals for replacing the spark plugs.
The following generally applies: the spark plugs should be changed no later than every two years. This is aimed not only at maintaining engine performance but also protecting the expensive catalytic converter which can be damaged through misfiring. If we bear in mind the fact that, depending upon the number of cylinders and type of spark plug, a complete set of plugs can be bought for around just 20 Marks but a new catalytic converter can set you back at least 1,500 Marks, then you can see how important it is to check spark plugs regularly and replace them within the specified period.

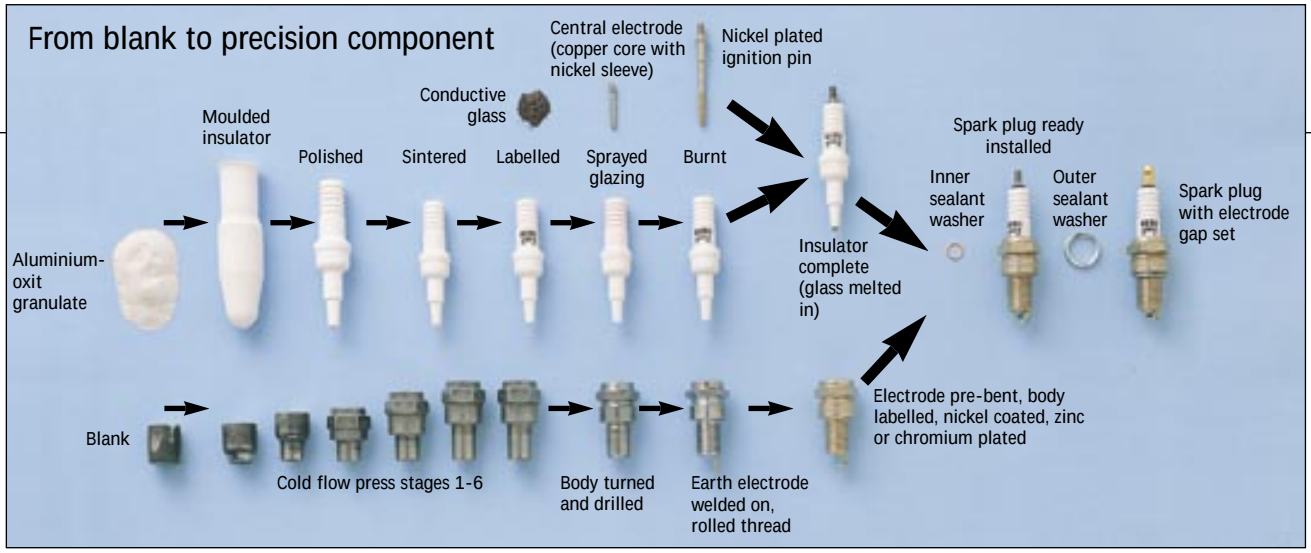
Testing the cold start response in the refrigeration unit at -30 °C.



Service life test – test bench

Beru services

International systems partner. Today, Beru is internationally recognised as one of the worldís leading suppliers for vehicle electrics. As a medium sized company Beru is flexible and can respond quickly when it comes to meeting customer wishes. A research and development department with around 150 development and design engineers produce on-going improvements to existing products and a continuous supply of new product developments.
Obviously, this team develops many of the products using its own ideas. Just as important however are those developments which Beru drives ahead in conjunction with the client. By taking this approach, special applications, developed personally for the Beru partners, ensure that vehicle manufacturers are supplied with customised products designed to meet their needs precisely. That is why Beru is increasingly developing complete system solutions instead of just individual components.



Engine characteristics

Optimised processes. Ever-increasing demands for environmental protection, such as optimum fuel consumption, optimum combustion levels and consequently minimal noise and exhaust emissions can only be met with the help of efficient ignition systems. The spark plug has a very special task to fulfil in this context.

All the processes which characterise an engine take place within the 120° crankshaft angle of rotation. The engine will only run smoothly, produce high performance and low exhaust emissions if the necessary quantity of the optimum fuel-air mixture composition is present in the cylinder, if a strong ignition spark jumps between the electrodes at the precisely predefined point and if the required combustion chamber temperature is maintained.

Spark plugs must therefore be precisely matched to suit the characteristics of an engine.

Spark plug production

From blank to precision component. Tremendous importance is attached to quality at Beru. Around ten per cent of all Beru employees are consequently engaged in the area of quality assurance. One of the basic principles of Beru's philosophy on quality is: production monitoring instead of product checking. Because quality must be built in and not simply tested.

In this context, Beru relies on the latest computer-aided processes. Only they guarantee that the properties which the client has been promised are also reliably ensured for each and every plug. Quality assurance does in fact however start with the actual choice of suppliers and materials. Beru only considers reliable partners and the best quality raw materials. Computer-controlled manufacture systems (see illustration above) are then used to create, step-by-step, quality spark plugs which rightly bear the name of Beru.

Cross section of the product range of automotive spark plugs from Beru.

Quality Standards

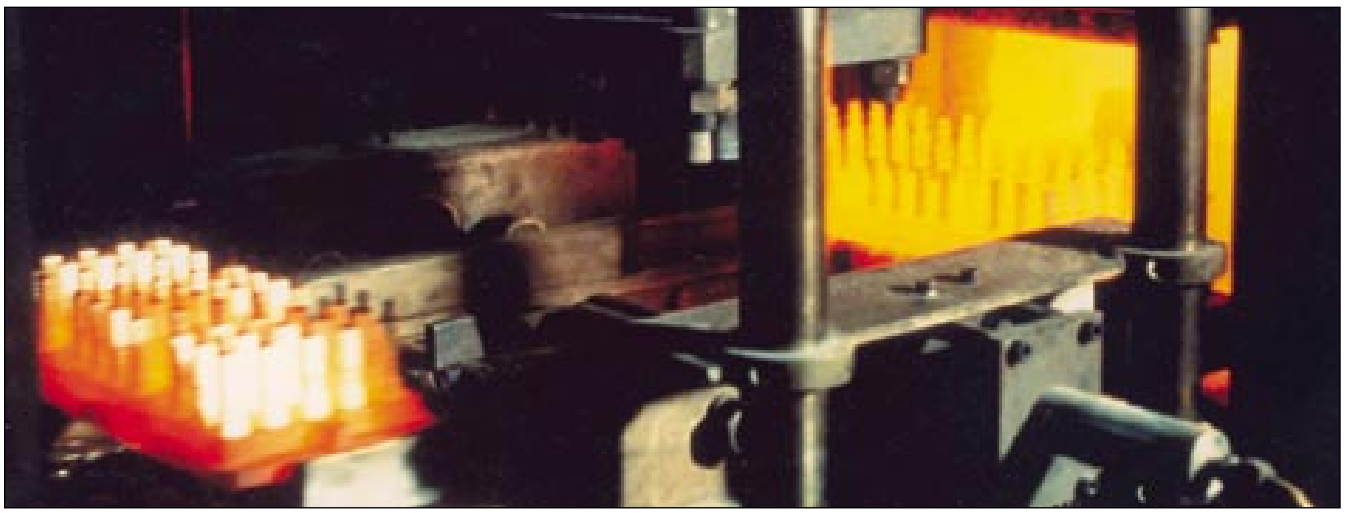
International quality standards. Quality is the highest priority to remain in the international competition. The early certification according to DIN/ISO 9001 was an obvious step for Beru. All Beru facilities – to include the complete area of Spark Plug manufacturing – are in accordance with DIN/ISO 9001. This includes the development, production, sales/marketing and management. The certification has to be redone every three years. This also includes production ideas, design and customer satisfaction. The ongoing compliance of the required demands guarantees the Beru quality, as well as two other important certifications.

Based on very rigorous German standards: VDA 6.1 and the quality norm QS 9000. The big American car manufacturers like Chrysler, Ford and General Motors require those. To assure these standards we must have a very special resource: quality employees.

Requirements for the future

Increased demands. The unpleasantness of the past – wars, infaltion, economic crises – were mastered by Beru. Now Beru has made it to be a global player in vehicle ignition electronics. The building of the new Research and Developement center at our headquaters in Ludwigsburg reflects this. Our Research and Development Center has specific testing equipment, most up-to-date test rigs, special measurement accommodations, climate rooms, ignition-, interference- and metal-graphica-laboratories. This opened Beru's possibility to master the requirements of the future. To be able to offer products for the pretentious engine concepts, stringent environmental requirements and highest conversation of resources. At the same time this is the only way to accommondate customer requests for lower failure rates (no more than 50 to 80 PPM) and to produce most cost effectively. Beru will continue to take on those future market requirements.

Quality spark plugs from Beru are created on computer-controlled production systems.



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