GLOWPLUG SYSTEMS (part 1)

I have written this article for those who want to know more about the glowplug system in their London Taxi vehicle. This part (1) is on the so-called ‘series systems’ as these have been installed in the FX3D and FX4D models with the Austin/BMC 2.2 L diesel engine (1954-1972) and the FX4R with the early Rover 2.25 L diesel engine (1982-1983).

First I would like to tell you something on what the smoke coming out of a diesel exhaust-pipe can tell you about the engine and it’s condition, *… sometimes live is hard with an (older) diesel engine.*

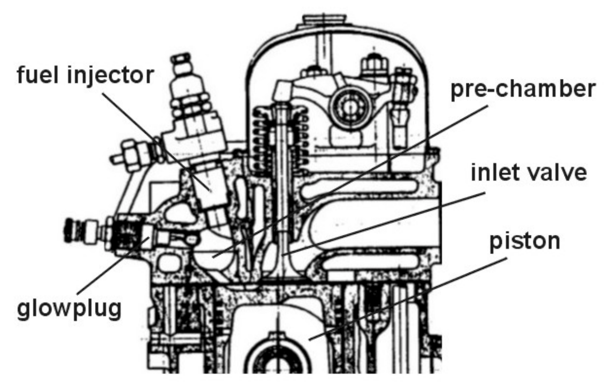
In general the color of the exhaust-gasses (diesel-smoke) from a diesel engine are a reliable indication on what might be a problem with the diesel engine, as the following indicates … when having problems <u>with starting</u> the diesel engine:

black >	injectors malfunctioning (wrong spray-patern), wrong adjustment of the fuel-pump-injection-timing or injection-pump defective, airfilter element blocked (unsufficient air supply), too low compression (piston-rings worn/broken, burned valves and/or seats, general wear)
blue/grey >	glowplug system does not work (glowplug(s) defective, power supply open circuit, series-resistor open circuit)

And when finally running and producing a white smokescreen (pointing at a low engine-temperature), the conclusion is that something is wrong with the glowplug-system and that’s what we will learn more about here.

Glow- (or heater) plugs are a cold-start aid for diesel engines. They have the task to heat-up the air in the combustion-chamber befor starting and to initiate the firing of the injected fuel particulates by their glow element during starting. As soon as the engine runs (or shortly after) these have to be switched off to prevent damage.

In particular engines with pre-chambers (indirect injection) as in the above mentioned variants and shown in the picture (fig.1.), starting is more difficult because the incoming air cools down in the pre-chamber and combustion chamber above the piston, so a bigger ‘heat give off’ area.



<u>fig.1. section from BMC 2.2 L diesel engine</u>

The reached compression-end temperature at a cold engine can, without the help of a glowplug system, not take care of the fuel being burned and to start the engine at the first injections. Therefore it is necessary that the temperature of the glow-element rises to 900-1200 °C. That the glowplug has no easy live, we can conclude from the fact that it has to stand high pressures and temperatures, vibrations and chemical influences.

The glowplug construction

These early glowplugs exsist of a plug-housing, connection-housing, isolator, terminal-nut and of course a glow-element. This element is at one end connected to the terminal-nut and at the other end to the connection-housing, so the glowplug has two poles (and therefore there is no electrical connection to mass/ground, that is the engine's cylinderhead).
The isolation is mostly made from glass or some ceramic material.
The glow-element is made from chromsteel or chromnickelsteel and has a heating power of about 70 Watts.

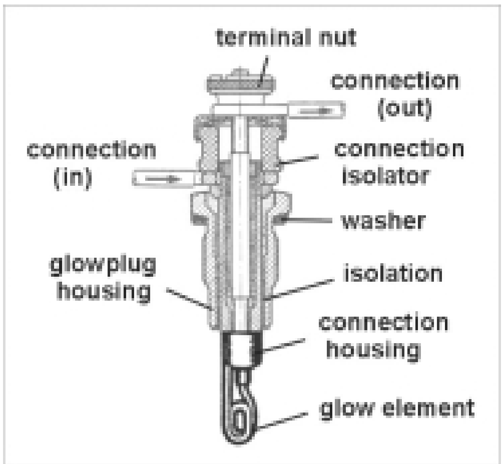


fig.2. glow plug construction

The glowplug 'series system'

Sofar the physical stuff, now onto the electrical part. The glowplug system as been used on the above mentioned engines in the FX3 and FX4 models is basically built up as shown in the next picture (part of the vehicle wiring-diagram);

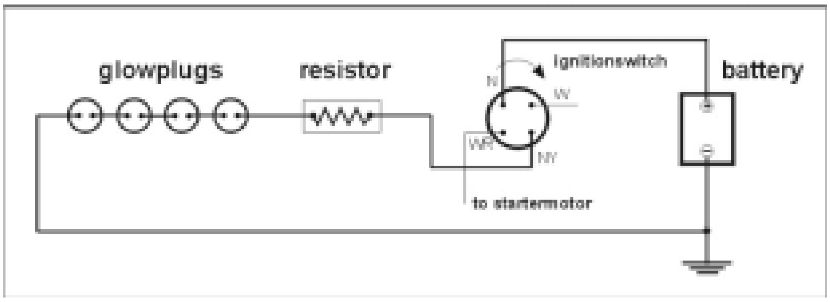


fig.3. system electrical diagram

This is a so-called 'series system (circuit)', which in electrical sense means that the elements in the chain are connected in one line (the one after the other), starting at the battery's plus pole going around via the ignitionswitch, the series-resistor and the glowplugs themselves to the minus pole as in the above diagram.

One of the characteristics of a series circuit is that only an electrical current in Amps, which has the same value on each point in the chain, will flow when the whole circuit is in tact that means is closed from the battery's plus to minus pole. This also means that if one of the elements in the chain is broken (open circuit) no current can flow! With only one blown glowplug you will have great difficulties in starting the engine, because none of the glowplugs work (like the lights in a christmas tree, turn one out and all the other will also dim).
The battery is the element that supplies the electrical potential, the voltage expressed in Volts, to the circuit. All elements together in the chain form the total (chain-) resistance expressed in Ohms.

And there we have all the necessary quantities, to explain Ohm's Law which is of vital importance when you want to understand an electrical circuit.

Ohm's Law says: a Voltage (in Volts) across a Resistor (in Ohms) causes a Current (in Amps) flowing through this Resistor which is (in value) equal to this Voltage divided by the Resistor's Resistance. In a mathematical formula it shows as follows:

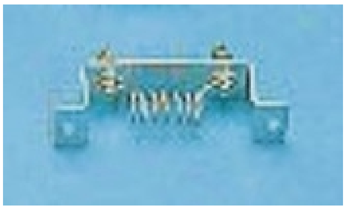
Current (Amps) I = Voltage (Volts) U / Resistor (Ohms) R   or   I = U/R.

This is also applicable to an individual element. For example from the original used glowplugs for the Austin/BMC 2.2 diesel engine the Champion AG4, the electrical characteristics are: 2 Volts, 36 Amps.
Some additional information; these early glowplugs as mentioned befor need to be robust to stand high pressures and temperatures, vibrations and chemical influences. The glow-element is of the open type and has to be made from a relative thick material wire and therefore has a low resistance.

We can calculate it's resistance with the formula above: I=U/R which mathematical can also be written as: R=U/I, that is Rg (Ohms) = 2 (Volts) / 36 (Amps), so
Rg = 0.055 Ohms.

This low operating voltage is also the reason why the glowplugs have to be put in series and 4 in a row results in: 4 x 2 Volts = 8 Volts which means that the battery's voltage of 12 Volts is still too high.

And this finally explains why there is a Resistor in series with the glowplugs which has to take care of (dissipate) the remaining 4 Volts.



It's resistance can be calculated from:

R=U/I, that is Rs (Ohms) = 4 (Volts) / 36 (Amps)
so Rs = 0.111 Ohms.

fig.4.   series resistor

For the whole chain the resistance is (4 * 0.055 Ohms) + 0.111 Ohms = 0.331 Ohms. The current in the circuit: I=U/R, is the battery voltage of 12 Volts divided by this total chain-resistance of 0.331 Ohms, which (of course) again results in 36 Amps.

Remark: In the calculations made the results are rounded and we go from a battery that supplies 12 Volts allthough in practise this will be between 14 Volts for a fully charged one and 10 Volts for a battery under load (i.e. glowing and starting).

Trouble shooting a series system (circuit)

The advantage of a series circuit is, that it's working well or it's not working at all and this you will allmost immediately discover and in our case the diesel engine will be very hard to start in particular when it's getting colder.
Furthermore most of the time it is only one of the elements in the chain that is broken (open-circuit) probably one of the glowplugs or a loose contact.

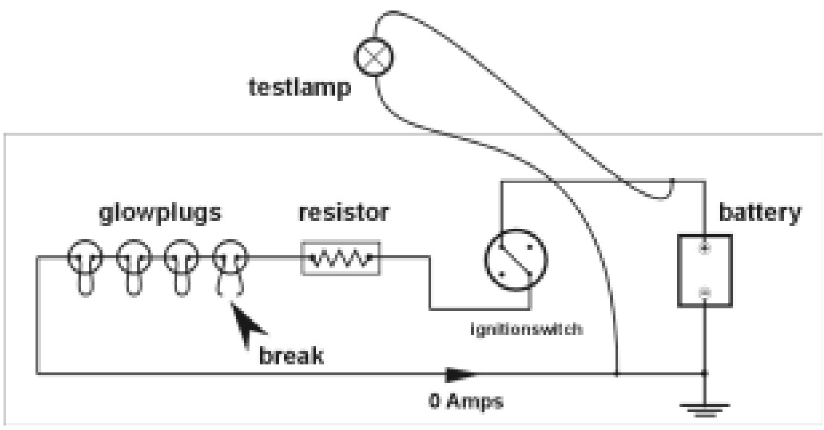
We therefore first visually check the circuit in the vehicle for loose (which also means corroded) contacts, broken wires etc. starting with the wire that runs from the ignitionswitch to the series-resistor onto the glowplugs No.4, 3, 2 and 1 and then back to ground. If no luck sofar we have to proceed with the following.

From the above we now know that in a series circuit each element causes a voltage-drop (from the battery's plus pole: 12 Volts to it's minus pole: 0 Volts), the glowplugs each cause a 2 Volts drop, in total: 4 x 2 Volts = 8 Volts and the series-resistor takes 4 Volts. When in good order the ignitionswitch and the wires and their connections have no (or negligible low) resistance and therefore (theoretically) cause no voltage-drop. We can also calculate this voltage-drop backwards with the formula above: I=U/R which mathematical can also be written as: U=I*R, i.e. for Rs: Us (Volts) = 36 (Amps) * 0.111 (Ohms) = 4 Volts.

Now we come to the point of using this knowledge for trouble shooting a series circuit, because when this is 'open', no current (0 Amps) will flow which means that across each element in the chain there will be no (0 Volts) voltage-drop simply because: 0 (Amps) * Rx (Ohms) = 0 Volts.

Then back to the circuit as given in fig.5. with a broken (open circuit) glowplug which means there is no current flowing and therefore no voltage-drop over any element. And that means that the full 12 Volts from the battery is present across the 'break'. In our case across the faulty glowplug!

To detect the faulty spot (element) in the electrical chain a handy instrument is a small 12 Volt testlamp with two wires attached, starting from the battery's plus and minus pole (see fig.5.) where the lamp should light because it get's the full 12 Volts. And then with the wire on the plus side move along the chain touching the intermediate contacts, passing the ignitionswitch, the series-resistor and finally the glowplugs one by one. At a certain point the light does not light-up anymore and that is the place we you just passed the faulty spot. Just befor this point the testlamp gets the battery voltage and at this point it is (also) connected to ground.



<u>fig.5. system electrical diagram with break</u>

Of course during this test procedure somebody has to keep the ignitionswitch in the right position, otherwise you could conclude that this might be the faulty spot.

When the faulty part has been detected i.e. a broken glowplug take it out of the cylinderhead and ones again check it separate. Connect it across the battery in series with the same testlamp and when it indeed is faulty the testlamp will not light.

<u>When you have to look for alternative glowplugs and/or resistor</u>

If the original glowplugs are nolonger available you have to look for an alternative. These should physically fit to the cylinderhead, so have the same dimensions in particular the part that goes into the cylinderhead including the screw thread.

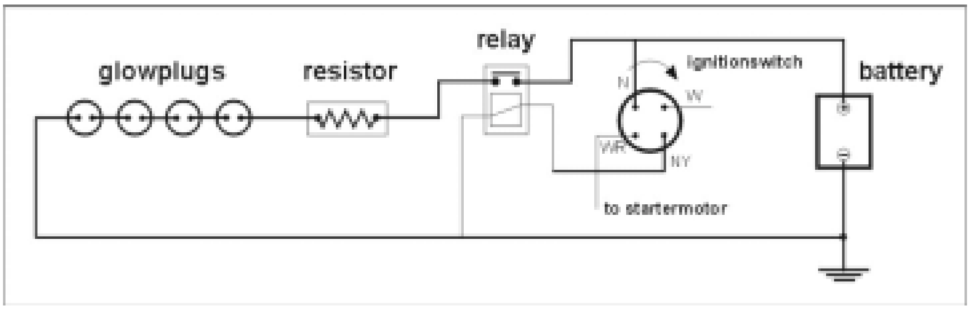
Furthermore the electrical characterstics should be taken into acount and if not queit the same some calculations have to be made and may be it is advisable to also change other parts in the system like the series-resistor.

Sofar we did not mention the heating power generated by this early glowplug which is expressed in Watts like other electrical equipment. The power P (in Watts) is equal to the product of U the voltage (in Volts) over and I the current (in Amps) through the element. In formula it is P=U*I.
For the Champion AG4 glowplug: 2 Volts, 36 Amps the power P=U*I is 2 x 36 = 72 Watts. Also for the series-resistor this can be done: P=U*I is 4 x 36 = 144 Watts and that is a lot of power that has to be dissipated by this resistor, that is to be transfered into heat and blown into the air.

<u>And some extra’s for the glowplug system in your vehicle</u>

1. Installation of a power relay

In these older systems the full glowplug current from about 40 Amps runs through the ignitionswitch which is a heavy load for this switch. This can be prevented by installing a power relay between the battery plus and the series resistor (hot end). The following diagram shows how this modification can be done.

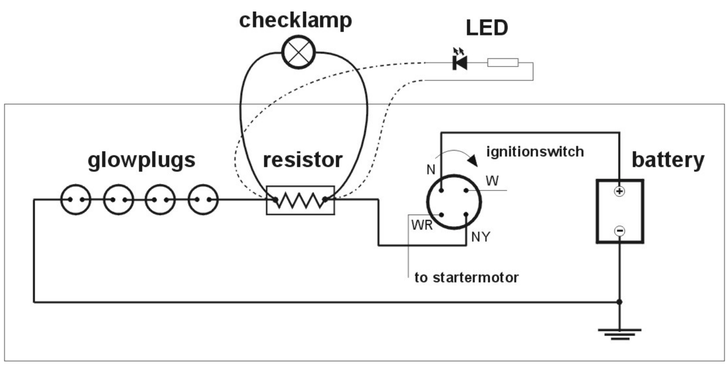


Now the ignitionswitch only has to switch the very low relay-coil current.
For the relay use a type that can handle (switch) at least twice the main current, in this case about 80 Amps. At the moment of switching-on the glowplugs are cold and for a split second they take upto the dubble current, the same as with normal light bulbs.

2. Installation of a glow checklamp

These early London Taxi models have no glowplug (check)lamp whereas it is such a handy control method everytime you start the diesel engine. To actually check if there is a current flowing we use the voltage-drop over the resistor in the series system being about 4 Volts.

For this purpose we use A small 4 to 6 Volt check-lamp with two wires attached fitted in the dashboard and covered by a yellow glass.
The wires should be connected each with one end of the series resistor.



When we now turn the ignitionswitch in the ‘glow’ position this checklamp should light, if not (no voltage-drop over the series resistor) we know that we have a problem with the glowplug system (open circuit).

Also possible is to install a yellow coloured LED (Light Emitting Diode) instead of the lamp. Because as with glowplugs a LED only may get a certain voltage to light which is about 1.8 Volts and again the difference in voltage has to be taken away by a series resistor, which can be calculated as follows: R = (Ur-1.8) / 0.05 =
(4 –1.8) / 0.05 = 2.2 / 0.05 = 44 Ohms. So, we take a 47 Ohm sample out of the standard range.

Add. Info: The original glowplugs originaly used in the early **Rover 2.25** L diesel, are the Champion AG45 (1.7 Volts / 40 Amps).

Sources: London Taxis Int. / Carbodies (Austin and Rover) manuals
Fachkunde “Kraftfahrzeuge”

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