# ELECTRIC VEHICLES

# WORKING SAFELY WHEN THERE IS NO BIG ORANGE PLUG (MSD)

# INFORMATION SHEET

Things have moved on in the electric vehicle world and unfortunately a number of vehicle manufacturers have decided not to fit a **Manual Service Disconnec**t (the big orange plug) to their vehicles. Instead, they now rely solely on the use of a **Service plug** to interrupt the **Pilot Line** (safety interlock circuit) thus disengaging the big high voltage DC relays (contactors) in the high voltage battery.

There is a school of thought that pulling the service plug on its own makes it safe enough. After all, the chances of both high voltage relays in the battery pack jamming in the closed position are very low, as is the possibility that the circuit controlling them could accidently become energised.

That being said, when working with potentially fatal high voltages, there is another school of thought that says it is better to have multiple layers of protection in place instead of relying on just one. For example, we use both insulated gloves and insulated tools; either one will protect us from the hazardous voltage as we undo the bolt on a terminal on its own but by using both we are still safe even if the insulation on the tool failed unexpectedly. By using both a single failure does not result in danger.

The technician working on your vehicle must adapt their processes and this leads to the question – How do you work safely when there is no big orange plug?

Before we try and answer that question however, let's refresh our memory on what the 'Service plug' and the 'Manual Service Disconnect' are.

## The 'Manual service disconnect' (MSD)

This is a big orange plug that is normally part of, or very close to, the high voltage battery. Its function is to disconnect the power to enable maintenance work on the car to be safety carried out.

The MSD is actually one of the links between the battery cells, usually the middle one, so that the battery is separated into two parts and thus the maximum voltage present inside the battery pack is halved and because the circuit is broken there is no path for electricity to flow outside the battery pack.

Most MSDs also contain a high amperage fuse.

The MSD is also part of the pilot line safety interlock circuit, so removing it also disables the high voltage relays in the same way that pulling the service plug would. As the pilot line circuit will already have caused the high voltage DC relays to open, there will be no load on the MSD when it is withdrawn and thus no risk of arc flash – provided the system is working properly that is, but the technician wears protective gloves anyway to protect them in the eventuality it hasn't.

Thus, with the MSD removed the technician is safe as:

- We have physically interrupted the HV circuit in the battery.
- We have interrupted the pilot line so the high voltage relays cannot engage.

## The Service Plug

This is usually a small green connector located under the bonnet, although with at least one manufacturer it is a small orange connector under the vehicle, next to the high voltage battery pack. It does not disconnect the high voltage system directly; instead, it interrupts the **pilot line.**

The service plug is also known as a:

- Maintenance plug
- Maintenance connector
- Service connector

The green part of the service plug is captive and when pulled out as far as it will go, it will expose a hole to allow a padlock to be inserted. This prevents it being pushed back in accidently.

As the pilot line is a low voltage circuit it is acceptable to use a metal padlock to lock it out, however it is better to use the non-conductive padlock you will have on hand anyway for locking out an MSD and, as these are red or another bright colour, they provide a visible sign to those near the vehicle that it has been locked out for safety. It is also the case that the plastic padlock is less likely to damage the service plug than a metal one

## The Pilot line

The Pilot line is a low voltage circuit that forms one continuous loop around all the high voltage components and if that loop is broken at any point the high voltage relays in the high voltage battery will open and disconnect the power to prevent danger.

With a basic pilot line, it would not be possible to detect if the outgoing and return parts of the line were shorted together. If this occurred near the battery pack the pilot line would not operate as it can only detect an open circuit. To address this problem some manufacturers, have resistors inserted into the line inside key components, the line is then monitored by the Battery Management Module to ensure the resistance is correct. If the resistance is too high or too low the Battery Management Module will remove power from the high voltage DC relays to disconnect the high voltage from the rest of the vehicle. As the pilot line is signalling to the Battery Management Module that a disconnection of power is required rather than acting directly on the high voltage relay control circuit, this does raise the possibility that, although unlikely, a fault in the Battery Management Module could prevent the safety system acting as intended

The pilot line is also known as:

- The safety interlock circuit
- The High Voltage Interlock Loop
- The HVIL

The **Pilot Line** should not be confused with either the **Proximity Pilot** or the **Control Pilot** circuits these are part of the system for connecting an eternal charger to the vehicle.

## Making the vehicle safe to work on

The manufacturers process must be followed. This is either supplied by the manufacturer or from another reliable source such as Autodata®, HaynesPro® or similar.

In broad terms the process can be outlined as follows:

- Put up warning signs
- Pull out the Service Plug
- Secure the Service Plug with a suitable padlock. Make sure only the technician working on the vehicle has the padlock key
- Check for the message confirming the high voltage system has been disabled. This can be shown on the dashboard display for some vehicles and on others will require the use of a scan tool
- Secure the vehicle key in a locked metal box. If it's of the keyless entry type, then place it in a faraday signal blocking pouch first
- Disconnect the 12 volt battery (negative terminal)
- Place a plastic cap over the negative battery terminal to prevent inadvertent reconnection
- Check your Personal Protective Equipment (PPE) is not damaged and put it on (I'll talk about this later)
- Now follow steps **A** or **B** as appropriate

**A) For vehicles where the battery cable <u>plugs</u> into the inverter with an orange connector**

- Unplug the battery cable from the inverter
- Verify your 2 pole voltage detector works on a known source
- Test for voltage at the connector, it should be zero volts or as close to zero as makes no difference
- Verify your 2 pole voltage detector still works on a known source
- Wait ten minutes for the capacitor in the inverter to discharge
- Remove the cover from the inverter (or elsewhere as directed by the vehicle manufacturer)
- Test for voltage at all terminals, and between all terminals and the vehicle body. It should be zero volts or as close to zero as makes no difference
- Verify your 2 pole voltage detector still works on a known source
- Remove your Personal Protective equipment (PPE)
- Put the inverters (or other) covers back on
- Cover the orange connector from the battery either with a clam shell lock out (the sort for big industrial plugs should fit) or if this is not available cover with a heavy-duty plastic bag.

**B) For vehicles where the battery cable has ring terminals bolted to the inverter**

- Wait ten minutes for the capacitor in the inverter to discharge
- Remove the cover on the inverter (or elsewhere as directed by the vehicle manufacturer)
- Verify your 2 pole voltage detector works on a known source
- Test for voltage at all terminals, and between all terminals and the vehicle body. It should be zero volts or as close to zero as makes no difference
- Verify your 2 pole voltage detector still works on a known source
- Disconnect the high voltage cable and cover the ends with a suitable high voltage insulating cable end shroud such as Laser part 7550 or 6703. Don't be tempted to use insulating tape instead.
- Remove your PPE

In the above section you will observe I recommend a '2 pole voltage detector' and not a multimeter. The Health and Safety Executive (HSE) have stated in GS38 – "*The use of incorrectly set multimeters (or makeshift devices) for voltage detection has often caused accidents*."

## Personal protective equipment (PPE)

When working on the electric vehicle's high voltage system we are principally concerned with protection from electric shock, burns and arc flash. Naturally we will be wearing safety boots in the normal way to protect our feet from mechanical injury. Ultimately what PPE you select will depend on your working environment, the type of work performed there and most importantly your risk assessment.

As with all personal protective equipment it is best if each technician has been issued their own set; this is not only more hygienic but as most equipment is not 'one size fits all' having it sized correctly for the technician will enable them to work more efficiently.

## Hands

The hands must be protected from:

- Contact with live parts
- Burns
- Arc flash

Suitable protection from these hazards can be obtained from wearing either of the following glove sets:

- Cotton under-gloves (optional) and Class 0 1000 volt electrician's dielectric insulating gloves with Leather over-gloves
- Cotton under-gloves (optional) with Composite Class 0 1000 volt electrician's dielectric insulating gloves with mechanical protection, these are like the standard glove but have a hard wearing outer coating and are thus less flexible than the standard glove

The electrician's dielectric insulating gloves must conform to standard EN60903

The use of the cotton under-gloves is to improve dexterity by filling the free space between the insulating glove and your finger. The cotton gloves also improve comfort by absorbing sweat, and are also good for hygiene as they can be washed easily.

Do **not** use class 00 gloves as these are only rated to 500 volts. You can of course use class 1 gloves or higher, but as the voltage protection class increases the rubber gets thicker and less flexible.

Leather over-gloves help prevent damage to the insulating gloves and provide a degree of protection from burns and arc flash. Make sure the leather over-glove is shorter than the insulating rubber glove underneath. Ensure there is several centimetres of rubber showing at the top to prevent high voltage being conducted through the leather and up your arm.

Insulating gloves only work if they are not damaged. Before **every** use they must be visually inspected for holes or other damage. After visual inspection the gloves should then be air tested.

You can perform an air test on the gloves by using either of these methods:

- Using a Pneumatic Glove Tester – like a sort of very expensive balloon pump
- Trapping some air in the glove and rolling the end over a few times to seal it. Then pressing gently to confirm it is not leaking out.

Carefully check for air leakage, if there are any holes however small the glove must be replaced.

The pneumatic glove tester does have the drawback that it is very expensive. So, provided you don't mind spinning your glove around like a market stall holder sealing the top of a paper bag, I would suggest that a pneumatic glove tester is something that is definitely not essential.

Whilst we are on the subject of insulating gloves, don't blow into them as the moisture in your breath will not improve the insulating properties of the glove nor the longevity of the rubber.

Remember also that the glove packs are available in a number of sizes, your experience with them and dexterity will be greatly improved by having the correct size.

## Feet

As well as the usual mechanical protection, e.g. toe cap and reinforced midsole, we must protect ourselves from electric shock hazards. This can be achieved by using one of the following:

- Safety boots and an insulated floor mat rated to IEC 61111 Class 0 or higher
- Safety boots and dielectric over boots (but these can be rather cumbersome as it's hard to get a good fit between the safety boot and the over boot)
- Electrician's safety boots, with insulated sole, upper and non-conductive toe cap. (Also available as wellington style boots for working outside)

For workshop use a pair of insulated rubber mats, one in front of and one behind the vehicle, can prove to be a cost-effective solution. If you work outside or do a lot of work on electric vehicles then electrician's safety boots will be more suitable.

Occasionally people confuse anti-static boots for electronics work with electrician's safety boots; this is a very dangerous mistake as they are very different. Check the label on new boots very carefully to ensure you are getting protection up to at least 1000 volts.

## Eyes and face

When working on the high voltage elements of an electric vehicle we must protect our head, most importantly our face and eyes from arc flash this can be obtained by using one of the following:

- Safety goggles rated for arc flash
- Face shield rated for arc flash
- Switch room / linesman's helmet

Obviously goggles only protect your eyes so a face shield or linesman's helmet are to be preferred as either of these will offer significantly more protection, and are less likely to interfere with your glasses. For electric vehicle work the arc flash rated face shield will provide the best compromise between comfort and protection. Check the label on goggles and face shields carefully as the type of eye protection normally used in the workshop will not be rated to provide protection from arc flash.