A Comparison of Functions and Safety Features on Electric Pressure Cookers

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Introduction

There are dozens of different electric pressure cookers (EPCs) on the market for domestic and small commercial use. They range in price from about £50 to well over £100. Seven EPCs are compared here. One, the BES model is designed for use with a 12V DC electricity, whereas the others are all designed for 230V AC electricity. Section 1 describes the functions and features. Section 2 describes the safety features.

This document does not make recommendations as to one type over another, but sets out a factual comparison of functions, external and internal features. **However, major safety concerns have been identified in the BES 12V DC EPC and are described in section 3.**

1. Functions and Features

The functions and external features of the EPCs are described in Table 1. While all EPCs work as pressure cookers, they vary in other functions available to the user. A few functions are still unknown at this stage, without detailed testing. Most EPCs are capable of gentle shallow frying / sauté / browning but not all. Some, but not all, are also capable of baking or roasting in some form but baking a cake is different from baking a potato or roasting meat.

There is a high degree of uniformity in pot diameter such that one glass lid fits all the inner cooking pots, Figure 1. The glass lid happens to be supplied by Instant Pot. This may be useful for minimising heat loss during shallow frying, thereby speeding up the frying process.

Figure 1. Instant Pot glass lid fitting on the Aobosi inner pot

Two of the EPCs have an inner pot made of polished stainless steel. The others have a pot with a non-stick inner surface.

There are significant differences in the construction of the pressure lid, Figure 2. Some top surfaces consist mostly of bare stainless steel with no air gap between the pressure vessel and the outer surface. The bare metal has relatively high thermal conductivity and results in a very hot outer surface when in use. Other EPCs have a plastic covering on the lid, with or without an air gap between the pressure vessel and the plastic cover. Where an air gap was present, its depth was measured as 14mm approximately. The plastic covers have lower thermal conductivity than any metal and are therefore expected to reduce heat transfer and lid external temperature. An air gap is expected to further reduce the heat loss rate and external lid surface temperature, but this is yet to be tested in the laboratory.

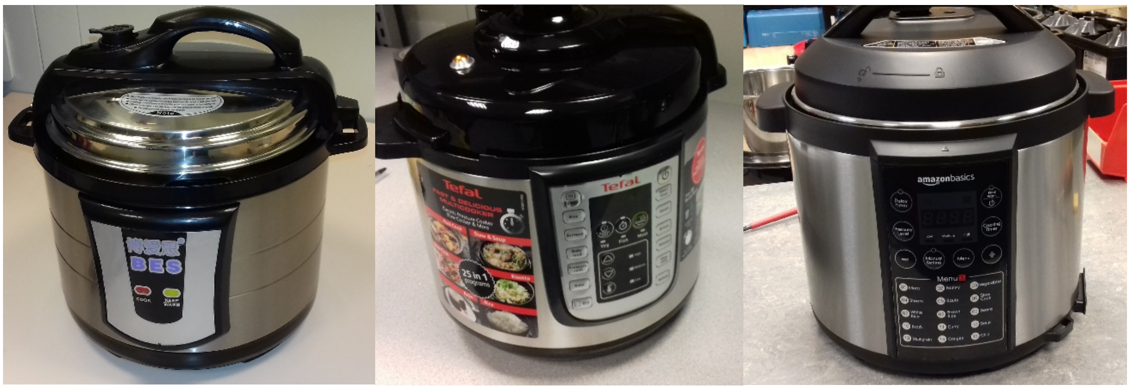

Figure 2. EPC lids showing (a) mostly bare metal surface (b) plastic covered surface and (c) raised plastic cover containing an air gap

Some EPCs have a hinged lid while others do not. Non-hinged lids simply twist to open and lift off. Hinged lids are also removable for cleaning in one way or another, either by twisting and sliding the lid from its hinge, or by unscrewing a central knurled nut to release the lid from a hinged bracket, Figure 3. The Chinese BES 12V EPC is unique amongst those examined in that the lid twists clockwise to open.

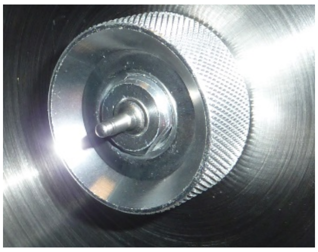

Figure 3. Knurled nut in the middle of the inside surface of a lid. The nut is undone to remove the lid. In the centre is a temperature probe for control of cooking temperature

The EPCs have differing methods to release steam from the main weighted valve. At the end of the pressure-cooking process, it may be necessary to manually release the pressure. Most EPCs require the user to manually lift and twist the weight. Two of the EPCs have a separate pressure-release button several cm's away from the valve to reduce the scalding hazard, Figure 4. A third, the SAGE, has an additional electrically operated solenoid to release the pressure, either automatically at the end of cooking or manually via a button on the control panel.

Figure 4. Remote steam release button in the centre of the lid of an EPC

Finally, the user-interfaces and options vary greatly. Most EPCs have multiple buttons for selecting pre-programmed cooking programmes for different types of food; these are culturally specific to the intended country of sales. One EPC offers a simple timer control, the BES 12V cooker provides no user controls, it is switched on by connecting to the 12V source.

Figure 5. Timer control on the Tower 5-litre EPC

Table 1. Functions and external features of electric pressure cookers

Make and model	Shallow fry / sauté / brown?	Bake / Roast	Inner pot surface	Exposed / covered lid? Hinge?	Remote steam release?	User Controls
BES 12V DC Chinese	No	No	Non-stick	Bare metal. No hinge. Rotate clockwise to remove	No	No controls. It is on when connected to 12V DC.
Tower 5 litre T16004	No	No	Non-stick	Plastic, no air gap. No hinge.	No	Simple timer knob with bell.
Tower 6 litre T16005	Reportedly no, but max. temp is 160°C	Yes, 'cake'	Non-stick	Plastic, no air gap. No hinge.	No	Multiple buttons for pre-set programmes
Amazon Basics	Yes, sauté, unknown temperature	No	Non-stick	Plastic cover, 14mm air gap, but exposed rim. No hinge.	No	Multiple buttons for pre-set programmes
Instant Pot Duo	Yes, sauté, 'less' = 135-150°C, 'normal' = 160 - 175°C 'more' = 175-210°C	No	Stainless steel	Most of top is bare metal. No hinge	No	Multiple buttons for pre-set programmes
Aobosi YBW60-100Q1	Yes, sauté, unknown temperature	Yes	Stainless steel	Plastic cover, with 14mm air gap. Hinged lid removed by sliding hinge.	Yes manual	Multiple buttons for pre-set programmes
Tefal EPC06	Yes, 'brown', up to 160°C	Yes	Non-stick	Plastic, no air gap. Hinged lid removed by undoing a knurled nut.	Yes manual	Multiple buttons for pre-set programmes
Sage BPR700	Yes, saute, unknown temperature	Yes 'Pot roast'	Non-stick	Bare metal. Hinged lid removed by undoing a knurled nut.	Yes electron ic	Pre-set programs, or control of temperature and time

2. Safety Features

A pressure cooker cooks faster than normal cooking by raising the internal pressure of the cooking pot and thereby raising the boiling point of water contained in the pot. Any uncontrolled release of steam from the EPC would present a severe hazard due to the heat and pressure energy contained in the steam. Safety features of the 7 examined EPCs are compared in Table 2.

As a minimum, all EPCs have a safety valve with a simple weight, Figure 6, Figure 7, Figure 8, Figure 9. In each case, the hole covered by the weight is about 3mm in diameter and the weights are consistently approximately 80g. The steam release pressure varies between 30 and 70 kPa gauge; maximum temperatures have been calculated in Table 2.

The underside of the weighted valve may be covered by a perforated dome, Figure 7, Figure 8, Figure 9, or the whole underside of the lid may be lined by a removable, perforated aluminium disc. In each case, these features reduce the risk of the valve being blocked by food.

Figure 6. Top of an EPC showing the weighted valve (top) and a micro-switch button (in the moat below)

Table 2. Pressure release vent static opening pressure and calculated temperatures.

	Weighted pressure vent in lid (+/- 0.5g)	Orifice diameter (mm)	Static gauge pressure at which valve starts to vent (kPa) 100 kPa ~ 1 atmospheres)	Max temperature rise at vent pressure	Pressure marked on weight
BES 12V Chinese domestic	82.5g	4.00	64.4	14.4	n/a
Tower TI6004	78.5g	3.12	100.7	20.5	G90 kPa
Tower TI6005	81.5g	3.12	104.5	21.1	G90 kPa
Amazon Basics	83g	3.05	111.4	22.2	n/a
Instant Pot Duo	82g	3.05	110.1	22.0	105-135
Aobosi YBW60-100Q1	85.5g	2.87	129.6	24.8	100
TEFAL EPC06	80.5g	3.16	100.7	20.5	n/a
SAGE BPR700	81g	3.00	112.4	22.3	n/a

When pressurised, the silicon sealing ring seals the lid and cooking pot which together form the pressure vessel. Nevertheless, to prevent the lid from being turned under pressure, and to prevent a sudden release of steam, all EPCs also contain a pressure-actuated mechanical lid interlock against opening the lid while under elevated internal pressure, Figure 7, Figure 8, Figure 9. Pressure forces a post upwards through a hole in a slider, locking the slider. The slider is connected to a push rod that prevents the lid from turning.

Figure 7. The main valve weight, and parts of the pressure-activated interlock to stop the lid being opened under pressure

When cooking soft foods, for example finely milled oats or flour, there is a danger that the food will block the safety valve hole. Therefore, some EPCs include another pressure-operated sprung pressure vent, Figure 8, Figure 9.

Figure 8. Features on the underside of an EPC lid. Top: Cover of principal weighted valve. Right: Secondary, sprung loaded valve. Left: Pressure-operated rotation locking post. Centre: temperature sensor with knurled nut removed.

Figure 9. Underside of another EPC lid showing safety features. Top: underside of main weight valve. Left: pressure-operated rotation locking post. Bottom: temperature probe.

Some EPCs include a micro-switch in the moat or in the lid to indicate to the control system when the lid is moved, Figure 6, Figure 16. The function of the moat micro-switch appears to be to signal to the control circuit that the lid is on but not locked which is required for certain cooking programmes.

All EPCs contain a thermal switch or sensor, or both. In the BES 12V EPC, a thermal switch is directly bolted to the hotplate, Figure 10. In all other EPCs, the switch or sensor is located in a sprung-loaded button, Figure 11, that protrudes up through a hole in the hotplate to ensure good thermal contact with the cooking pot. All these buttons are about 20mm in diameter.

Switches have been identified as bimetal thermostatic switches, Figure 10.

Figure 10. Bimetal temperature sensor (a) attached to hotplate of BES 12V EPC with red wires attached and (b) removed to reveal labelling

Figure 11. Bucket-shaped chassis that surrounds the inner pot. At the bottom is the hotplate and in the centre of the hotplate is a sprung button.

Some EPCs contain Negative Temperature Coefficient (NTC) thermistor temperature sensors in their sprung button. Some EPCs contain both, Figure 12. Where the button has a temperature sensor the button also has an electrical earth connection because the sensor has a low voltage power connection.

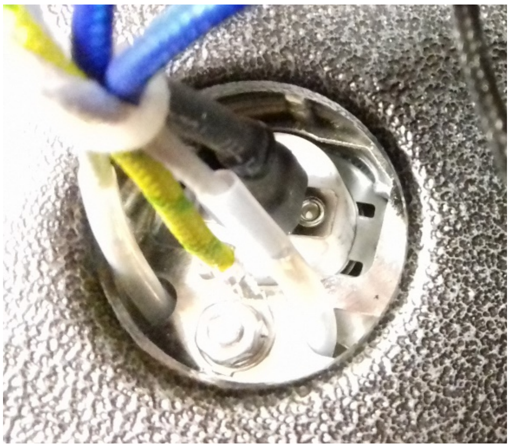

Figure 12. Underside of a sprung button in the centre of a hotplate. This button contains a thermostatic switch (blue wires) and a thermistor (white wires).

Most EPCs also use one or more larger bimetallic strips outside the chassis. It appears that the bimetallic switch is activated by either a temperature rise, or a pressure rise, or a combination of both, Figure 13. In the Tower 5-litre EPC, there is an additional bimetal switch that is only temperature operated, Figure 14. In the Tower 5-litre EPC, the switch acts on the main power wires but in the other EPC's it operates on a signal wire to a circuit board. In order to be pressure activated, the pressure-operated switches are connected to a post through the chassis, connected to the hotplate. The hotplate is forced downwards by the pressure inside the pot, against a circular spring plate.

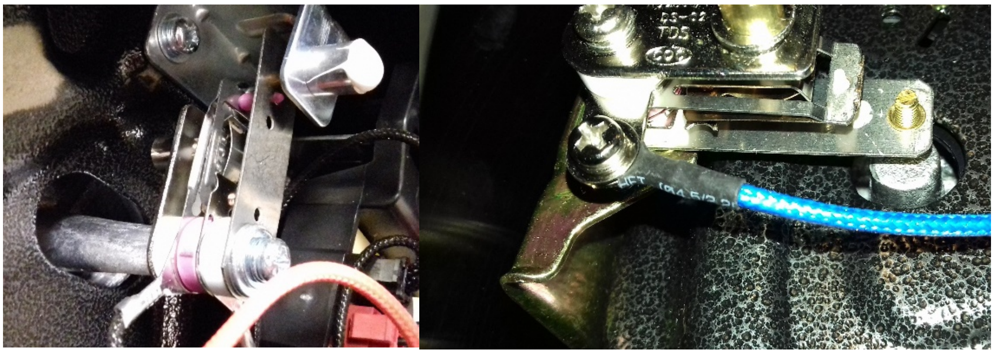

Figure 13. Combined temperature and pressure operated bimetal switches on the exterior of the chassis

Figure 14. Bimetal switch on the exterior of a chassis operated by temperature alone

All except the BES EPC also have thermal fuses to protect against over-temperature, Figure 15. Once activated, a thermal fuse breaks a circuit that prevents the EPC from working until the fuse is replaced. There are usually 2 thermal fuses per EPC, and they are usually located on the main live wire and on the main return or neutral wire conducting all power within the EPC. The operating temperature of each fuse is marked on the body of the fuse itself, and the fuse is located inside a fibreglass sleeve. The fuse temperatures range from 130°C to 192°C but the locations are different from one EPC to another: The 130°C fuses are located about 4cm below the chassis; the 142°C fuses are located on the side of the chassis; Most of the 192°C fuses are located directly under the base of the chassis, very close to the heating element.

Figure 15. Thermal fuses (a) mounted in their sleeves and (b) removed from sleeve, close-up

Finally, some EPCs have a temperature probe, consisting of a thermocouple, in the lid of the EPC, Figure 8, Figure 9. when the lid is attached via a hinge, the wire to the probe passes through the hinge, but where the lid is detachable the probe appears to be connected via a contactless induction loop in the moat of the EPC, Figure 16, Figure 17. Note that two of the EPCs, the Instant Pot Duo and the Amazon Basics are almost identical inside, with identical components but different external designs. Both have a micro-switch in the moat and a temperature probe in the lid connected by an induction loop in the moat.

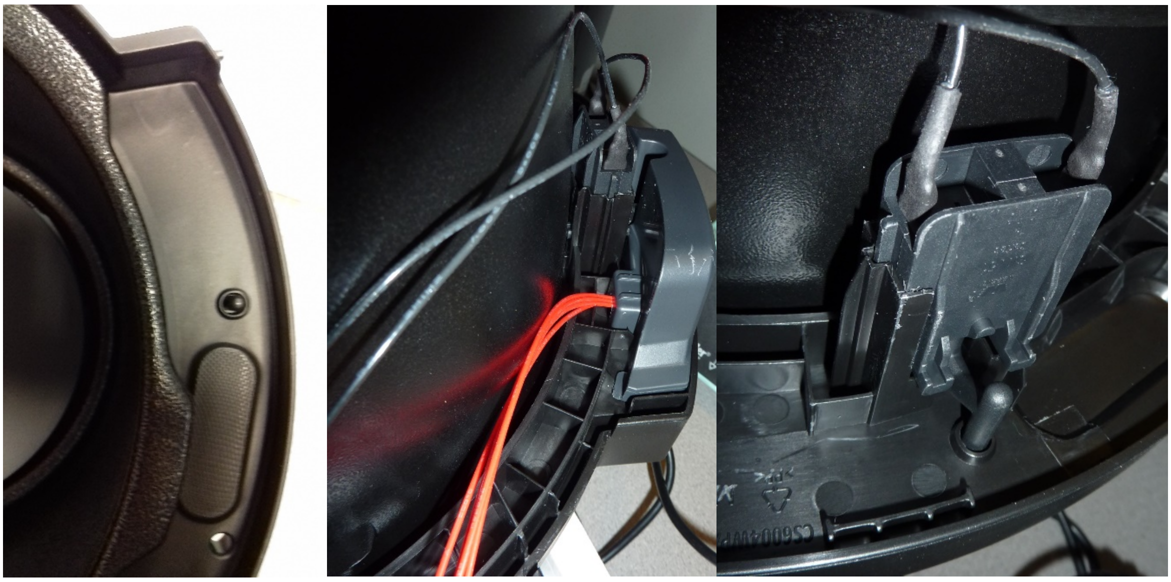

Figure 16. Features in the moat of some EPCs. (a) Top view of induction loop and micro-switch button (b) Rear view of moat removed from case showing connection wires (c) Rear view of micro-switch button

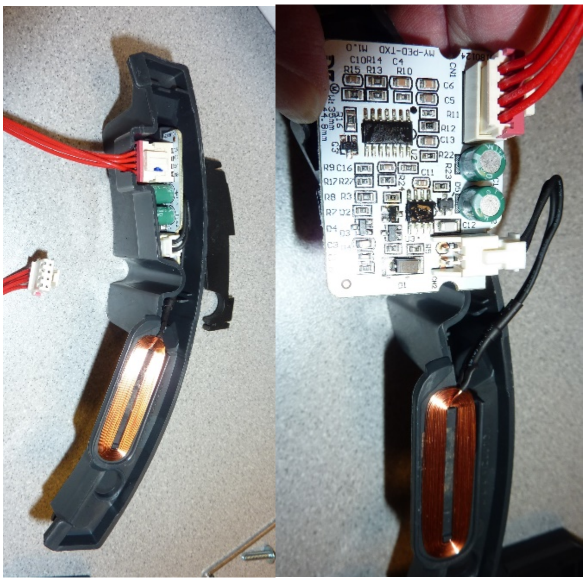

Figure 17. (a) Induction loop removed from moat and (b) its circuit board close-up

Table 3 Safety features of electric pressure cookers

	Mechanical				Electrical					
	Weighted pressure vent in lid	Pressure activated lid interlock	Other pressure operated sprung vent	Micro-switch	Small thermal switch in hotplate	NTC thermistor sensor in sprung button	Thermal Bimetal switch on chassis	Combined* thermal/ pressure switch (*presumed)	Thermal fuse	Temperature probe (thermo-couple)
BES 12V Chinese domestic	82.5g	Y			Two fixed to hotplate, 140°C					
Tower TI6004	78.5g	Y			Y (In sprung button)		Y (power wires)	Y (power wires)	192°C	
Tower TI6005	81.5g	Y				Y (no earth wire)		Y (sensor wires)	192°C	
Amazon Basics	83g	Y		Y	Y (In sprung button)	Y		Y (sensor wires)	142°C	Y (in lid via contactless)
Instant Pot Duo	82g	Y		Y	Y (In sprung button)	Y		Y (sensor wires)	142°C	Y (in lid via contactless)
Aobosi YBW60-100Q1	85.5g	Y				Y		Y (sensor wires)	130°C (not on chassis)	
TEFAL EPC06	80.5g	Y	Y	Y (in lid)		Y			216°C x2	Y (in lid)
SAGE BPR700	81g	Y	Y	Y (in lid)		Y			192°C	Y (in lid + 1 other, a thermal fuse?)

3. Safety Concerns of the BES 12V Cooker

Current drawn

With the nominal power of 250W at 12V, the current must be about 21 Amps. The cold resistance of the heating element has been measured at 0.5Ω, which is consistent with that current, allowing for a small increase in resistance with temperature.

Internal wire current rating

The internal wire has been measured as having 1.3mm2 cross-sectional area, equivalent to 16 AWG. It appears to be sheathed in fibreglass.

A single copper 16 AWG cable in PVC sheathing has a maximum rated current of 15 Amps at 30°C. At 50°C a PVC-sheathed cable is de-rated to 58% or 8.7 Amps. The internal fibreglass insulated wires must be assumed to be subject to rising to the 140°C switching temperature of the hotplate (below which PVC sheath would fail). However, the precise derating factor for the fibreglass cannot be calculated without knowledge of the cable construction since it depends on materials used as well as the specific application, heat sources and geometry. Fibreglass sheathed wire can be rated to 250°C (e.g. RS #819-9650) or higher.

External wire current rating

Each conductor of the external cable has a cross-sectional area of 2.1mm^2, equivalent to 14 AWG. As multicore cable the maximum current is 15 Amps at 30°C, because the conductors are also surrounded by an additional PVC outer sheath. At 40°C, the potential ambient temperature, the cable is de-rated to 82% or 12.3 Amps.

Appliance inlet connector

The BES 12V cooker is connected to its external cable by an IEC 60320 C13 plug and C18 socket coupler. The C13/C14 plug and socket carry three pins and are typically used for personal computers. Note: “Kettle leads” are C15/C16 couplers that are rated for higher temperature. The C17/C18 plug and socket couplers carry only two pins. Each of these couplers are rated at up to 10A in the IEC 60320 standard. Therefore, the connector is overloaded and was observed to become hot when used in the BES 12V cooker.

In addition, and of even greater concern, is that the BES 12V cooler could be connected to a 230V AC grid electricity supply using another IEC 60320 C13 or C17 plug lead. If that were to happen, the BES 12V cooker would briefly attempt to draw over 100kW. At best, the large current would blow a fuse in the plug lead. At worst it would cause wires to melt very quickly and create an explosion anywhere in the local wiring.

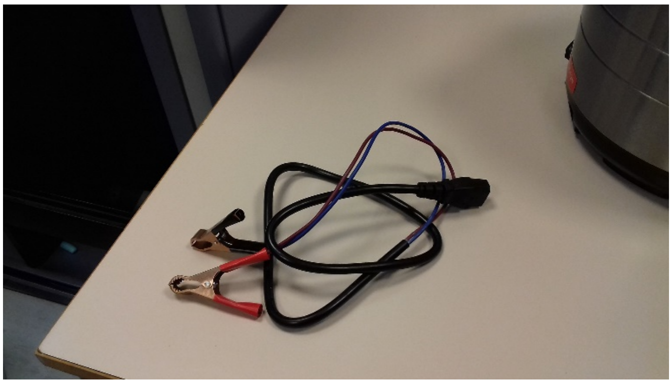

Figure 18. IEC 60320 C14 plug lead and crocodile clips used with the BES 12V DC EPC

Jagged and rusty metal

Internal examination reveals a rough-cut hole in the chassis of the BES 12V cooker, Figure 19. Internal wires can rub against the edges of that hole and already show signs of abrasion. Further examination revealed a rusty retention plate holding the heating element in place on the hotplate, Figure 20. Thermal conduction is poorer than if the heating element were fully encapsulated. The corrosion indicates a limitation to the lifetime and integrity of the cooker.

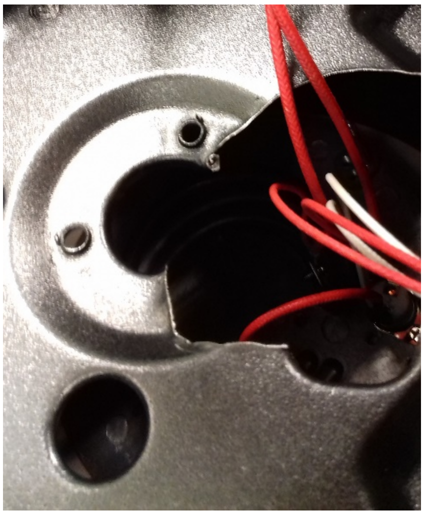

Figure 19. BES 12V DC EPC chassis with jagged roughly cut hole and wires

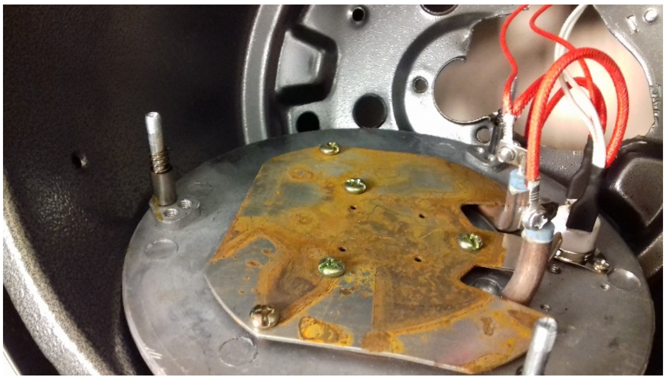

Figure 20. BES 12V DC EPC. Rusty sheet of metal holding the heating element in place on the hotplate.

This concludes the findings of the comparisons of functions and safety features in the electric pressure cookers that were examined in this study.