MECS Modern Energy Cooking Services

A brief performance and safety assessment of a 24V DC Electric Pressure Cooker intended for the Chinese domestic market

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Summary

A previous example of the BES branded DC electric pressure cooker range, the 5 litre 12 VDC model, was assessed during 2019 and was discovered to suffer fundamental safety flaws such that attempting to incorporate the cooker in the MECS programme would breach Loughborough University Ethical Policy Framework requirements.

Recent examination of two examples of a different BES branded DC EPC (3 litre 24 VDC model) discovered essentially the same set of safety flaws. The ex-factory cooker (for either model) would not be legal to be sold within the UK or EU.

Introduction

In an earlier report, major concerns were expressed regarding the safety of the ‘5 litre 12V BES DC Electric Pressure Cooker’ (EPC) bought in China and intended for domestic customers (see our report ‘A Comparison of Functions and Safety Features on Electric Pressure Cookers’ available from https://www.mecs.org.uk). In summary, the internal and external wires were of inadequate gauge for the expected current, there were jagged metal edges roughly cut inside the cooker base which could quickly abrade wire sheathing, there were minimal safety controls, the lid external temperature exceeded 100°C, plus, worst by far, the power socket was the same shape as an IEC60320 standard 230VAC mains connector - there is nothing to prevent this cooker being connected to a 230V AC mains outlet.

More recently, a smaller, nominally 3 litre version of this manufacturer’s EPC has been obtained, rated for 24V DC. This report details its construction, safety features and thermodynamic behaviour in brief. In the context of the MECS programme, a DC cooker will avoid the need for an inverter in a battery supported system with its associated efficiency reduction and energy loss. 24V nominal voltage level significantly reduces current compared to 12V in general but this example is rated 300W nominal which also reduces current* and eases the burden on the battery capacity and cycle life. In contrast, quite such a low power may lead to excessive pre-heat times. (*Compared to the conventional 1-1.2kW power rating of mains EPCs.)

Despite the lower current, the cabling is barely adequate. The location of internal cables is away from jagged metal edges but not adequately restrained to completely prevent chafing. The cable sheathing is particularly weak. The lid becomes excessively hot. The number of safety features remains minimal. The power socket retains the IEC60320 style. This is absolutely not acceptable for a product intended for use in any country using IEC60320 mains couplers.

1. Functions, Features and Safety Assessment

The cooking pan holds 2.5 litres filled to the brim. Practical capacity will be 2 litres of liquids or 1.5 litres of foaming, frothing or swelling foods such as rice or oats according to the conventional 4/5ths and 3/5ths ratios. The lid is conventional stainless steel with plastic diametric handle that also houses the interlock and steam vent mechanisms. The cooker itself doesn’t include an on/off switch but the power cable is supplied with an inline switch. The underside of the lid supports an aluminium disc which supports the sealing ring as well as protecting the steam vent from contamination or blockage from food splashes, etc. The steam vent release is awkward to operate safely.

Figure 1. EPC and lid from above showing external thermocouple positions and from below with splashguard dismounted.

A simple wiring schematic is shown in figure 2 and can be understood as follows. When power is applied, current flows through the heating element in parallel with the red LED but bypasses the green LED via the NC (normally closed) thermostatic switch mounted to the hot plate underside. The thermostat is marked 140°C. If the hotplate and anything in its immediate proximity (such as the pan and contents) reached 140°C, the switch would open so that current will still flow via the heating element but in series with the green LED and associated 2.66kOhm resistor at approx. 10mA / .25W. The green LED will light, the red LED will extinguish. This would be the so-called 'keep-warm' phase when, in fact, the cooker is cooling down.

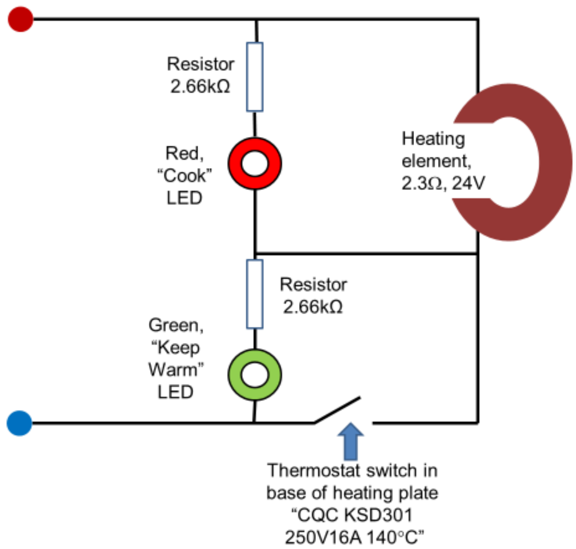

Figure 1. Simple wiring schematic

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 to prevent this and commonly found in EPCs are shown in Table 1.

Table 1 Safety features of electric pressure cookers

Mechanical		BES 24V DC	BES 12V DC
	Weighted pressure vent in lid	80.5g	82.5g
	Pressure activated lid interlock	Y	Y
	Other pressure operated sprung vent	no	no
	Micro-switch lid position sensor	no	no
Electrical			
	Bimetallic power thermostatic switch	Fixed to hotplate, 140°C	Fixed to hotplate, 140°C
	NTC thermistor sensor in sprung button	no	no
	Thermal Bimetal switch on chassis	no	no
	Combined thermal/ pressure switch	no	no
	Thermal fuse	no	no

As a minimum, all EPCs have a safety valve with a simple weight, figure 3. In most EPC's, the hole covered by the weight is approximately 3mm in diameter and the weights are consistently around 80g. The underside of the lid is lined by a removable, perforated aluminium disc. This reduces the risk of the valve being blocked by food as well as carrying the silicone sealing ring, figure 1.

Figure 3. Top of BES 24 V DC EPC showing the weighted valve removed and close up of the orifice.

Generally, steam release pressure varies between 30 and 70 kPa gauge; maximum temperatures at which steam pressure is equal to safety valve orifice pressure have been calculated in Table 2. For the BES 24V 3 litre cooker, calculated venting temperature is 115.2C so that the thermostat must be considered a safety feature not a temperature control feature. This is consistent with other DC products assessed.

Table 2. Pressure release vent static opening pressure and calculated temperatures for a range of electric pressure cookers.

	Weighted pressure vent in lid (+/- 0.5g)	Orifice diameter (mm)	Static gauge pressure at which valve starts to vent (kPa) [100 kPa ~ 1 atmosphere]	Max temperature rise at vent pressure	Pressure marked on weight
BES 24V DC (Chinese domestic)	80.5	3.8	69.6	15.3	n/a
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
Sayona PPS100 (Kenya)	94	3.36	104	20.6	n/a

When pressurised, the silicone sealing ring seals the lid and cooking pan which together form the pressure vessel. To prevent the lid from being turned to open the cooker whilst under pressure (to prevent a sudden release of steam), this BES EPC incorporates the standard steam and pressure-actuated mechanical lid interlock Figure 4. Escaping steam forces a post upwards through a hole in a slider, locking the slider, while internal pressure then keeps the post in position. The slider is connected to a push rod that prevents the lid from turning.

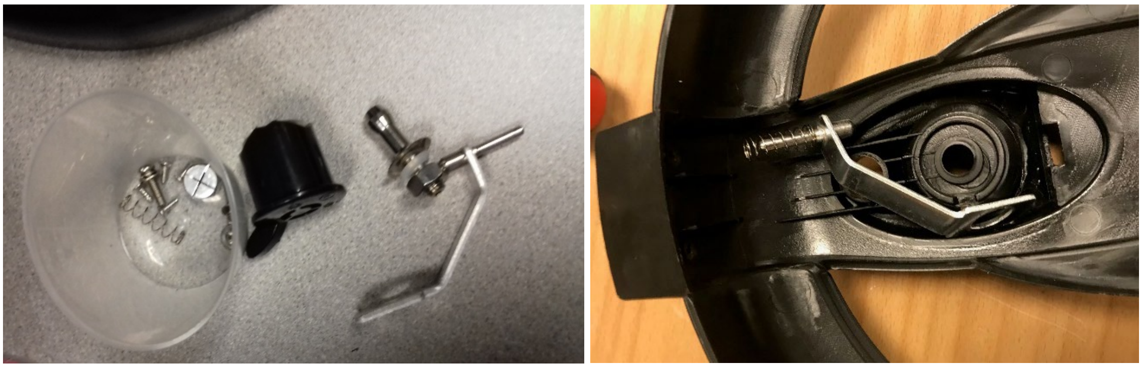

Figure 4. The main valve weight, and parts of the pressure-activated interlock.

In most electric pressure cookers, the heating element/hotplate assembly, and therefore the pan when installed and with the lid fitted, are supported via a strong tempered steel disc. This acts as a spring to allow the pan to move away from the lid as pressure builds between them. In consequence, a switch actuated by this movement will either directly cut power or signal the i.c. controller to cut power to the heating element. This generally appears to be used to mark the completion of the pre-heat or pressurisation stage and commencement of the cooking phase. In the BES cooker, all these components are effectively clamped solidly together.

All EPCs contain a thermal switch or sensor or both. In the BES 24V EPC, like the BES 12V EPC, a bimetal thermal switch (thermostat) is directly bolted to the hotplate, Figure 5.

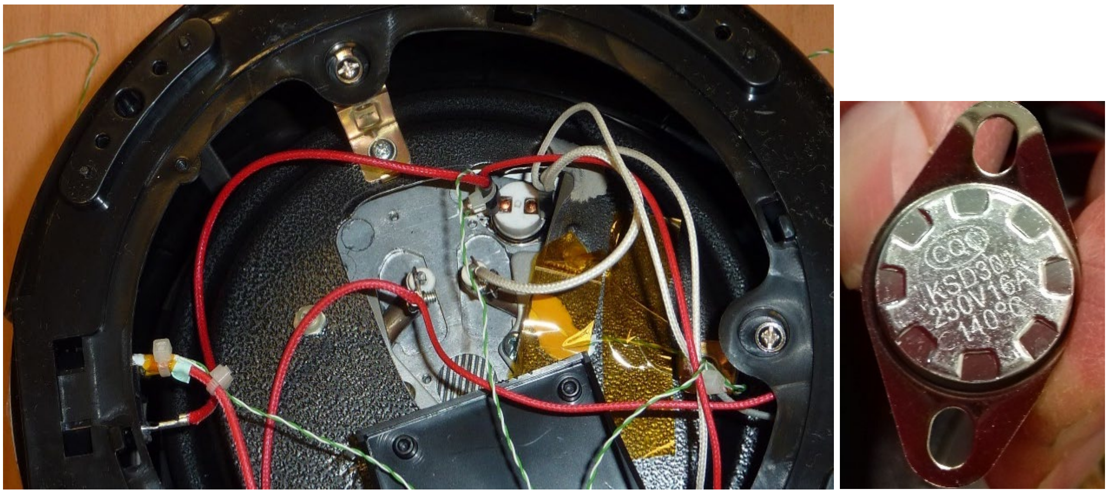

Figure 5. Bimetal temperature switch attached to hotplate showing 'socket', 'chassis' and 'thermostat' thermocouple positions and thermostat removed to reveal labelling

It is notable the BES EPC lacks an in-line thermal fuse to protect against over-temperature as found in most EPCs.

2. Brief Performance Assessment

This report does not contain a comprehensive performance assessment. The improvements demanded in the summary section should improve the cooker performance such that the current performance characteristics can't be assumed to be representative of a modified cooker.

Instead, a brief check of performance in EPC mode and comparison to and validation of performance in a potential rice-cooker mode is made, figure 6 and figure 7.

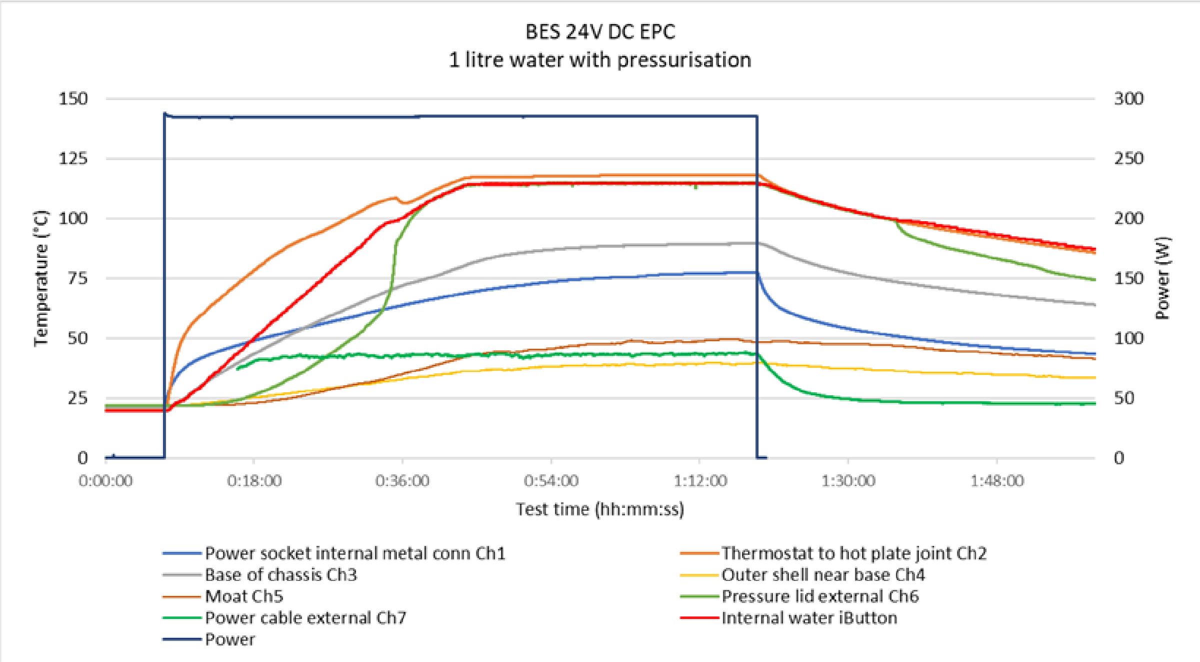

Figure 6. Temperature and power data heating 1 litre water with pressurisation. Power supply set at 25.2V DC (data courtesy of Shahendra Mendis).

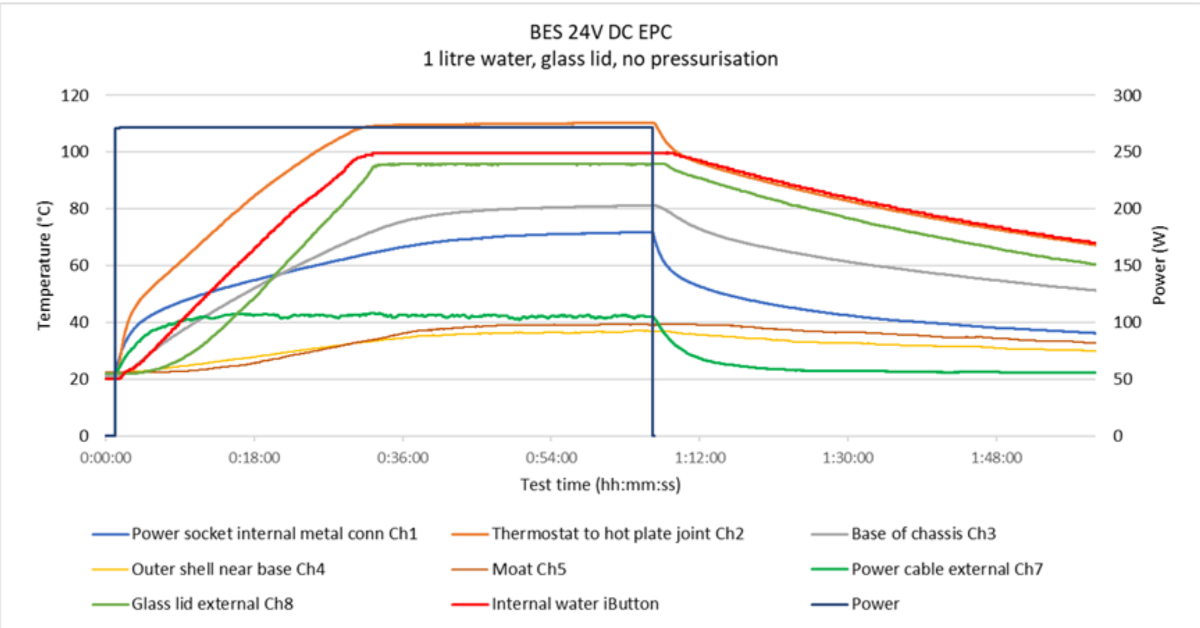

Figure 7. Temperature and power data heating 1 litre water without pressurisation.

Interpretation is as follows. Initially 1 litre water is heated in EPC mode. Temperatures stabilised as shown in figure 6. The apparent discontinuity whilst heating is as boiling begins. The equivalent on cooling is when the water drops below boiling. The valve opening/venting temperature calculates as beginning at 115.3°C. The iButton reported 114.5°C, slightly below the lid external 114.7°C (within measurement error tolerance, but believable). It is worth noting the thermostat switch only reached ~118°C, far below the marked 140°C rating; power cycling did not occur. This type does have a wide tolerance band but not normally this large. The steam vent was continuously venting a low volume of steam. 300W input appears to be balanced with heat losses. Water loss was not recorded.

After an overnight cooling period, 1 litre water was heated in 'rice-cooker' mode, i.e. simply replacing the pressure lid with a glass lid, which fitted well without being tight. Temperature and power data are shown in figure 7. Maximum water temperature predictably reaches 100°C, which supports the accuracy of the iButton data. Other temperatures are a few degrees lower but the cooking (boiling) period was shorter (31 mins vs 54 mins under pressure) and the internal temps can be seen to be still increasing slowly. Water loss was 177g, total energy input was 295 Wh over 1hr 5mins, average power 271.8W. Heating the water used 93.5 Wh, converting 117g to steam consumed 73.3 Wh, leaving 105 Wh absorbed by the cooker and/or radiated away.

Assuming evaporation of 117g occurred evenly during boiling for 35 mins = .056 g/s = 125.7 W leaving 146 W radiated heat loss assuming everything has reached stable temps. One can then estimate thermal mass of the cooker (less lid and compare with pressurised operation. A comparison with other heating methods will be made in a future report.

3. Safety Concerns of the BES 24V Electric Pressure Cooker

The 24V 3 litre model has the same minimal set of safety features as found in the 12V 5 litre model: weighted pressure vent valve, pressure activated lid interlock, thermostatic power switch attached to base of hotplate.

Current drawn

Although the nominal voltage is 24V, emulating the voltage output by a 24V LiFePO4 as 25.6V, the current is measured at approximately 11 A and power 272W. The resistance of the heating element is calculated as 2.38Ω.

Internal power-wire gauge is 0.86mm^2 or approx. 18 AWG which is usually good for 9.5A at 30°C in PVC sheathing. This would strictly be inadequate in this application but similar standards are not available for fibreglass sheathed wire.

The internal wires appear to be sheathed in fibreglass in a soft matrix, possibly latex. Whatever the materials, the abrasion resistance was found to be negligible: scraping the sheath with a thumb nail using moderate pressure for less than 10 repeats was sufficient to expose the inner conductors.

Appliance power connector/coupler

The BES 24V cooker is connected to its external cable by an IEC 60320 C13 connector and C18 inlet. The C13/C14 plug and socket carry three pins and are typically used for personal computers. 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 measured rising to 75°C when used within the BES 24V cooker.

In addition, and of even greater concern, is that the BES 24V cooker could be connected to a 230V AC grid electricity supply using another IEC 60320 plug lead. If that were to happen, the BES 24V cooker would briefly attempt to draw over 23 kW. At best, the large current would fail 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.

Jagged metal edges

Internal examination reveals a rough-cut hole in the chassis of the BES 24V DC cooker, exactly like the 12V version, Figure 8. Internal wires could rub against the edges of this hole.

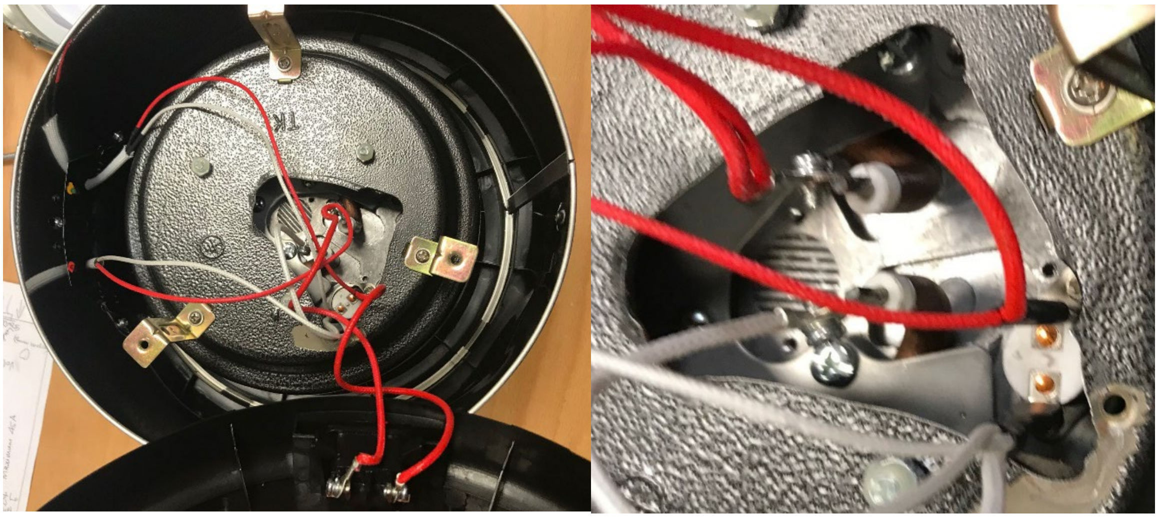

Figure 8. BES 24V DC EPC chassis showing jagged roughly cut hole and wires

4. Modifications

The following modifications will be required *inter alia* to enable a modified version of the product to meet the requirements set out *inter alia* within BS EN 60335-1 ‘Household and similar electrical appliances – Safety Part 1: General requirements’ in general, BS EN 60335-2-15:2016 ‘Part 2-15: Particular requirements for appliances for heating liquids’ in particular and BS EN 12778:2002 ‘Cookware – Pressure cookers for domestic use’ specifically. Independent testing would be required to prove product conformity against these standards. Additionally, CE marking assurance would need to be passed to an external organisation in order for the MECS programme and Loughborough University to be adequately absolved from product liability.

1. Replace the IEC60320 AC socket with a polarised DC inlet of suitable current capability and provide sufficient sockets and cabling of the same specification to connect the appliance through to the DC power supply. Ensure connections are made by competent persons.

2. Replace the wiring harness with suitable gauge wire rated for the local environment temperature in the enclosed base of the cooker (as illustrated in figures 6 and 7). The sheathing should be suitable for elevated surrounding temperatures and abrasion resistance.

3. Ensure the internal cabling is suitably restrained to avoid the possibility of chafing against metal edges.

4. Apply and fix an additional layer of suitable sheathing such as loose fibreglass tubing where cabling passes through metal apertures having unfinished edges or replace the components having such unfinished edges. Apply and fix in place suitable protection such as gromets or split rubber-tubing to the edges of unfinished apertures in metal or other potentially abrasive materials.

5. Add a switch that cycles at appropriate temperatures leaving the 140°C switch as a fail-safe. This should reduce the cooking-phase average power to 100W or better.

6. Add a non-resettable failsafe such as a thermal fuse inserted into the power conductor.