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Prepared for
PIVOT STOVE AND HEATING



**PARTICULATE EMISSIONS, POWER OUTPUT AND
THERMAL EFFICIENCY TESTING OF THE
CHARNWOOD AIRE 3 FREE-STANDING SOLID
FUEL APPLIANCE**

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by

Steve Marland



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Revision Details

Revision	Date	Comments
0	18/11/2020	Preliminary Issue – pending payment of invoice and engineering drawings
1	15/12/2020	Issue of NATA endorsed test report

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EXECUTIVE SUMMARY

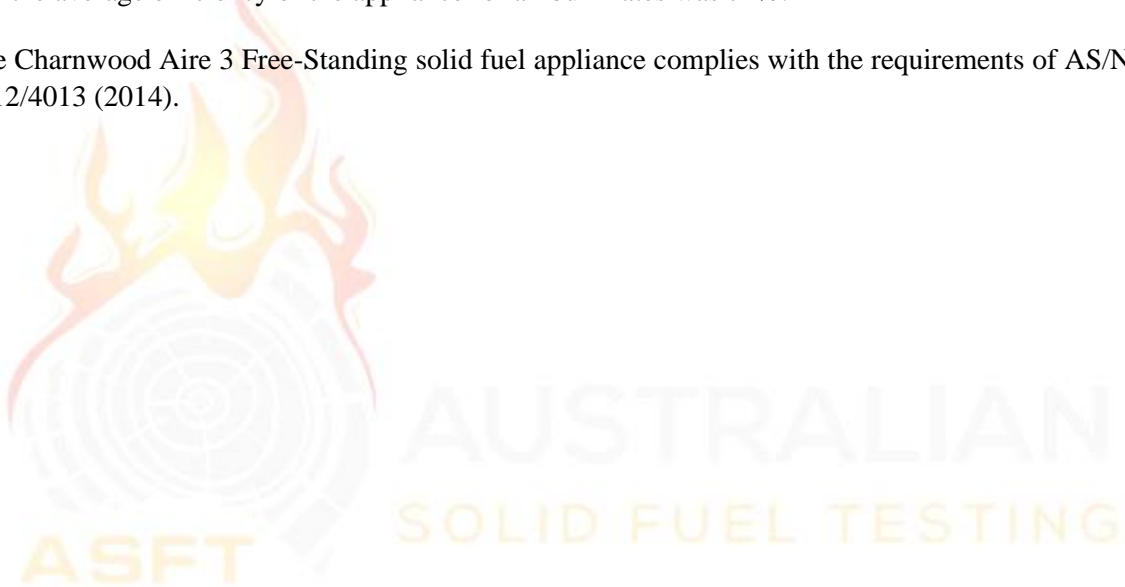
The Charnwood Aire 3 Free-Standing solid fuel appliance was tested for particulate emissions power output and efficiency according to the requirements of the joint Australian/New Zealand Standard AS/NZS 4012/4013 (2014).

Below is a summary of the appliance results;

Primary Air Settings	Average Power (kW)	Average Peak Power (kW)	Efficiency (%)	Average Dry Fuel Consumption Rate (kg/hr)	Average Burn Time (mins)	Particulate Emission Factor (g/kg) Oven Dry Wood
High	2.7	3.5	71	0.7	109	1.0
Medium	2.0		74	0.5	158	1.0
Low	1.6		76	0.4	213	1.8

The appliance particulate emissions factor was 1.3g/kg of hardwood that complies to AS/NZS 4014.1, and the average efficiency of the appliance for all burn rates was 74%.

The Charnwood Aire 3 Free-Standing solid fuel appliance complies with the requirements of AS/NZS 4012/4013 (2014).



Signed	
Name	Steve Marland
Title	<i>Managing Director – Australian Solid Fuel Testing</i>
Date	15 December 2020

1 INTRODUCTION

Testing of the Charnwood Aire 3 Free-Standing took place from November 12 to 17, 2020 at the Australian Solid Fuel Testing Laboratory located at 3 Garden Street, Morwell, Victoria. The testing was performed by Mr S. Marland and Mr G. Mooney.

Particulate emissions, power output and thermal efficiency testing of the appliance was performed according to the requirements of the joint Australian/New Zealand Standard AS/NZS 4012/4013 (2014).

The appliance was tested using hardwood as the test fuel. This test fuel was used after conforming to the requirements of the joint AS/NZS 4014.1 (1999).

2 INSTALLATION OF THE APPLIANCE

The appliance firebox was measured according to the method described in the joint standard AS/NZS 4012. The appliance fuel load, fuel length and number of wood pieces were then calculated as per section 5 of AS/NZS4012.

Prior to testing, the appliance was burnt for a minimum of 16 hours (two \times 8 hours) as per section 6.1.2 of AS/NZS4012:2014.

Testing was conducted according to the manufacturer's verbal or written instructions (joint AS/NZS 4013 Paragraph 8.20[c]).

3 PROCEDURE

The appliance firebox was measured according to the method described in the joint standard AS/NZS 4012. The appliance fuel load, fuel length and number of wood pieces were then calculated as per section 5 of AS/NZS4012. The test fuel was loaded according to the manufacturer's instructions.

Appendix 1 shows photographs of the appliance under test and a typical fuel load and loading geometry.

3.1 Power Output and Thermal Efficiency (AS/NZS4012)

Australian Solid Fuel Testing uses a calorimetry room which is an insulated room (75 mm thick polystyrene lined on walls, floor and ceiling) of internal dimensions 3.0 m \times 3.0 m \times 2.4 m high.

Air flow into the room is via a 300 mm diameter duct from a manually controlled variable speed fan. Air flow out of the room is via a 300 mm diameter duct also connected to a variable speed fan. The outlet duct air pressure is kept at 57Pa (recorded on Dwyer digital 607D-11 manometer) while the inlet air fan speed is adjusted via the variable speed drive to keep the calorimeter room at atmospheric pressure. (by use of a Dwyer digital DP 607D-02 manometer)

Air flow temperatures are measured by three type K thermocouples (batch calibrated by ECE Fast report 14705) in both the inlet and outlet ducts. The Appliance being tested sits on a 0 –600 kg digital

platform scales (Ohaus VE1500RA). The flue system consists of an insulated silicone oil bath that isolates the weight of the appliance from the remainder of the flue. The flue, where it exits from the room, passes into an insulated flue casing. Total flue length above the top of the scales is set at 4.6 ± 0.1 m.

Temperatures and transducer signals are fed to a National Instruments DAQMX that is connected to a computer. A digital signal from the scales is also sent to the computer. The ASFT Labview/SQL designed computer program records all data and displays realtime results as they are collected.

The calorimeter room heat losses through the walls have been measured and accounted for by calibration from an electrical resistance heater of known output (NATA certified kWhr meter).

3.2 Particulate Emissions (AS/NZS4013)

The emissions equipment consists of a dilution tunnel, collection hood, pitot tube and NATA certified digital manometer (Dwyer digital DP 607D-02) for air flow measurement and sampling train/probe.

The sampling train/probe consists of a sample probe, double filter assembly, including thermocouple, a gas drier, vacuum pump and NATA certified gas meter (Landis & Gyr).

Grade 333, forty-seven millimetre glass fibre filters are pre-weighed (by way of Ohaus PA114C balance) and are mounted in the filter assembly.

Data from thermocouples, manometer and dry gas meter is fed to a National Instruments DAQMX and ASFT's labview/SQL designed computer program. The particulate emissions information is collected at the same time as data from the calorimeter room.

At the completion of a burn cycle, the filters are removed from the filter holders and placed in a desiccator for drying. Condensed and entrapped emissions from the sample probe are washed with acetone into a glass beaker. A rifle cleaning rod is used to clean the inside of the sampling probe. The cleaning rod is then washed with acetone (into the glass beaker). The acetone washing is allowed to vaporise to dryness and the residue weight determined. The two dried filters are re-weighed.

Emission weight is then determined by totalling the filter weight increases from the two filters and the residue from acetone washings.

4 DETAILS OF APPLIANCE

The test results reported directly relate to the appliance provided by the manufacturer for testing. The details of the appliance given in this section include features which may affect the particulate emissions, power output and thermal efficiency. Any change in the design/construction of this appliance may invalidate this report. Engineering diagrams were sighted and checked by Australian Solid Fuel Testing against test appliance measurements recorded in the table below. (joint AS/NZS 4013 Paragraph 8.2 [d]).

Appliance Model Name: Aire 3		Serial No: AA00500
Manufacturer: Charnwood		
Overall Height: 665mm	Overall Depth: 345mm	Overall Width: 375mm
Top Plate Width: 375mm	Top Plate Depth: 315mm	Top Plate Thickness: 10mm
Log Storage Area Height: 110mm	Depth: 260-270mm	Width: 340mm
Usable Firebox Height: 200-230mm	Width: 273mm	Depth: 140mm
Usable Firebox Volume: 8.6 Litres		
Firebox Material Type/Seam Fully Welded: Fully welded 5mm steel		
Firebrick Type: 30mm compressed vermiculite		
Main Door Opening Height: 288mm	Width: 274mm	
Door Height: 367mm	Width: 340mm	Depth: 30-42mm
Door glass Height: 215-235mm	Width: 258mm	
Primary Air Location: Below firebox		
Dimension of Primary Air: Fully open, 2 slots 25×17mm + 2 slots 7×13mm Open to 1st click, 2 slots 10×17mm + 2 slots 10×10mm Fully closed, 5×17mm + 2 trapezoids 5mm top, 10mm bottom, 4mm high		
Area of Primary (mm ²): Fully open, 850 + 182 = 1032mm² 1st click, 340 + 200 = 540mm² Fully closed, 170 + 60 = 230mm²		
Secondary/Tertiary Air Location: Rear of firebox, 30-60mm below baffle		
Dimension of Secondary/Tertiary Air: 30 holes @ 3mm		
Area of Secondary/Tertiary Air (mm ²): 212.1mm²		
Baffle Plate size: 290×144×30mm compressed vermiculite		
Flue Dimensions: 152mm		
Spigot Dimensions:	OD: 142mm	ID: 135mm
Spigot to Rear of Appliance: 60mm		
Rear Internal to External Heat Shield: 37mm		
Firebox to Side External Heat Shield: N/A		
Heat Shield Material Type: 1.4mm steel		
Water Heater Fitted: N/A		
Fan Location/Speeds: No		
Catalytic Combustor fitted: No		
Grate: No		
Ash pan: Yes		
NOTE: Accuracy of measurement is ±5% of the measured value		

4.1 Test Fuel

The appliance was fired using the fuel type specified in the table below;

Fuel Type	Hardwood
Common Name	Redgum
Scientific name	Eucalyptus Camaldulensis
Average Fuel load	1.5kg
Average moisture content	13.7%
Dry density	0.86kg/L
Fuel length	112mm
No. of pieces	2
Method of loading (fuel placement)	Front to rear
Calorific Value (Gross Dry)	20.5MJ/kg
Ash Content	<0.1% db

ASFT AUSTRALIAN SOLID FUEL TESTING

5 RESULTS

5.1 High Burn Cycles

The appliance was fully fired in accordance with Section 6.3(a) of the joint AS/NZS 4012. Below is a table of the appliance setting for the high burn cycles;

Primary air setting	Average Fuel load	Fan Setting
20mm (1032mm ²)	1.4kg	N/A

5.2 Low Burn Cycles

The appliance was fired in accordance with Section 6.3(b) of the joint AS/NZS 4012. Below is a table of the appliance setting for the Low burn cycles;

Primary air setting for first 20% fuel reduction	Primary air setting after 20% fuel reduction	Average Fuel load	Fan Setting
20mm (1032mm ²)	0mm (230mm ²)	1.5kg	N/A

5.3 Medium Burn Cycles

The appliance was fired in accordance with Section 6.3(c) of the joint AS/NZS 4012. Below is a table of the appliance setting for the Medium burn cycles;

Primary air setting for first 20% fuel reduction	Primary air setting after 20% fuel reduction	Average Fuel load	Fan Setting
20mm (1032mm ²)	5mm – 1 st click	1.5kg	N/A

5.4 Leak Test Results

The appliance passed the post-conditioning air flow test with a flue velocity of 0.70m³/min at 25 Pa (<1 m³/min required in Standard).

The appliance passed the post-burn air flow test with a flue velocity of 0.74m³/min at 25 Pa (<1 m³/min required in Standard).

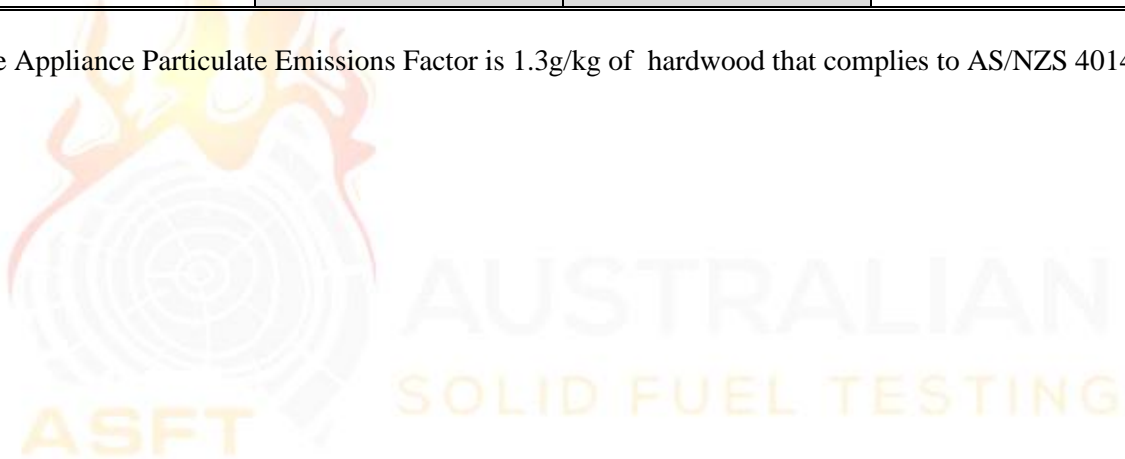
The appliance conforms with clause 6.10 of AS/NZS 4012 (2014).

5.5 Particulate Emissions Factor

The table below shows the particulate emissions values for each burn cycle and the resultant appliance particulate emission factor.

Primary Air Setting	Total Emission Weight (mg)	Sample Dilution Tunnel Ratio	Particulate Emission Factor (g/kg) Oven Dry Wood
High No 1	1.6	1012.5	1.3
High No 2	1.0	1006.9	0.8
High No 3	1.1	970.5	0.9
Average			1.0
Medium No 1	1.0	990.5	0.8
Medium No 2	1.4	1011.9	1.1
Medium No 3	1.3	1070.5	1.1
Average			1.0
Low No 1	2.8	1060.4	2.4
Low No 2	1.9	1064.5	1.6
Low No 3	1.6	1009.6	1.3
Average			1.8

The Appliance Particulate Emissions Factor is 1.3g/kg of hardwood that complies to AS/NZS 4014.1.



5.6 Efficiency/Power Results

The tables below shows the summary of the appliance average power, dry fuel consumption rate and burn time for each burn cycle.

Primary Air Settings	Average Power (kW)	Average Peak Power (kW)	Efficiency (%)	Average Dry Fuel Consumption Rate (kg/hr)	Average Burn Time (mins)
High	2.7	3.5	71	0.7	109
Medium	2.0		74	0.5	158
Low	1.6		76	0.4	213

Appliance Combined Efficiency is 74% when tested with hardwood that complies to AS/NZS 4014.1.

Primary Air Setting	Commencement Date and Time	Cycle Time (mins)	Average Power (kW)	Wet Wood Mass (kg)	Wood Moisture Content (wt%)	Power Efficiency (%)	Peak Power (kW)	Dry Fuel Consumption Rate (kg/hr)
High No 1	12/11/2020 10:15	109	2.68	1.45	15.7	70.0	3.46	0.67
High No 2	12/11/2020 12:14	120	2.40	1.40	13.7	69.8	3.55	0.60
High No 3	12/11/2020 14:23	99	2.99	1.40	13.7	72.0	3.51	0.73
Medium No 1	16/11/2020 12:45	159	2.06	1.45	12.9	75.9		0.48
Medium No 2	16/11/2020 15:28	150	2.14	1.50	14.1	72.8		0.52
Medium No 3	16/11/2020 18:02	165	1.94	1.50	13.7	72.0		0.47
Low No 1	12/11/2020 19:38	209	1.55	1.45	14.5	76.5		0.36
Low No 2	13/11/2020 08:43	195	1.73	1.45	12.2	77.3		0.39
Low No 3	13/11/2020 12:24	234	1.40	1.45	12.4	75.4		0.33

5.7 Uncertainty of Measurement Statement

- a) The uncertainty of temperature measurement during the entire test period was $\pm 1.5^{\circ}\text{C}$ (at the 95% confidence level).
- b) The uncertainty of power measurement was $\pm 5\%$.
- c) The uncertainty of the outlet air pressure was $\pm 0.6\text{ Pa}$.
- d) The uncertainty of the dilution tunnel pressure was $\pm 1\text{ Pa}$.
- e) The uncertainty of particulate emission weights was $\pm 0.4\text{ mg}$.
- g) The uncertainty of the test fuel mass was $\pm 50\text{ gm}$ (on appliance balance).

6 CONCLUSION

The Charnwood Aire 3 Free-Standing solid fuel burning appliance produced an appliance particulate emissions factor of 1.3g/kg and an average efficiency of 74% for all burn rates, using hardwood that complies to AS/NZS 4014.1, when tested according to joint AS/NZS 4012, AS/NZS 4013 (2014).

The Charnwood Aire 3 Free-Standing solid fuel burning appliance complies with the requirement of a combined efficiency of not less than 60% and a particulate emissions factor of not greater than 1.5g/kg of hardwood that complies to AS/NZS4014.

APPENDIX 1



Figure 1: Appliance during testing.



Figure 2: Test fuel load.