Final Report for determining the energy CO_2 and costs savings using the Chimney Sheep®

Final Report 57966/1

Carried out for
Chimney Sheep Ltd

By Vitor Carneiro

21st October 2016

Final Report for determining the energy CO_2 and costs savings using the Chimney Sheep®

Carried out for:
Chimney Sheep® Ltd
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Contract: **Final Report 57966/1**

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1 INTRODUCTION

This report details the methodology developed and subsequent results of laboratory tests carried out at BSRIA to determine the energy CO_2 and costs savings when using the Chimney Sheep ® chimney draught excluder installed in a chimney. The work was requested by Sally Phillips of Chimney Sheep Ltd, and the test work was carried out on 26th and 27th April 2016.

The above tests were conducted under BSRIA's UKAS accreditation in accordance with ISO17025. Comments and opinions are outside the scope of the UKAS accreditation.

The results in this report are based on tests carried out on a 200 mm diameter sample of the above mentioned product.

The energy / cost / carbon savings given are for a reference airflow rate of 40m^3/hr according to SAP2012.

This report refers only to the items tested and no others.

2 OBJECTIVES

The objectives of the project were as follows:

1. To develop a methodology that produces robust test data to be used to determine the energy, CO_2 and costs savings.
2. To conduct a series of laboratory tests in accordance with the methodology developed in item 1 in order to quantify the reduction in the air flow rate up the chimney when the draught excluder is installed in the chimney.
3. To produce a detailed report including calculations to determine the energy, CO_2 and costs savings in accordance with the methodology developed in item 1.

All tests were conducted in accordance with the methodology as defined in BSRIA Methodology Report 57966/8 and Section 6 of this report, which describes the procedure used to carry out the laboratory tests and how the energy and CO_2 savings were determined.

3 ITEMS RECEIVED FOR TEST

Chimney Sheep Ltd. provided a batch of 8 chimney draught excluders for test, each with a diameter of 200mm. The samples were made from 100% Herdwick wool and had a plastic handle. One sample was selected at random in order to carry out the testing.

Figure 1 200mm sample of Chimney Sheep® chimney draught excluder

The Chimney Sheep® is claimed by the manufacturer to be a simple and effective method of blocking the bottom of the chimney on open fire places (when not in use) to prevent the heat from the primary heating within dwellings from being lost up the chimney.

The Chimney Sheep® works by being a little larger than the flue so it can grip onto the sides and hold itself in place. The amount of overlap is not critical as the material from which it is made is compressible and can fit into a range of gaps. The Manufacturer's manual may be found in Appendix F.

4 TEST FACILTY

Testing was carried out using a purpose-designed fireplace and chimney, typical of those found in dwellings with a height of approximately 4.5 m located inside an environmental chamber at BSRIA's laboratory in Bracknell.

The masonry flue was constructed using Dunbrik Class A1 concrete flue liners and was encased in LBC facing bricks. The internal diameter of the flue lining was 200 mm (minimum requirement in the Building Regulation ADJ (Approved Document J)) and will accommodate the vast majority of solid fuel burning appliances (whether or not a fireback is installed) and both Decorative and Inset Living Flame Effect gas fires as well as most domestic stoves. The flue design is suitable for all domestic fuels including coal and properly seasoned wood. The flue liner complies with the requirements within ADJ, BS EN 1857 for appliances using solid and gaseous fuels.

The fireplace opening was sized in relation to the flue height and the flue internal diameter in accordance with appendix A of the methodology and represents a typical fire place for an open fire. The fireplace is constructed with a builders maximum recess opening of 610 (H) by 600 mm (W).

The outlet of the chimney was connected to a section of ductwork that was in turn connected to a Laminar Flow Element (LFE) where the differential pressure was measured using a differential pressure transducer in order to determine the airflow. The outlet of the LFE was connected to a variable speed fan via another section of ductwork. The variable speed fan was installed in the same environmental chamber as the fireplace.

A static pressure ring was installed on the section of ductwork (before the LFE) that was in turn connected to a pressure transducer.

Two temperature sensors were installed on the test rig, where the first sensor was inserted into the ductwork near the inlet of the LFE in order to measure the ambient temperature and subsequently correct the measured airflow. The second temperature sensor was located at the inlet of the fireplace.

A relative humidity sensor was located at the inlet of the fireplace throughout testing.

Figure 2 and Figure 3 show a schematic and a photograph of the test rig respectively.

Figure 2 Schematic of Test Facility

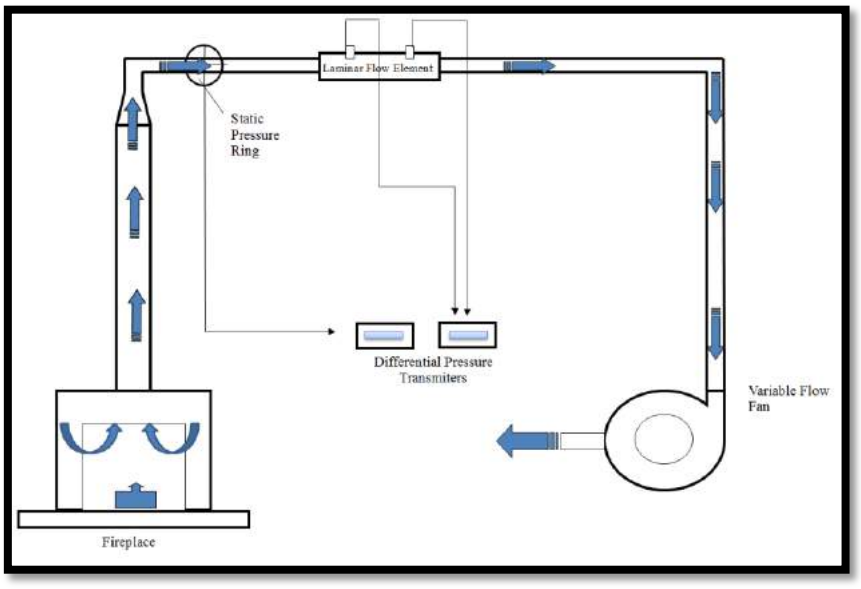


Figure 3 Fireplace and Chimney

5 INSTRUMENTATION

Table 1 shows a list of the instrumentation used during testing.

Table 1 Instrumentation

Instrument	Serial number and BSRIA ID number	Calibration Expiry Date
FC0332 Transmitter (0 to + 50 Pa)	Serial no: 1210063 - BSRIA ID number 1353	22-02-2017
FC0332 Transmitter (0 to +100 Pa)	Serial no:990471 - BSRIA ID number 2975	01-02-2017
FC0332 Transmitter (0 to +500 Pa)	Serial no:0740312 - BSRIA ID number 2987	11-02-2017
FCO96G-200L Flow Element (0 – 200 L/min)	Serial no:9640418	22-12-2018
FCO96 Flow Element (500 – 2000 L/min)	Serial number 871189 - BSRIA ID number 56	12-02-2017
Platinum Resistance Thermometer (PRT's)	BSRIA ID number 2976 to 2984	22-01-2017
2005 Extech HD500 Mulifunction meter (Humidity)	Serial number 09108256 - BSRIA ID number 2005	30-09-2016

6 TEST METHOD

6.1 REDUCTION IN AIRFLOW PERFORMANCE TEST PROCEDURE

The reduction in airflow performance tests were designed to measure the reduction of the airflow rate when the Chimney Sheep® is inserted in the chimney compared to open chimney. The measured reduction of the airflow rate was then used in the calculations to determine the energy, CO_2 and cost savings.

Before commencement of testing, the chimney and airflow measuring system was tested for gas tightness to check compliance against the gas tightness requirement (maximum leakage rate) of 2.0 litres/sec/m^2 at a test pressure of 40 Pa in accordance with BS EN 1857:2010 "Chimneys – Components- Concrete flue liners.

The measured leakage rate of the chimney was 0.389 litres/sec/m^2 which was within the maximum allowable leakage rate as defined in BS EN 1857:2010.

During the airflow performance tests the average ambient temperature in the environmental chamber and in the ductwork were such that no correction factors had to be applied to the airflow measured by the Laminar Flow Element (LFE).

Spot readings of relative humidity at the inlet of the fireplace during testing were recorded with an average of 29.5%.

The following methodology was applied in order to determine the reduction in airflow performance as a result of the Chimney Sheep® being inserted in a chimney:

1. The first test was carried out with an open chimney (Chimney Sheep® not installed). The fan speed was adjusted to provide an airflow in m^3/hr of 10, 20, 30, 40, 50, 60, 70 and 80 respectively. At each airflow rate the static pressure in the ductwork and the differential pressure across the LFE (500 – 2000 l/min range) was measured.

2. The Chimney Sheep® was inserted in the chimney as per the instructions provided by Chimney Sheep Ltd (See Appendix D) and the fan speed was adjusted to provide an airflow in m^3/hr of 1, 2, 4, 6, 8 and 10 respectively. At each airflow rate the static pressure in the ductwork and the differential pressure across the LFE (0-200 l/min range) was measured.

3. A period of 2 minutes was allowed for stabilisation at each airflow prior to the data collection period. Throughout the reduction in airflow performance tests data was logged at 60 second intervals for a period of 3 minutes once stability was achieved.

4. The airflow rate was calculated using the measured differential pressure across the LFE.

6.2 REDUCTION IN AIRFLOW PERFORMANCE CALCULATIONS

The static pressure measured in the ductwork was plotted against the calculated airflow rate as shown in Section 7.1. The blockage factor was determined based on the measured reduction of the airflow using the following formula:

The blockage factor (B_F) is defined as = $(Q_{ref} - Q_{Chimney\ Sheep®})/ Q_{ref}$ (1)

Where:

Q_{ref} *=reference airflow rate in open chimney (40* m^3*/hr)*

$Q_{Chimney\ Sheep®}$ *= air flow rate in chimney with Chimney Sheep®*

The reference airflow rate of 40 m^3/hr was obtained from the Government's Draft SAP 2012 document (Table 2.1 of the methodology) for a chimney with open flue conditions. See Table 2.1 in Draft SAP 2012.
http://www.bre.co.uk/filelibrary/SAP/2012/Draft_SAP_2012_December_2011.pdf

The actual airflow rate or ventilation rate through a chimney in a dwelling without the operation of the fire is dependent of different factors, including the following:

6.2.1 Stack effect

This is a function of the internal/external temperature differences, chimney height and opening area. The opening area will consist of the total equivalent area of permanent open air vents within the room where the chimney is installed and the leakage area from the building air tightness tests. The leakage area is a result of inadvertent gaps and openings in the structure of the dwelling and permeability of the materials.

6.2.2 Wind effects

The effect of external wind conditions on the airflow rate in a chimney is complex and subject to various parameters. When wind blows across a building, it is most likely to produce a pressure differential between the bottom of the chimney and the chimney terminal. This will depend upon the following:

1. Wind speed and direction, which will be affected by geographical features and climatic conditions (e.g. hills and valleys).

2. Aerodynamics of the chimney terminal - There are many designs of terminals that are fitted to chimneys. Each design would have a different aerodynamic performance and would therefore affect the air flow within a chimney differently.

3. Position of the chimney terminal in relation to the building- Chimneys are fitted on roof ridges, between ridges, flat roofs etc. The wind speed at the chimney termination would therefore be dependent on the siting.

4. Slope of the roof and whether the chimney is installed on the windward or leeward side. There can be adverse effects (downdraughts) on the air flow within open chimneys that are installed on the windward slope of a roof on a building due to the positive pressure in this region.

5. Location of neighbouring buildings and structures. The above variables can result in a increased airflow, reduced airflow or intermittent downdraught in an open chimney.
   For the purposes of this study, the effects of wind speed were therefore not considered for the calculations.

6.3 LIFE CYCLE TEST PROCEDURE

The life cycle tests follow the reduction in airflow performance tests and were designed to determine how effective the Chimney Sheep® is at reducing the airflow after it is removed and reinstalled from the chimney a number of times by the homeowner.

The main objective was to determine after how many cycles the chimney draught excluder performance began to deteriorate.

One complete cycle was defined as the period when the Chimney Sheep® was inserted once into the chimney and subsequently removed. On each cycle the Chimney Sheep® was inserted into the chimney and a period of one minute was given to allow the sample to "relax" prior to the test commencing.

The number of test cycles up to 300 represents the estimated maximum usage of the Chimney Sheep® over a period of 10 years assuming the chimney draught excluder is inserted and removed 30 times per year.

6.4 ENERGY, CO2 & COST SAVINGS CALCULATIONS

The energy, CO_2 and cost savings as a result of inserting the Chimney Sheep® into the chimney are due to a reduction in airflow up the chimney. The airflow through a chimney is dependent on the dwelling air infiltration rate through the purpose provided permanent vent, additional adventitious ventilation due to living room permeability, height of the chimney, temperature differences between the inside and outside of the dwelling etc.

Energy saving measures such as cavity wall and loft insulation, double glazing, use of condensing boiler, will not affect the airflow infiltration rate as this is fixed by the size of the purpose provided permanent vent and cracks/openings in the building structure. The savings from the Chimney Sheep® chimney draught excluder are therefore not influenced by these energy savings measures; hence these variables are not considered in the calculations.

Previous work conducted by BRE for the client has shown that energy/CO_2 savings produced by the Chimney sheep are neither influenced by the type or structure of dwelling and energy/carbon savings measures that are already installed. The losses through the chimney will be the same whether it's a mid-terrace house or a detached house, if the hours of heating, internal temperature, external temperature and wind, and leakage areas (including chimneys) are the same. The savings from the chimney sheep are therefore only related to the reduction in the air flow rate of warm air up the chimney. This is demonstrated in the savings reported in the BRE paper which, in kWh, are similar for the different house types.

The main variables which will affect the energy/CO_2 and cost savings are therefore:

1. The volumetric flow rate of air up the chimney (Q ref)
2. The blockage factor of the chimney sheep
3. The temperature difference between the inside and outside air of the dwelling
4. The heating season length and hours of operation of the primary heating system
5. The fuel type and fuel tariffs
6. The efficiency of the primary heating appliance
7. The number of chimneys

6.4.1 Energy & cost savings formulas

The energy and cost savings were calculated using the following formulas using three types of energy source, mains gas, heating oil and electricity. The formulas are applicable to all types of dwellings with single and multiple chimneys:

$$\textit{Energy Savings/annum (kWh)} = N \times (B_F \times \rho \times Q_{Ref} \times C_p \times \Delta T \times P)/3600\,\acute{\eta} \quad (2)$$

$$\textit{Energy costs savings/annum (£)} = N \times (B_F \times \rho \times Q_{Ref} \times C_p \times \Delta T \times P \times \Phi)/3600\acute{\eta} \quad (3)$$

Where:

N = *number of chimneys*

B_f = *blockage factor*

(ρ) = *the density of air* (ρ) *at* 21^oC *i.e.* $\rho = 1.23\ kg/m^3$

Q_{ref} = *reference airflow rate in open chimney* $(40\ m^3/hr)$

C_p = *specific heat capacity of air at* 21^oC *i.e.* $C_p = 1.005kJ/(kg\ K)$

ΔT = *the temperature difference between the inside and outside air of the dwelling which is* $11.73\ ^oC$. *See section 6.4.2*

P = *heating season length (days) ×hours of operation of the primary heating system (hrs)*

In accordance with the normal SAP heating schedule, the heating season would comprise 68 weekend days with 16 hours of heating and 170 weekdays with 9 hours of heating (2 hours in the morning and 7 hours in the evening). Hence P = 2618 hrs

$\acute{\eta}$ = *Sedbuk efficiency of primary heating appliance (%) - See Table 2*

Φ = *SAP fuel tariff for gas and oil (pence/kWh) - See Table 3*

Table 2 shows the SEDBUK Efficiencies for multiple boiler types taken from SAP 2012, Table 4B.

Table 2 Sedbuk Efficiencies

Boiler Type	Sedbuk Efficiences %
Regular condensing gas boiler with automatic ignition	84
Standard oil fired boiler 1985 to 1997	71
Electric heat pump for water heating only*	170

* "If available use data from the boiler database instead of the value in this table. This is done by assigning a second main heating system with space heating fraction of 0." (SAP 2012 page 206)

Table 3 shows the fuel prices for multiple energy sources taken from SAP 2012, Table 12.

Table 3 Fuel Prices

Fuel Type	Φ Fuel Prices Pence/kWh
Mains gas	3.48
Heating oil	5.44
Electricity (standard tariff)	13.19

6.4.2 Heating days in a season

For the present calculation SAP 2012 references were taken in consideration as per section "N3.3 Mean Internal temperature".

Regarding the amount of date to be displayed in this report it was agreed with client to choose the external temperature for "UK average" in order to determine energy and CO_2 savings.

According to SAP 2012, the heating season comprises the following months: Jan, Dec, Feb, Mar, Nov, Apr, Oct, May (coldest to the warmest).

The average external temperatures can be found in Table 4 - Table U1: Mean external temperature (°C) – SAP 2012. With the previously months chosen it is possible to get the average external temperature as formula 4 demonstrates.

$$\text{UK average} = \frac{Jan + Feb + Mar + Apr + May + Oct + Nov + Dec}{8\ months} = 7.28℃ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Referring to SAP 2012 - "N3.3 Mean Internal temperature", the mean room temperatures recorded during the heating season were 19.3°C for the living room, 18.8°C for the hallway and 18.9°C for the bedroom, the averages of which resulted in a mean temperature of 18.8°C for zone 2 and 19.0°C for the whole dwelling."

Using the reference 19.0°C for the whole dwelling, the temperature difference between the inside and outside air of the dwelling will be:

ΔT = 19.0°C - 7.28 °C = 11.73°C ... . *(5)*

This ΔT of 11.73°C is then the final value to be used in energy & cost savings formulas.

Table 4 Table U1: Mean external temperature (°C) – SAP 2012

Region	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 UK average	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2
1 Thames	5.1	5.6	7.4	9.9	13	16	17.9	17.8	15.2	11.6	8	5.1
2 SE England	5	5.4	7.1	9.5	12.6	15.4	17.4	17.5	15	11.7	8.1	5.2
3 Southern England	5.4	5.7	7.3	9.6	12.6	15.4	17.3	17.3	15	11.8	8.4	5.5
4 SW England	6.1	6.4	7.5	9.3	11.9	14.5	16.2	16.3	14.6	11.8	9	6.4
5 Severn Wales/England	4.9	5.3	7	9.3	12.2	15	16.7	16.7	14.4	11.1	7.8	4.9
6 Midlands	4.3	4.8	6.6	9	11.8	14.8	16.6	16.5	14	10.5	7.1	4.2
7 West Pennines	4.7	5.2	6.7	9.1	12	14.7	16.4	16.3	14.1	10.7	7.5	4.6
8 NW England SW Scotland	3.9	4.3	5.6	7.9	10.7	13.2	14.9	14.8	12.8	9.7	6.6	3.7
9 Borders England Scotland	4	4.5	5.8	7.9	10.4	13.3	15.2	15.1	13.1	9.7	6.6	3.7
10 NE England	4	4.6	6.1	8.3	10.9	13.8	15.8	15.6	13.5	10.1	6.7	3.8
11 East Pennines	4.3	4.9	6.5	8.9	11.7	14.6	16.6	16.4	14.1	10.6	7.1	4.2
12 East Anglia	4.7	5.2	7	9.5	12.5	15.4	17.6	17.6	15	11.4	7.7	4.7
13 Wales	5	5.3	6.5	8.5	11.2	13.7	15.3	15.3	13.5	10.7	7.8	5.2
14 W Scotland	4	4.4	5.6	7.9	10.4	13	14.5	14.4	12.5	9.3	6.5	3.8
15 E Scotland	3.6	4	5.4	7.7	10.1	12.9	14.6	14.5	12.5	9.2	6.1	3.2
16 NE Scotland	3.3	3.6	5	7.1	9.3	12.2	14	13.9	12	8.8	5.7	2.9
17 Highland	3.1	3.2	4.4	6.6	8.9	11.4	13.2	13.1	11.3	8.2	5.4	2.7
18 Western Isles	5.2	5	5.8	7.6	9.7	11.8	13.4	13.6	12.1	9.6	7.3	5.2
19 Orkney	4.4	4.2	5	7	8.9	11.2	13.1	13.2	11.7	9.1	6.6	4.3
20 Shetland	4.6	4.1	4.7	6.5	8.3	10.5	12.4	12.8	11.4	8.8	6.5	4.6
21 Northern Ireland	4.8	5.2	6.4	8.4	10.9	13.5	15	14.9	13.1	10	7.2	4.7

6.4.3 CO_2 savings formula

The CO_2 savings (tonnes) were calculated using the following formula using three types of energy source, mains gas, heating oil and electricity. The formula is applicable to all types of dwellings with single and multiple chimneys:

$$CO_2 \text{ savings/annum}_{\text{chimney sheep}} = [N \times (B_F \times \rho \times Q_{Ref} \times C_p \times \Delta T \times P)/3600\ \eta] \times \text{Fuel emissions factor (F) (kg } CO_2\text{/KWh)}] \times 0.001 \quad \ldots\ldots(6)$$

For comparison, the CO_2 emissions without the chimney sheep can be determined using the following formula:

$$CO_2 \text{ emission/annum}_{Ref} = [N \times (\rho \times Q_{Ref} \times C_p \times \Delta T \times P)/3600\ \eta \times F \text{ (kg } CO_2\text{/KWh)}] \times 0.001 \quad \ldots\ldots(7)$$

The CO_2 savings can be determined using the following formula:

$$CO_2 \text{ savings} = CO_2 \text{ emission/annum}_{Ref} - CO_2 \text{ emission/annum}_{\text{chimney sheep}} \quad \ldots\ldots(8)$$

Table 5 shows the fuel emission factors taken from SAP 2012 Table 12 used for mains gas, heating oil and electricity in order to calculate the CO_2 savings.

Table 5 Fuel emission factors

Fuel Type	Fuel emissions factors (F) kgCO2/kWh
Mains gas	0.216
Heating oil	0.298
Electricity (standard tariff)	0.519

7 TEST RESULTS

7.1 REDUCTION IN AIRFLOW PERFORMANCE TEST RESULTS

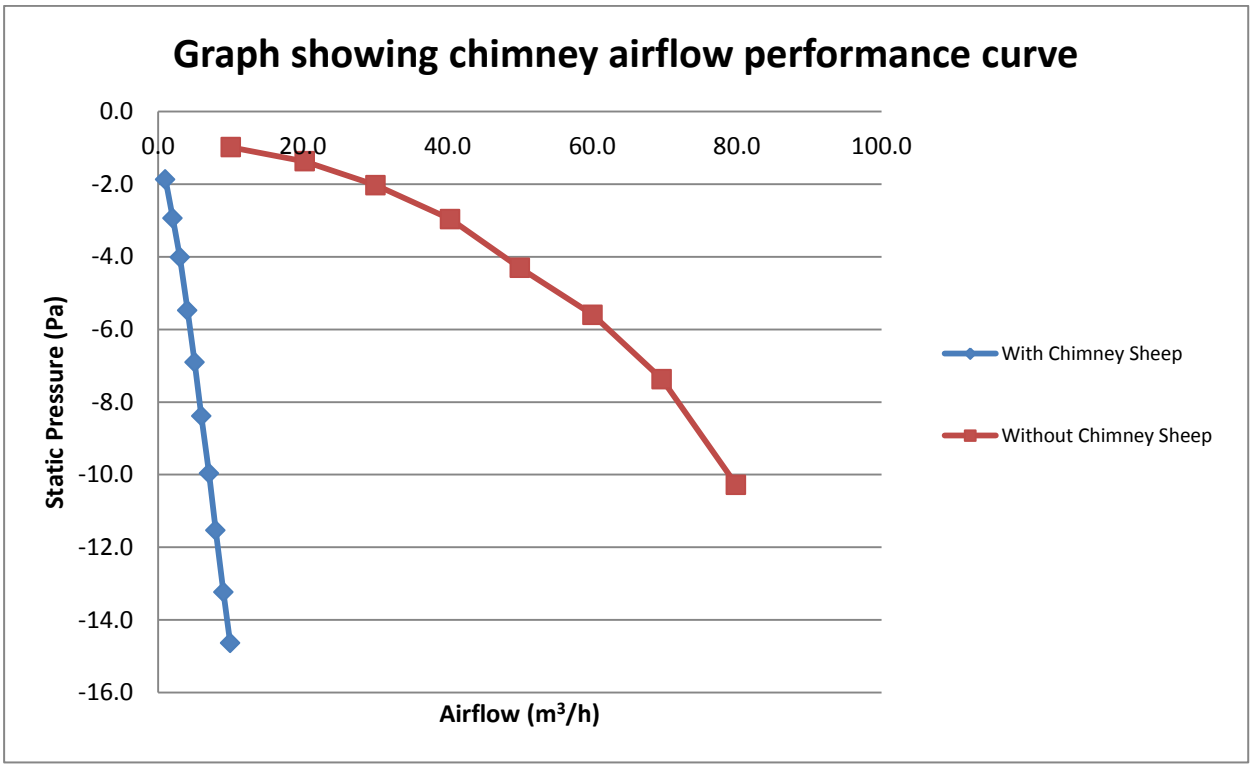
Table 6 shows the results of the reduction in airflow performance tests carried out with and without the Chimney Sheep® inserted in the chimney.

Table 6 Airflow performance results

With Chimney Sheep® inserted		Without Chimney Sheep® inserted	
Airflow (m^3/h)	Static Pressure (Pa)	Airflow (m^3/h)	Static Pressure (Pa)
1.0	-1.9	10.1	-1.0
2.0	-2.9	20.3	-1.4
3.0	-4.0	30.1	-2.0
4.0	-5.5	40.4	-3.0
5.0	-6.9	50.0	-4.3
6.0	-8.4	60.1	-5.6
7.0	-10.0	69.6	-7.4
7.9	-11.5	79.9	-10.3
9.0	-13.2	-	-
10.0	-14.6	-	-

Figure 4 shows the results of the reduction in airflow performance tests carried out with and without the Chimney Sheep® inserted in the chimney.

Figure 4 Airflow performance curves



The following formula was derived from the airflow performance curve given in Figure 4 without the Chimney Sheep® inserted in the chimney. The formula allows for the static pressure in Pa to be calculated at the corresponding Q_{ref} airflow ($40m^3/hr$)

Static Pressure (Pa) = -0.1281x + 1.4107……(9)

Where:
x = Airflow (m^3/hr)

A graph of the airflow in m^3/hr against the static pressure in Pa using the results in Table 6 was plotted to derive the following formula in order to calculate the airflow through the chimney with the Chimney Sheep® inserted at the corresponding Q_{ref} airflow ($40m^3/hr$) static pressure.

Airflow (m^3/hr) = -0.6831x + 0.1029 ……(10)

Where:
x = Static Pressure (Pa)

Table 7 shows the results of the calculated airflow performance of the Chimney Sheep® when inserted in the chimney using the Q_{ref} static pressure.

Table 7 Calculated airflow performance using Q_{ref} static pressure

With Chimney Sheep®		Without Chimney Sheep®	
Airflow (m^3/h)	Static Pressure (Pa)	Airflow (m^3/h)	Static Pressure (Pa)
2.64	-3.71	40.0	-3.71

The effect of the Chimney Sheep® being inserted in the chimney caused the airflow rate to be reduced from 40.0 m^3/hr to 2.64 m^3/hr at the same static pressure.

The reduction in airflow performance through the chimney with Chimney Sheep® inserted is 37.36m^3/hr. This represents a blockage factor of 0.934 (93.4%) as calculated using formula 1.

7.2 LIFE CYCLE TESTS RESULTS

Figure 5 shows the Chimney Sheep® before and after the life cycle tests. The full evolution of the cycles can be observed in Appendix A. Full results can be observed on Appendix B.

Figure 5 Chimney Sheep® before and after tests

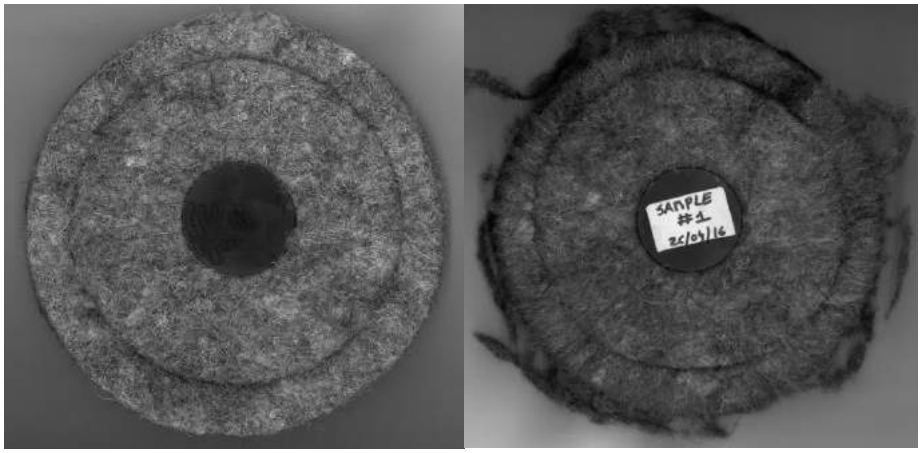
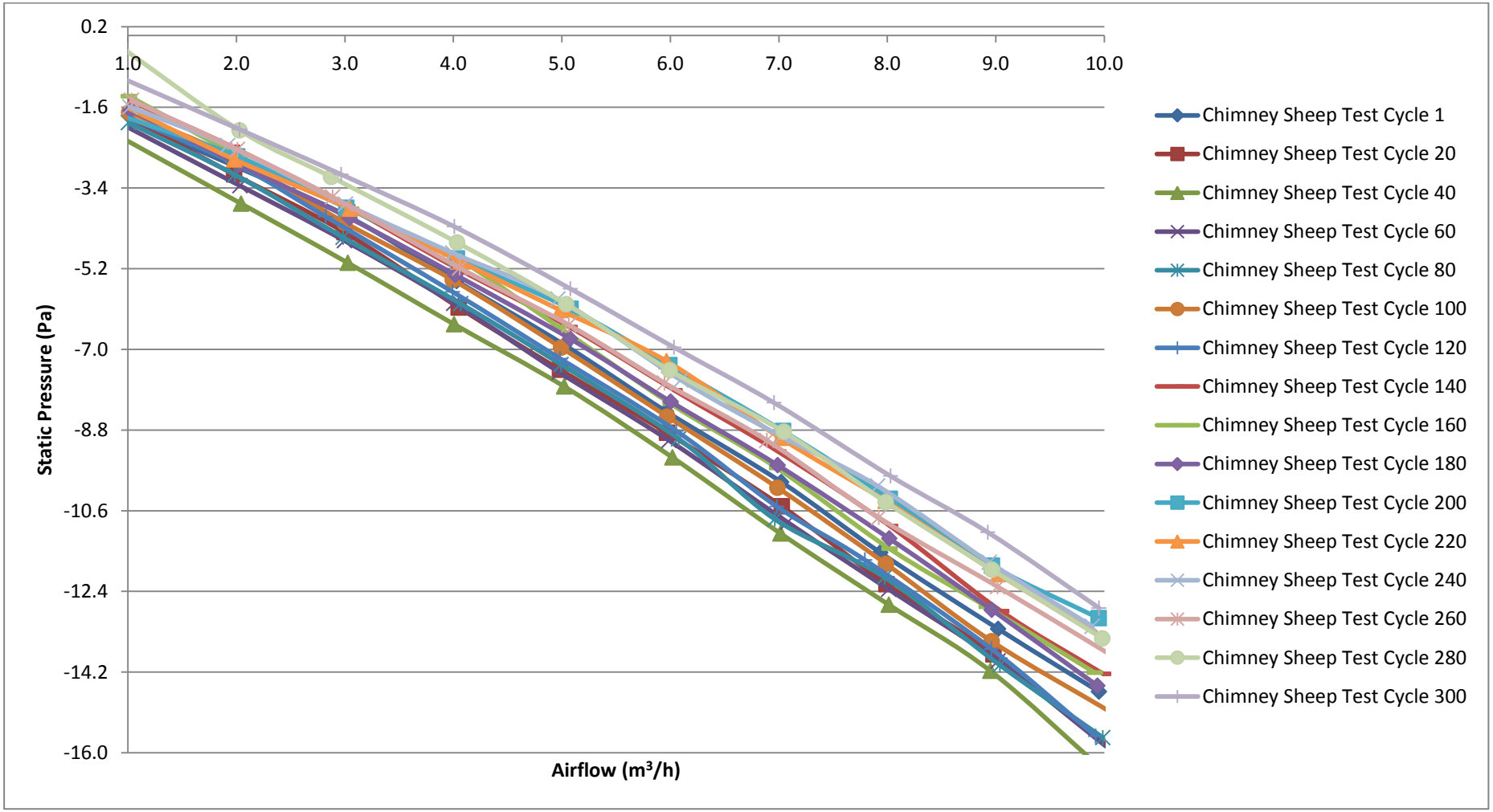


Figure 6 shows the airflow performance of the Chimney Sheep® from 1 to 300 cycles in 20 cycle increments.

Figure 6 Life Cycles Tests



7.3 ENERGY, CO_2 & COST SAVINGS RESULTS

For the purpose of calculating the energy, CO_2 and cost savings the airflow performance data of the Chimney Sheep® after 1 cycle (brand new), 40 cycles (Chimney Sheep® was most effective) and 300 cycles (Chimney Sheep® was least effective) were used.

A graph of the airflow in m^3/hr against the static pressure in Pa using the results in Figure 6 was plotted to derive the relevant formula in order to calculate the airflow through the chimney with the Chimney Sheep® inserted at the corresponding Q_{ref} airflow ($40m^3$/hr) static pressure after 1, 40 and 300 cycles. Note: Formula 12 shows the derivation used for test cycle 1.

Table 8 shows the calculated cost and energy savings after 1, 40 and 300 cycles. The energy savings were calculated using formula 2, and the energy cost savings were calculated using formula 3.

Table 8 Cost and energy savings for a Qref of 40 m^3/h

Test Cycle	Q ref (m^3/h)	Blockage Factor (%)	Energy Savings (kWh per annum)			Energy costs savings (£ per annum)		
			Mains Gas	Heating oil	Electric heat source	Mains Gas	Heating oil	Electric heat source
1	40	93.4%	468.8	554.6	231.6	£13.26	£24.53	£24.84
40	40	94.7%	475.3	562.3	234.9	£13.45	£24.87	£25.19
300	40	91.5%	459.3	543.3	226.9	£12.99	£24.03	£24.33

Figure 7 shows a graph of the blockage factor results of the Chimney Sheep® inserted in the chimney taken from Table 8 after cycles 1, 40 and 300 respectively.

Figure 7 Blockage Factor Trend

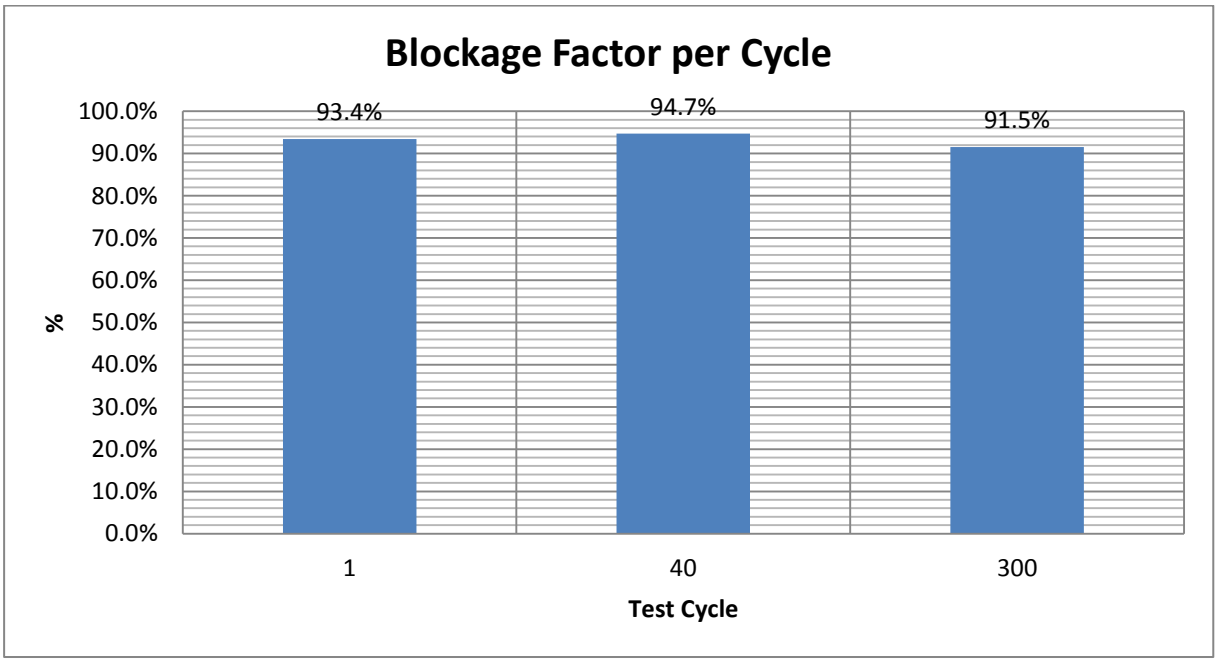


Figure 8 shows a graph of the energy savings results (kWh) taken from Table 8 after cycles 1, 40 and 300 respectively.

Figure 8 Energy Savings (kWh) with Chimney Sheep® inserted in the chimney.

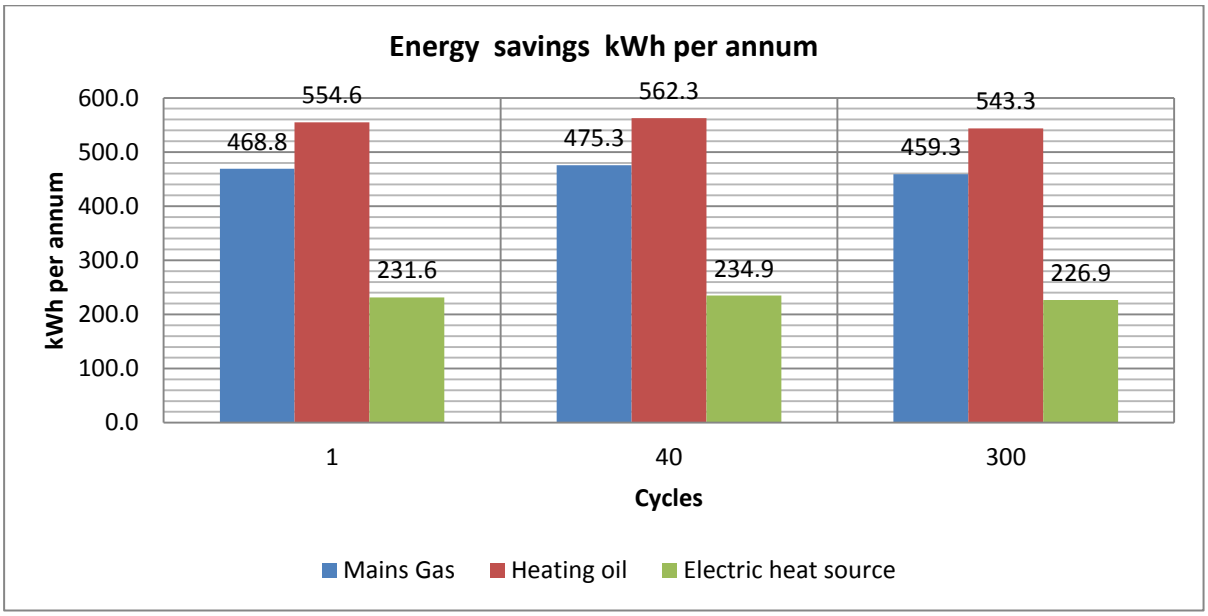
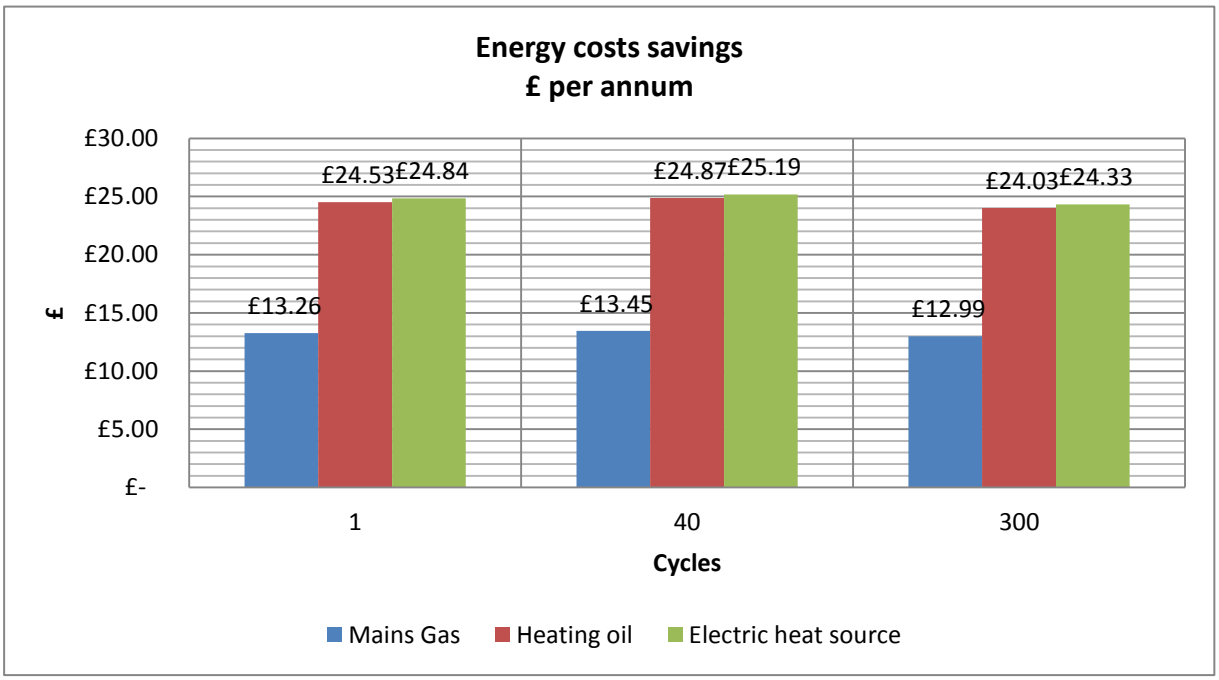


Figure 9 shows a graph of the energy cost savings (£ per annum) results taken from Table 8 after cycles 1, 40 and 300 respectively.

Figure 9 Energy Cost Savings



For the purpose of calculating the energy, CO_2 savings the airflow performance data of the Chimney Sheep® after 1 cycle (brand new), 40 cycles (Chimney Sheep® was most effective) and 300 cycles (Chimney Sheep® was least effective) were used.

Table 9 shows the calculated CO_2 emissions and savings with Chimney Sheep® inserted in the chimney after 1, 40 and 300 cycles and without Chimney Sheep® inserted. The CO_2 emissions without Chimney Sheep® inserted were calculated using formula 9. The CO_2 emissions with the Chimney Sheep® inserted were calculated using formula 8. The CO_2 savings were calculated using formula 10.

Table 9 CO_2 savings & emissions for an Qref of 40 $m^{3/}h$

Test Cycle	CO_2 emissions per annum without Chimney Sheep® inserted (tonnes per annum)			CO_2 emissions per annum with Chimney Sheep® inserted (tonnes per annum)			CO_2 savings per annum with Chimney Sheep® inserted (tonnes per annum)		
	Mains Gas	Heating oil	Electric	Mains Gas	Heating oil	Electric	Mains Gas	Heating oil	Electric
1	0.108*	0.177*	0.129*	0.007	0.012	0.008	0.101	0.165	0.120
40				0.006	0.009	0.007	0.103	0.168	0.122
300				0.009	0.015	0.011	0.099	0.162	0.118

*CO_2 emissions without Chimney Sheep® are not affected by cycles because the draught excluder is not inserted in the chimney.

Figure 10, 11 and 12 shows a graph of the CO_2 savings (tonnes per annum) results taken from Table 9 after cycles 1, 40 and 300 respectively for different fuel sources.

Figure 10 CO_2 emissions using main gas (tonnes per annum)

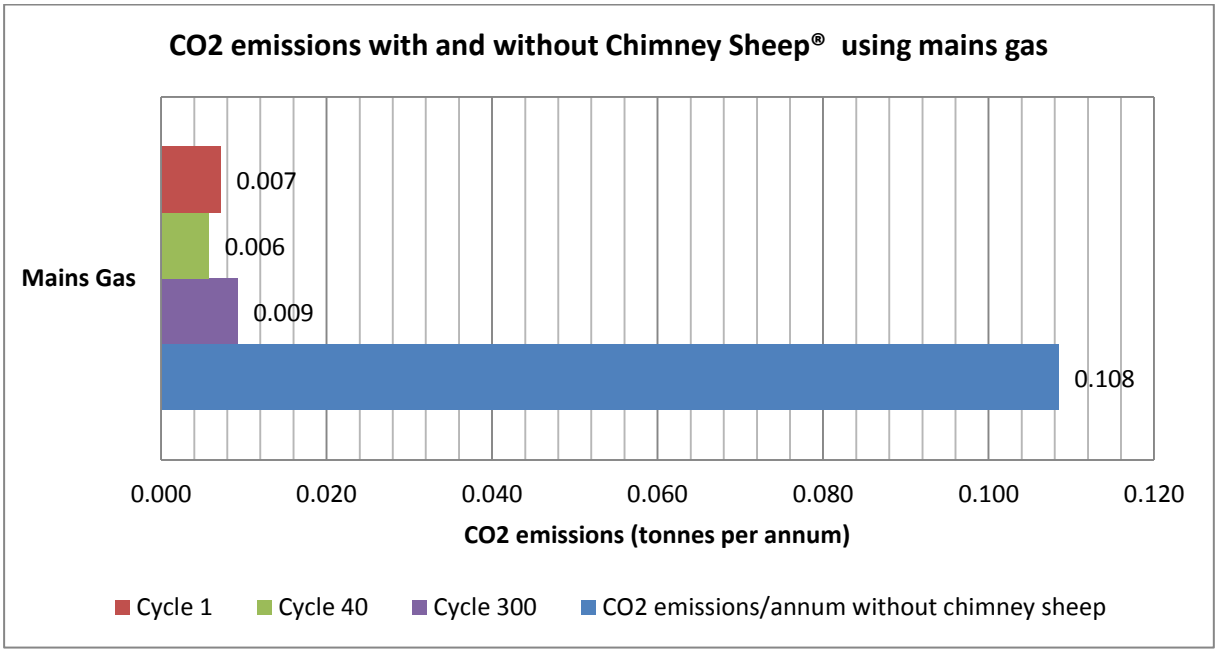


Figure 11 CO_2 emissions using heating oil (tonnes per annum)

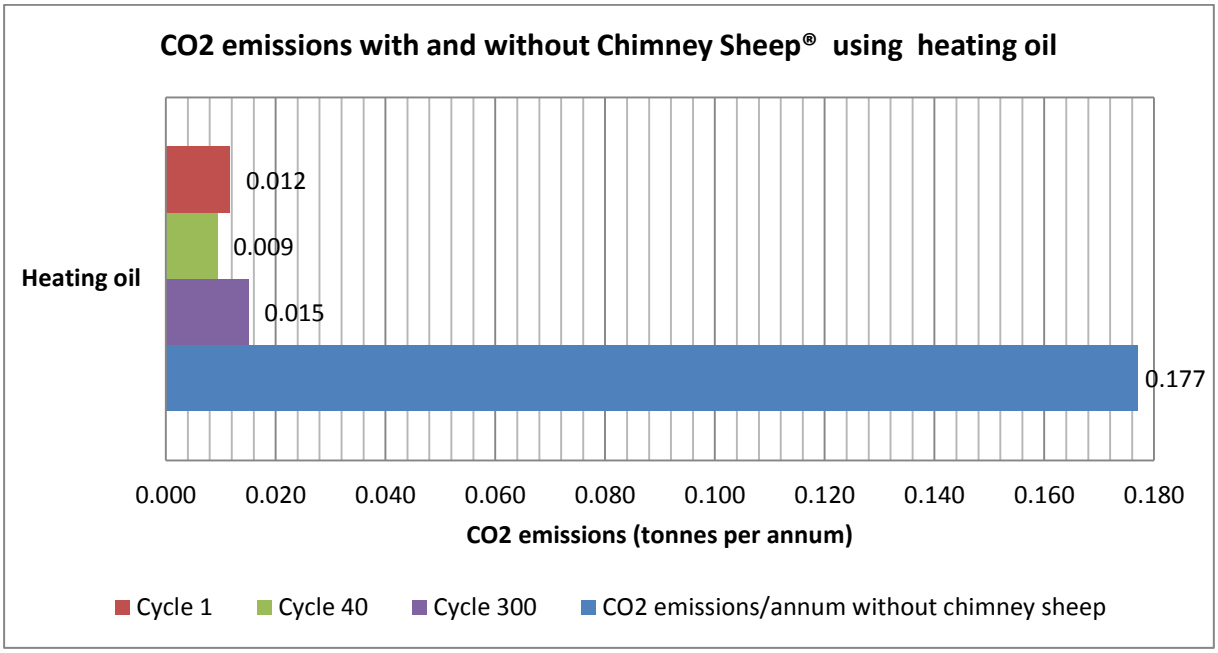
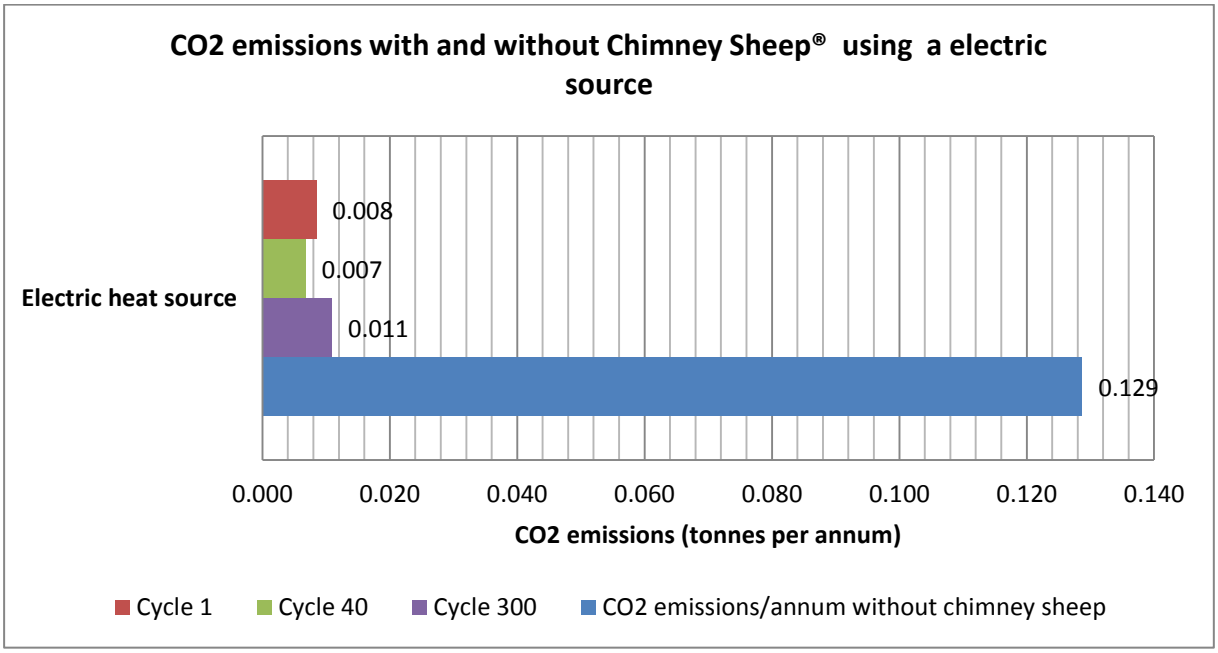


Figure 12 CO_2 emissions using a electric heat source (tonnes per annum)



7.4 OTHER RESULTS

At the request of the client additional energy / cost / carbon savings given for a reference airflow rate of 20 m^3/hr and 80 m^3/hr were included.

Table 10 shows the calculated cost and energy savings after 1, 40 and 300 cycles. The energy savings were calculated using formula 2, and the energy cost savings were calculated using formula 3.

Table 10 Cost and energy savings for a Qref of 20 $m^{3/}$h

Test Cycle	Q ref (m^3/h)	Blockage Factor (%)	Energy Savings (kWh per annum)			Energy costs savings (£ per annum)		
			Mains Gas	Heating oil	Electric heat source	Mains Gas	Heating oil	Electric heat source
1	20	95.6 %	239.8	283.7	118.5	£6.78	£12.55	£12.71
40	20	97.6 %	244.9	289.8	121.0	£6.93	£12.82	£12.98
300	20	92.8 %	232.8	275.4	115.0	£6.59	£12.18	£12.34

Table 11 shows the calculated CO_2 emissions and savings with Chimney Sheep® inserted in the chimney after 1, 40 and 300 cycles and without Chimney Sheep® inserted. The CO_2 emissions without Chimney Sheep® inserted were calculated using formula 9. The CO_2 emissions with the Chimney Sheep® inserted were calculated using formula 8. The CO_2 savings were calculated using formula 10.

Table 11 CO_2 savings & emissions for a Qref of 20 $m^{3/}$h

Test Cycle	CO_2 emissions per annum without Chimney Sheep® inserted (tonnes per annum)			CO_2 emissions per annum with Chimney Sheep® inserted (tonnes per annum)			CO_2 savings per annum with Chimney Sheep® inserted (tonnes per annum)		
	Mains Gas	Heating oil	Electric	Mains Gas	Heating oil	Electric	Mains Gas	Heating oil	Electric
1	0.054*	0.088*	0.064*	0.002	0.004	0.003	0.052	0.085	0.061
40				0.001	0.002	0.002	0.053	0.086	0.063
300				0.004	0.006	0.005	0.050	0.082	0.060

*CO_2 emissions without Chimney Sheep® are not affected by cycles because the draught excluder is not inserted in the chimney.

Table 12 shows the calculated cost and energy savings after 1, 40 and 300 cycles for a reference airflow of 20 m^3/h. The energy savings were calculated using formula 2, and the energy cost savings were calculated using formula 3.

Table 12 Cost and energy savings for a Qref of 80 $m^{3/}h$

Test Cycle	Q ref (m^3/h)	Blockage Factor (%)	Energy Savings (kWh per annum)			Energy costs savings (£ per annum)		
			Mains Gas	Heating oil	Electric heat source	Mains Gas	Heating oil	Electric heat source
1	80	92.3 %	926.8	1096.5	457.9	£26.22	£48.49	£49.11
40	80	93.2 %	935.4	1106.7	462.2	£26.47	£48.95	£49.57
300	80	92.3 %	926.8	1096.5	457.9	£26.22	£48.49	£49.11

Table 13 shows the calculated CO_2 emissions and savings with Chimney Sheep® inserted in the chimney after 1, 40 and 300 cycles and without Chimney Sheep® inserted. The CO_2 emissions without Chimney Sheep® inserted were calculated using formula 9. The CO_2 emissions with the Chimney Sheep® inserted were calculated using formula 8. The CO_2 savings were calculated using formula 10.

Table 13 CO_2 savings & emissions for a Qref of 80 $m^{3/}h$

Test Cycle	CO_2 emissions per annum without Chimney Sheep® inserted (tonnes per annum)			CO_2 emissions per annum with Chimney Sheep® inserted (tonnes per annum)			CO_2 savings per annum with Chimney Sheep® inserted (tonnes per annum)		
	Mains Gas	Heating oil	Electric	Mains Gas	Heating oil	Electric	Mains Gas	Heating oil	Electric
1	0.217*	0.354*	0.257*	0.017	0.027	0.020	0.200	0.327	0.238
40				0.015	0.024	0.018	0.202	0.330	0.240
300				0.017	0.027	0.020	0.200	0.327	0.238

*CO_2 emissions without Chimney Sheep® are not affected by cycles because the draught excluder is not inserted in the chimney.

8 CONCLUSIONS

Laboratory tests were carried out to determine the potential energy, CO_2 and cost savings when inserting a Chimney Sheep® chimney draught excluder in a chimney.

All tests were undertaken in a controlled environmental chamber in accordance with the previously agreed methodology.

The main findings are given below:

1. The blockage factor with the Chimney Sheep® inserted in the chimney after 1 complete cycle was 93.4%. This is equivalent to a reduction of the airflow rate from 40m^3/h to around 2.64 m^3/h at the same static pressure.

2. The performance of Chimney Sheep® improved after 40 complete cycles with the chimney draught excluder inserted in the chimney where the blockage factor was 94.7%.

3. The performance of Chimney Sheep® declined after 300 complete cycles with the chimney draught excluder inserted in the chimney due to the sample deteriorating through wear and tear. The blockage factor with the Chimney Sheep® inserted in the chimney after 300 complete cycles was 91.6%.

4. The analysis shows Chimney Sheep® had best results during test cycle 40, where for the various fuels, the best case results were energy savings of 562.3 kWh per annum, costs savings of £25.19 per annum and CO_2 savings of 0.168 tonnes per annum, when using the Chimney Sheep®.

5. The analysis shows Chimney Sheep® had poorest results during test cycle 300, where for the various fuels, the worst case results were energy savings of 226.9 kWh per annum, costs savings of £12.99 per annum and CO_2 savings of 0.099 tonnes per annum, when using the Chimney Sheep®.

6. Regarding section 7.4 of the present report it is possible to observe that for a Q_{ref} of 80 m^3/h the Energy Savings, Cost Savings and CO_2 savings per annum with Chimney Sheep® inserted are greater than the reference airflow of 40 m^3/h, although the blockage factor has declined.

7. Still regarding section 7.4 for a Q_{ref} of 20 m^3/h the Energy Savings, Cost Savings and CO_2 savings per annum with Chimney Sheep® inserted are lower than the reference airflow of 40 m^3/h, although the blockage factor has improved.

APPENDIX: A LIFE CYCLE TESTS EVOLUTION

Life Cycle Test 1

Life Cycle Test 20

Life Cycle Test 40

Life Cycle Test 60

Life Cycle Test 80

Life Cycle Test 100

Life Cycle Test 120

Life Cycle Test 140

Life Cycle Test 160

Life Cycle Test 180

Life Cycle Test 200

Life Cycle Test 220

Life Cycle Test 240

Life Cycle Test 260

Life Cycle Test 280

Life Cycle Test 300

APPENDIX: B LIFE CYCLE TEST SHEET RECORDS

LIFE CYCLE TEST SHEET

Client: Chimney Sheep® Ltd	**Sample ID:** #1
Product: Chimney Sheep® Draught Excluder	**Project no:** 57966

Test Cycle	Start Time (hh:mm)	Finish Time (hh:mm)	Initial Diameter (mm)	Final Diameter (mm)	Relative Humidity (%)		
					Start	Middle	Finish
1	10:20	11:16	220	220	30.7	37.1	34.1
20	11:21	12:11	220	220	34.4	32.9	35.4
40	12:30	13:22	220	220	34.5	31.7	28.3
60	13:35	14:25	220	220	27.7	28.7	30.4
80	14:33	15:26	220	220	29.7	27.3	30.5
100	15:32	16:21	220	220	26.9	26.7	29.1
120	16:27	17:21	220	220	29.7	31.4	33.5
140	17:26	18:15	220	220	34.4	33.2	21.9
160	08:12	09:00	220	220	25.9	23.9	28.9
180	09:07	09:59	220	220	30.3	33.2	33.2
200	10:07	10:58	220	220	30.4	31.3	29.7
220	11:06	12:00	220	220	30.4	27.4	28.9
240	12:07	13:04	220	220	30.4	30.2	30.9
260	13:21	14:09	220	220	31.4	31.7	32.1
280	16:31	17:21	220	220	21.8	22.9	24.2
300	17:26	18:18	220	220	24.0	20.8	22.9

Comments

Temperature was above 23C during Test Cycle 40 – test delayed to 12:30;

It looks like Chimney Sheep® has moved causing a slightly static pressure drop;

Temperature was above 23C during Test Cycle 280 – test delayed to 16:31.

Note:
All cycle tests from Test Cycle 1 to Test Cycle 140 were performed on 26/04/2016;
All cycle tests from Test Cycle 160 to Test Cycle 300 were performed on 27/04/2016;

Date: 26/04/2016 & 27/04/2016	**Engineer:** Vitor Carneiro

APPENDIX: C CALIBRATION CERTIFICATE FOR FLOW ELEMENTS

CERTIFICATE OF CALIBRATION

UKAS CALIBRATION 0625

Labcal Ltd

Unit C4
Pegasus Court
Ardglen Road
Whitchurch
Hampshire RG28 7BP
United Kingdom
Tel: +44 (0)1256 896636
Fax: +44 (0)1256 896004
Web: www.labcal.co.uk

Date of Issue

15 FEB. 2016

Certificate Number

K35987F

Page 1 of 2 Pages

Approved Signatory
D.N. AHAD ( ) J. RIVETT (✓)

Client	: BSRIA INSTRUMENT SOLUTIONS
Address	: OLD BRACKNELL LANE WEST BRACKNELL BERKSHIRE RG12 7AH
Order No.	: 73377
Equipment Tested	: LAMINAR FLOW ELEMENT
Type / Type No.	: FCO96G-200L
Equipment Serial No.	: 960418 (ZZ/LAM/05)
Range / Scale	: 200 L/min @ 11.12 mm H_2O DIFFERENTIAL PRESSURE
Manufacturer	: FURNESS CONTROLS
Date Calibration Completed	: 12 FEB. 2016
Calibration Fluid	: AIR
Laboratory Temperature	: 19.6 ± 2.0°C
Humidity	: 35 ± 10% RH
Reference No.	: K35987F119/66

Certified by J. Rivett

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

CERTIFICATE OF CALIBRATION

UKAS ACCREDITED CALIBRATION LABORATORY No. 0625

Certificate Number
K35987F
Page 2 of 2 Pages

THE METER WAS CALIBRATED USING VOLUME AND TIME PRINCIPLE. ALL VOLUMES ARE FOR 985.22 mbar abs AND 19.2°C. ALL MEASUREMENTS ARE TRACEABLE TO NATIONAL STANDARDS. THE RESULTS BELOW ARE THE AVERAGE OF THREE READINGS PER POINT.

ATMOSPHERIC PRESSURE : 983.73 mbar abs
METER PRESSURE : 985.22 mbar abs

Av. TEMPERATURE OF THE GAS AT THE METER : 19.9°C ± 1°C

MEASURED READING OF INSTRUMENT UNDER TEST UNITS : mm H_2O Differential Pressure	MEASURED FLOW RATE UNITS : L/min
2.178	39.860
4.358	79.474
6.534	118.758
8.727	157.940
11.191	201.465

THE UNCERTAINTY OF THE ABOVE MEASURED FLOW RATES IS [0.37% + 0.018 L/min OF THE FLOW RATE.

Test Engineer J. Rivett END

The reported expanded uncertainty is based on standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Furness Controls
Pressure | Flow | Leak Detection

Beeching Road, Bexhill-on-sea, East Sussex, England, TN39 3LG

0580

Certificate of Calibration

Calibration Certificate No: 12649R1

Issued by: Furness Controls Limited

Date of Issue: 13 January 2016

Customer	:	BSRIA Instrument Solutions, Old Bracknell Lane West, Bracknell, Berkshire, RG12 7AH.
Via	:	N/A
Reference No.	:	72735
Customer Order No.	:	33436
Date calibrated	:	18 & 21 December 2015
Instrument	:	FCO96 Flow Element
Manufacturer	:	Furness Controls Limited
Serial No.	:	871189
Flow Range	:	500 L/min & 2000 L/min
@ DP	:	52.61 Pa & 69.67 Pa

Approved: G Markham

Approved Signatories
I Clarke
A Leggat
G Markham
G Thorogood
DB Walker

Furness Controls Ltd
Beeching Road
Bexhill-on-Sea
East Sussex
TN39 3LG, UK
Tel : +44 (0) 1424 819980
e-mail : calibration@furness-controls.com

Furness Controls
Pressure | Flow | Leak Detection

Calibration Certificate No. 12649

UKAS Accredited Calibration Laboratory No. 0580

Flow Range: 0 to 500 L/min Nominal DP: 52.5 Pa

Results as received

Reference Flow L/min	Flow Element being calibrated Temperature °C	DP Pa	Deviation Pa	Error % of Rdg
105.11	21.06	11.11	0.02	0.15
202.47	21.01	21.36	-0.01	-0.04
302.57	21.03	31.95	0.02	0.05
402.30	21.02	42.36	-0.10	-0.23
512.64	21.02	54.07	-0.03	-0.06

Each result is the average of 50 readings taken.

Flow Range: 0 to 500 L/min Nominal DP: 52.61 Pa

Results corrected to 20°C

Flow L/min	Flow Element being calibrated DP Pa	Deviation Pa	Error % of Rdg
105.11	11.08	0.02	0.18
202.47	21.30	0.00	-0.02
302.57	31.86	0.02	0.07
402.30	42.25	-0.08	-0.19
512.64	53.93	-0.01	-0.02

Flow Range: 0 to 2000 L/min Nominal DP: 69.5 Pa

Results after cleaning

Reference Flow L/min	Flow Element being calibrated Temperature °C	DP Pa	Deviation Pa	Error % of Rdg
406.9	20.45	14.19	0.05	0.36
813.1	20.43	28.26	0.00	0.02
1210.8	20.42	42.14	0.06	0.15
1611.5	20.36	55.97	-0.03	-0.05
1998.6	20.31	69.94	0.49	0.70

Each result is the average of 50 readings taken.

Flow Range: 0 to 2000 L/min Nominal DP: 69.67 Pa

Results corrected to 20°C

Flow L/min	Flow Element being calibrated DP Pa	Deviation Pa	Error % of Rdg
406.9	14.17	0.00	-0.03
813.1	28.23	-0.09	-0.33
1210.8	42.09	-0.09	-0.21
1611.5	55.92	-0.22	-0.39
1998.6	69.88	0.26	0.37

Test Engineer : Geoff Thorogood Signature : G Thorogood

Furness Controls
Pressure | Flow | Leak Detection

Calibration Certificate No. 12649

UKAS Accredited Calibration Laboratory No. 0580

Procedure:

The instrument provides a differential pressure corresponding to the flow.
The differential pressure varies with temperature. A set of results is also shown corrected to 20°C.
The reference flow was measured using a standard laminar flow element and digital micromanometer.
The DP was measured using a digital micromanometer.
The calibration medium was ambient air.
The readings of the reference standards and of the instrument under test were taken either manually or via RS232 when available to a PC running a calibration program.
The ambient temperature was 20 ± 2 °C and the relative humidity was < 80 %.
A set of readings was taken as received. The nominal DP value was adjusted.
Reference flow readings were corrected to the working conditions of the instrument.
The working conditions were: 1020 mbar

Standards & Uncertainties

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.
The estimated uncertainty associated with the measurement of the applied flow is 0.6 % of reading.
The uncertainty of calibration of the DP (up to 220 Pa) is the flow uncertainty + 0.04 Pa.

Flow Standards:	FCO96 WS153 (2000 L/min)	FCO510 WS366 (0 to 2 kPa)
	FCO96 WS266 (500 L/min)	FCO510 WS366 (0 to 2 kPa)
DP Standards:	FCO510 WS366 (0 to 2 kPa)	
Abs Pressure Standards:	PTX520 RS37 (1600 mbar abs)	FCO510 WS366 (Indicator)
	PTX520 WS528 (1200 mbar abs)	FCO510 WS365 (Indicator)
Temperature Standards:	PRT WS564	FCO510 WS366 (Indicator)
	PRT WS507	FCO510 WS365 (Indicator)

All measuring standards are traceable to national or international standards.

Programme & version: CS043: V3.1.5.LFE.36

Comments:

The manufacturer's specification for accuracy of this instrument is 1.00 % R.

Test Engineer : Geoff Thorogood Signature : G Thorogood

End of calibration certificate

CERTIFICATE OF CALIBRATION

Issued By BSRIA Instrument Solutions **Certificate Number** UK14456
Date of Issue 22 February 2016

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0807

Page 1 of 3 Pages
Approved Signatory

Customer : BSRIA Ltd
Old Bracknell Lane West, Bracknell
Berkshire RG12 7AH

Date Received : 19 February 2016

Instrument -

System ID :	100151	Job Number : H42734-1
Description :	Pressure Transmitter (+50Pa)	Ref. Number : 1353
Manufacturer :	Furness Controls	
Model Number :	FCO332	
Serial Number :	1210063	
Procedure Version :	RUS095s1/N	

Environmental Conditions

Temperature :	20°C +/- 2°C	Mains Voltage :	240V +/- 10V
Relative Humidity :	50% +/- 20%	Mains Frequency :	50Hz +/- 1Hz

Comments

Results recorded as received. No adjustment performed.

Calibration Information

The instrument was calibrated against laboratory standards whose values are traceable to recognised National Standards. The uncertainty limits quoted refer to the measured values only, with no account being taken of the instruments ability to maintain its calibration.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Calibrated By : B. Huntsman **Date of Calibration :** 22 February 2016

This certificate is issued in accordance with the laboratory accreditation requirements of the United Kingdom Accreditation Service. It provides traceability of measurement to the SI system of units and/or to units of measurement realised at the National Physical Laboratory or other recognised national metrology institutes. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATE OF CALIBRATION

Certificate Number UK14456

UKAS Accredited Calibration Laboratory No. 0807
AS FOUND RESULTS

Page 3 of 3 Pages

CALIBRATION RESULTS

	APPLIED VALUE (Pa)	DISPLAYED FCO332 VALUE (Pa)	FCO332 ELECTRICAL OUTPUT (mA DC)
Pressure	0.00 Pa	0.00 Pa	4.0004 mA DC
	10.00 Pa	10.03 Pa	7.2055 mA DC
	20.00 Pa	20.11 Pa	10.4289 mA DC
	30.00 Pa	30.20 Pa	13.6730 mA DC
	40.00 Pa	40.23 Pa	16.8894 mA DC
	50.00 Pa	50.28 Pa	20.0980 mA DC
	30.00 Pa	30.20 Pa	13.6651 mA DC
	0.00 Pa	0.00 Pa	4.0006 mA DC

End.

Uncertainties

Pressure Range	0 to ±3000 Pa: ±(0.045% + 0.1 Pa)
mA DC Measurement	0.015 mA DC
Instrument Stability	For the displayed FCO332 pressure reading reported an additional uncertainty of 1 least significant digit shall also be added to the pressure uncertainty above.

CERTIFICATE OF CALIBRATION

Issued By BSRIA Instrument Solutions **Certificate Number** UK14339
Date of Issue 01 February 2016

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ilac-MRA UKAS CALIBRATION 0807

Page 1 of 3 Pages

Approved Signatory

Customer : BSRIA Ltd
Old Bracknell Lane West, Bracknell
Berkshire RG12 7AH

Date Received : 25 January 2016

Instrument -

System ID :	99468	Job Number :	H42227-1
Description :	Pressure Transmitter	Ref. Number :	ID2975
Manufacturer :	Furness Controls	Site :	
Model Number :	FCO332	Location :	
Serial Number :	1601032		
Procedure Version :	RUS095s1/N		

Environmental Conditions

Temperature : 20°C +/- 2°C
Relative Humidity : 50% +/- 20%
Mains Voltage : 240V +/- 10V
Mains Frequency : 50Hz +/- 1Hz

Comments

Results recorded as received. No adjustment performed.

Calibration Information

The instrument was calibrated against laboratory standards whose values are traceable to recognised National Standards. The uncertainty limits quoted refer to the measured values only, with no account being taken of the instruments ability to maintain its calibration.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Calibrated By : B. Huntsman **Date of Calibration :** 01 February 2016

CERTIFICATE OF CALIBRATION

UKAS Accredited Calibration Laboratory No. 0807
AS FOUND RESULTS

Certificate Number
UK 14339

CALIBRATION RESULTS

	APPLIED VALUE (Pa)	DISPLAYED FCO332 VALUE (Pa)	FCO332 ELECTRICAL OUTPUT (mA DC)
Pressure	0.00 Pa	0.0 Pa	4.0058 mA DC
	20.00 Pa	20.1 Pa	7.2132 mA DC
	40.00 Pa	40.1 Pa	10.4228 mA DC
	60.00 Pa	60.1 Pa	13.6240 mA DC
	80.00 Pa	80.1 Pa	16.8287 mA DC
	100.00 Pa	100.2 Pa	20.0410 mA DC
	80.00 Pa	80.1 Pa	16.8294 mA DC
	0.00 Pa	0.0 Pa	4.0059 mA DC

End.

Uncertainties

Pressure Range	0 to ±3000 Pa: ±(0.045% + 0.1 Pa)
mA DC Measurement	0.015 mA DC
Instrument Stability	For the displayed FCO332 pressure reading reported an additional uncertainty of 1 least significant digit shall also be added to the pressure uncertainty above.

CERTIFICATE OF CALIBRATION

Issued By BSRIA Instrument Solutions **Certificate Number** UK14338
Date of Issue 11 February 2016

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ilac-MRA UKAS CALIBRATION 0807

Approved Signatory

Customer : BSRIA Ltd
Old Bracknell Lane West, Bracknell
Berkshire RG12 7AH

Date Received : 27 January 2016

Instrument -

System ID :	99555	Job Number : H42266-1	
Description :	Pressure Transmitter (500Pa)		
Manufacturer :	Furness Controls	Site :	
Model Number :	FCO332	Location :	
Serial Number :	0704312		
Procedure Version :	RUS094s1/N		

Environmental Conditions

Temperature : 20°C +/- 2°C
Relative Humidity : 50% +/- 20%
Mains Voltage : 240V +/- 10V
Mains Frequency : 50Hz +/- 1Hz

Comments

Results recorded as received. No adjustment performed.

Calibration Information

The instrument was calibrated against laboratory standards whose values are traceable to recognised National Standards. The uncertainty limits quoted refer to the measured values only, with no account being taken of the instruments ability to maintain its calibration.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Calibrated By : B. Huntsman **Date of Calibration :** 11 February 2016

CERTIFICATE OF CALIBRATION

UKAS Accredited Calibration Laboratory No. 0807
AS FOUND RESULTS

Certificate Number
UK 14338

CALIBRATION RESULTS

	APPLIED VALUE (Pa)	DISPLAYED FCO332 VALUE (Pa)	FCO332 ELECTRICAL OUTPUT (V DC)
Pressure	0.00 Pa	0.0 Pa	0.0002 V DC
	10.00 Pa	10.0 Pa	0.0987 V DC
	25.00 Pa	25.1 Pa	0.2461 V DC
	50.00 Pa	50.0 Pa	0.4985 V DC
	100.00 Pa	100.0 Pa	0.9978 V DC
	250.00 Pa	250.2 Pa	2.5013 V DC
	500.00 Pa	500.0 Pa	5.0002 V DC
	250.00 Pa	250.2 Pa	2.5014 V DC
	0.00 Pa	0.0 Pa	0.0002 V DC

End.

VCTI

Uncertainties

Pressure Range	0 to ±3000 Pa: ±(0.045% + 0.1 Pa)
V DC Measurement	0.6 mV DC
Instrument Stability	For the displayed FCO332 pressure reading reported an additional uncertainty of 1 least significant digit shall also be added to the pressure uncertainty above.

CERTIFICATE OF CALIBRATION

Issued By BSRIA Instrument Solutions **Certificate Number** UK14197
Date of Issue 27 January 2016

BSRIA Instrument Solutions

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ilac-MRA UKAS CALIBRATION 0807

Approved Signatory

Customer : BSRIA Ltd
Old Bracknell Lane West, Bracknell
Berkshire RG12 7AH

Date Received : 20 January 2016

Instrument -

System ID :	99385 Job Number : H42118-1
Description :	Pressure Transmitter (2500Pa)
Manufacturer :	Furness Controls
Model Number :	FCO332
Serial Number :	0704316
Procedure Version :	RUS091s1/N

Environmental Conditions

Temperature :	20°C +/- 2°C	Mains Voltage :	240V +/- 10V
Relative Humidity :	50% +/- 20%	Mains Frequency :	50Hz +/- 1Hz

Comments

Results recorded as received. No adjustment performed.

Calibration Information

The instrument was calibrated against laboratory standards whose values are traceable to recognised National Standards. The uncertainty limits quoted refer to the measured values only, with no account being taken of the instruments ability to maintain its calibration.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with UKAS requirements.

Calibrated By : B. Huntsman **Date of Calibration :** 27 January 2016

CERTIFICATE OF CALIBRATION

Certificate Number UK14197

UKAS Accredited Calibration Laboratory No. 0807
AS FOUND RESULTS

CALIBRATION RESULTS

	APPLIED VALUE (Pa)	DISPLAYED FCO332 VALUE (Pa)	FCO332 ELECTRICAL OUTPUT (V DC)
Pressure	0.00 Pa	0 Pa	0.0000 V DC
	50.00 Pa	50 Pa	0.2016 V DC
	100.00 Pa	100 Pa	0.3990 V DC
	250.00 Pa	250 Pa	1.0012 V DC
	500.00 Pa	500 Pa	2.0016 V DC
	1000.00 Pa	1000 Pa	3.9982 V DC
	2500.00 Pa	2501 Pa	9.9986 V DC
	1000.00 Pa	1000 Pa	3.9982 V DC
	0.00 Pa	0 Pa	0.0000 V DC

End.

Uncertainties

Pressure Range	0 to ±3000 Pa: ±(0.045% + 0.1 Pa)
V DC Measurement	0.6 mV DC
Instrument Stability	For the displayed FCO332 pressure reading reported an additional uncertainty of 1 least significant digit shall also be added to the pressure uncertainty above.

APPENDIX: D PRT'S CALIBRATION SHEET

BSRIA CALIBRATION SHEET

Manufacturer TC Direct	
Instrument Platinum Resistance Thermometers	**BSRIA Ident 2976 to 2984**
Serial No. N/A	**Client No. N/A**
Medium Water **Baro. N/A**	**Temp. See Table**
Calibration instrument 1 Reference Probe A (743)	
Calibration instrument 2 ASL Precision Thermometer (742)	

PRT	ID no	Temperatures (°C)					Original Values		New Values	
		5	15	25	35	45	Slope	Intercept	Slope	Intercept
PRT 01	2976	4.73	14.75	24.68	34.69	44.70	1.00000	0.00000	0.99938	-0.01640
PRT 02	2977	4.71	14.73	24.66	34.67	44.68	1.00000	0.00000	0.99943	0.00197
PRT 03	2978	4.72	14.74	24.68	34.68	44.69	1.00000	0.00000	0.99924	-0.00465
PRT 04	2979	4.79	14.80	24.73	34.75	44.75	1.00000	0.00000	0.99957	-0.07406
PRT 05	2980	4.71	14.72	24.65	34.66	44.67	1.00000	0.00000	0.99967	0.00432
PRT 06	2981	4.80	14.81	24.74	34.75	44.76	1.00000	0.00000	0.99957	-0.08025
PRT 07	2982	4.86	14.88	24.82	34.83	44.83	1.00000	0.00000	0.99914	-0.14350
PRT 08	2983	4.59	14.60	24.53	34.52	44.51	1.00000	0.00000	1.00076	0.11050
PRT 09	2984	4.80	14.84	24.78	34.80	44.81	1.00000	0.00000	0.99839	-0.08663
	ASL	**4.72**	**14.72**	**24.65**	**34.65**	**44.66**				

Comments

A total of 9 PRT's were placed in water bath (ID 994) and measured at 5°C, 15°C, 25°C, 45°C. Measurements were taken every 60 seconds for a 15 minute period. The ASL precision thermometer (ID 742) was used as the calibrated reference probe (743). The PRT's were connected to a baby logger that was in turn connected to a PC where live data was displayed in Microsoft Excel.

The coefficients were reset at the start of the calibration, and the new values determined on completion of the measurements as shown above. Calibrated in accordance with CP 1 Edition 4.
Coefficients used for ASL: Probe 1/ChA,S/N.B1677A(User1)

Calibrated in accordance with CP 01

Date 22-01-2016	**Engineer** Vitor Carneiro

APPENDIX: E EXTECH HD500 HUMIDITY SENSOR CERTIFICATION OF CALIBRATION

CERTIFICATE OF CALIBRATION

Issued By BSRIA Instrument Solutions
Date of Issue 30 September 2015

Certificate Number STD75781
Page 1 of 4 Pages

BSRIA Instrument Solutions
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Approved Signatory
M.J Trotter

Customer : BSRIA Ltd

Date Received : 25 September 2015

Instrument -

System ID :	97042	
Description :	Multifunction (RH, IR, T/C)	Ref. Number : 2005
Manufacturer :	Extech	
Model Number :	HD500	
Serial Number :	09108256	
Procedure Version :	RH120V2	

Environmental Conditions

Temperature :	20°C +/- 4°C	Mains Voltage :	240V +/- 10V
Relative Humidity :	50% +/- 20%	Mains Frequency :	50Hz +/- 1Hz

Comments

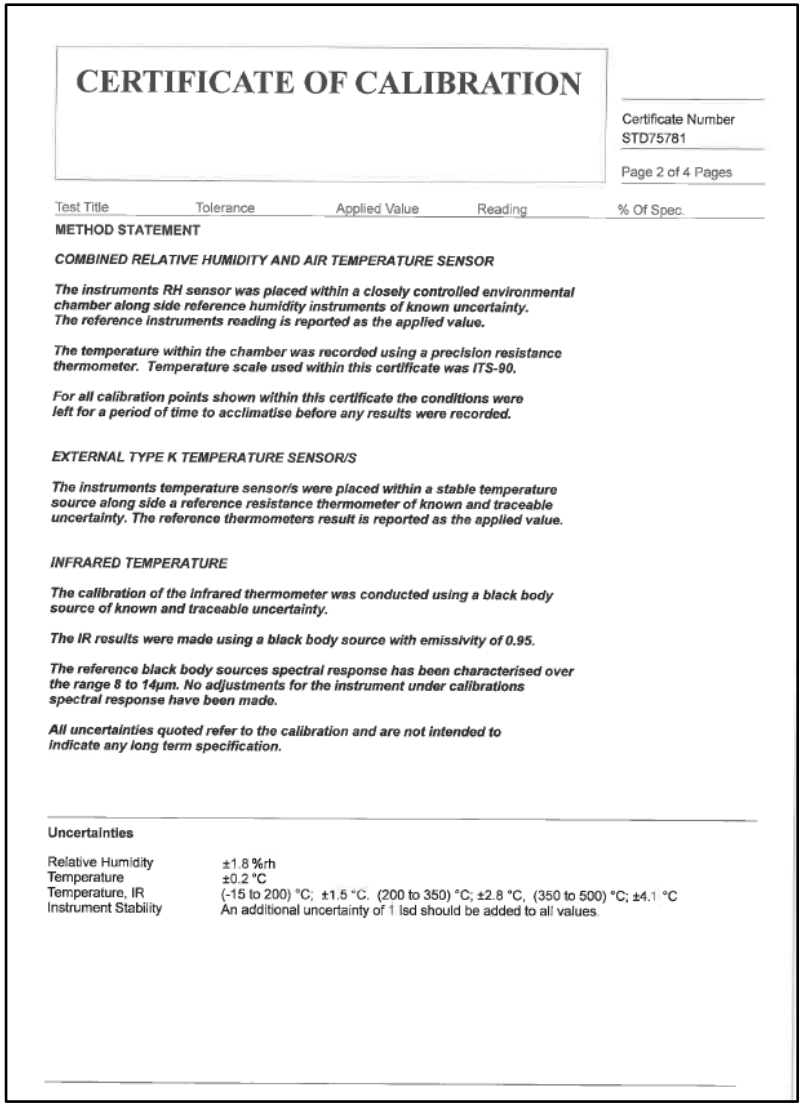
Unless stated otherwise all humidity readings were made at a nominal 25°C.
The Tolerances for the Themocouples were as stated in BS EN 60584-2:1993
Probe # 1:- BIS17299.

Results as found, no adjustments made.

Traceability Information

Instrument description	*Serial number*	*Certificate number*	*Cal. Date*	*Cal. Period*
Grant 1001 System (ZZPDL01)	K19537001	UK10640MN	05/11/2014	52
Resistance thermometer (ZZPRT41 to 43)	342024-1 (meter)	UK12796	23/07/2015	52
F150 with PRT Reference probe	058011 & 9351413	UK13265	24/09/2015	52
ZZBBS02 Black body source (RvA K013)	A88074	1324772	06/08/2014	104
ZZBBS03 Black body source (RvA K013)	A88173	1359156	02/10/2014	104

Calibrated By : D. M. Tovey D.M. Tovey Date of Calibration : 30 September 2015



CERTIFICATE OF CALIBRATION

Certificate Number STD75781
Page 2 of 4 Pages

Test Title	Tolerance	Applied Value	Reading	% Of Spec.

METHOD STATEMENT

COMBINED RELATIVE HUMIDITY AND AIR TEMPERATURE SENSOR

The instruments RH sensor was placed within a closely controlled environmental chamber along side reference humidity instruments of known uncertainty. The reference instruments reading is reported as the applied value.

The temperature within the chamber was recorded using a precision resistance thermometer. Temperature scale used within this certificate was ITS-90.

For all calibration points shown within this certificate the conditions were left for a period of time to acclimatise before any results were recorded.

EXTERNAL TYPE K TEMPERATURE SENSOR/S

The instruments temperature sensor/s were placed within a stable temperature source along side a reference resistance thermometer of known and traceable uncertainty. The reference thermometers result is reported as the applied value.

INFRARED TEMPERATURE

The calibration of the infrared thermometer was conducted using a black body source of known and traceable uncertainty.

The IR results were made using a black body source with emissivity of 0.95.

The reference black body sources spectral response has been characterised over the range 8 to 14µm. No adjustments for the instrument under calibrations spectral response have been made.

All uncertainties quoted refer to the calibration and are not intended to indicate any long term specification.

Uncertainties

Relative Humidity	±1.8 %rh
Temperature	±0.2 °C
Temperature, IR	(-15 to 200) °C; ±1.5 °C. (200 to 350) °C; ±2.8 °C, (350 to 500) °C; ±4.1 °C
Instrument Stability	An additional uncertainty of 1 lsd should be added to all values.

CERTIFICATE OF CALIBRATION

Certificate Number
STD75781

Page 3 of 4 Pages

Test Title	Tolerance	Applied Value	Reading	% Of Spec.
CALIBRATION RESULTS, TEMPERATURE / RH SENSOR				
Relative Humidity	2.1%rh	12.1%rh	11.5%rh	29%
	2.1%rh	49.5%rh	51.0%rh	71%
	2.1%rh	74.2%rh	75.1%rh	43%
Temperature, RH	1.5°C	25.07°C	24.8°C	18%
CALIBRATION RESULTS, IR TEMPERATURE				
Range -50 to 500°C	2.2°C	-10.0°C	-9.0°C	45%
	2°C	0.0°C	1.0°C	50%
	2.5°C	25.0°C	25.2°C	8%
	3°C	50.0°C	50.2°C	7%
	4°C	100.0°C	100.7°C	18%
	6°C	200.0°C	201.7°C	28%
	11°C	450.0°C	458.8°C	80%

The distance to the Black body source was 500mm.

Uncertainties

Relative Humidity	±1.8 %rh
Temperature	±0.2 °C
Temperature, IR	(-15 to 200) °C; ±1.5 °C. (200 to 350) °C; ±2.8 °C, (350 to 500) °C; ±4.1 °C
Instrument Stability	An additional uncertainty of 1 lsd should be added to all values.

CERTIFICATE OF CALIBRATION

Certificate Number
STD75781

Page 4 of 4 Pages

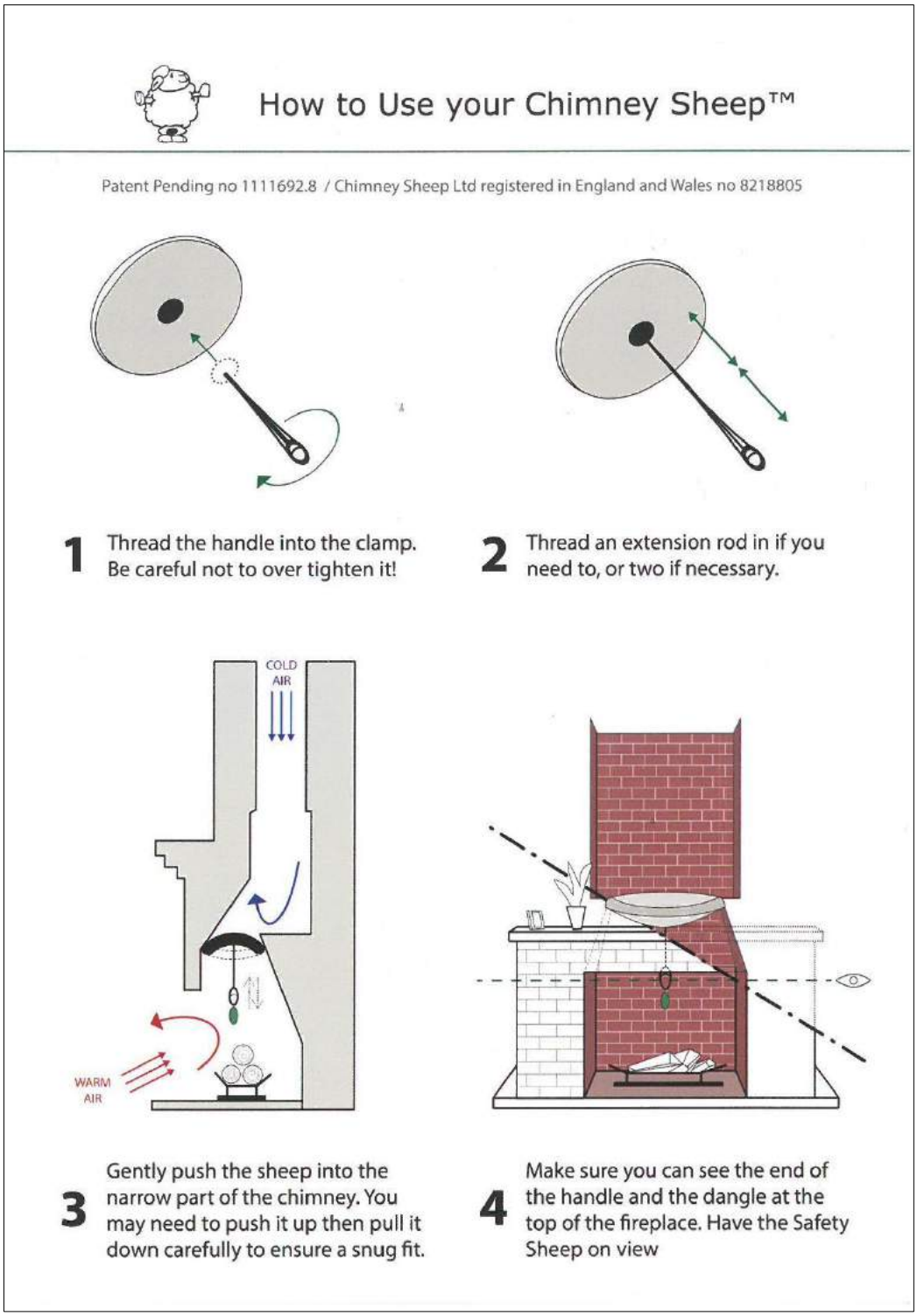
Test Title	Tolerance	Applied Value	Reading	% Of Spec.
CALIBRATION RESULTS, TEMPERATURE SENSOR/S				
Probe #1	1.5°C	-9.46°C	-5.2°C	284%
	1.5°C	0.28°C	4.4°C	275%
	1.5°C	25.07°C	27.3°C	149%
	1.6°C	100.12°C	101.2°C	68%

---- End of Data ----

Uncertainties

Relative Humidity	±1.8 %rh
Temperature	±0.2 °C
Temperature, IR	(-15 to 200) °C; ±1.5 °C. (200 to 350) °C; ±2.8 °C, (350 to 500) °C; ±4.1 °C
Instrument Stability	An additional uncertainty of 1 lsd should be added to all values.

APPENDIX: F MANUFACTURER'S MANUAL



How to Use your Chimney Sheep™

Patent Pending no 1111692.8 / Chimney Sheep Ltd registered in England and Wales no 8218805

1 Thread the handle into the clamp. Be careful not to over tighten it!

2 Thread an extension rod in if you need to, or two if necessary.

3 Gently push the sheep into the narrow part of the chimney. You may need to push it up then pull it down carefully to ensure a snug fit.

4 Make sure you can see the end of the handle and the dangle at the top of the fireplace. Have the Safety Sheep on view