Potential energy and CO_2 savings

Final Report 56137/1

Carried out for
Chimney Balloon Company

By Arnold Teekaram

20 June 2013

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Carried out for:

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1 INTRODUCTION

This report gives the results of laboratory tests at BSRIA and an analytical procedure to determine the energy and carbons savings from the use of a Chimney Balloon.

The Chimney Balloon or Chimney Pillow is designed as a simple and effective method of blocking the chimney on open fireplaces (when not in use) to prevent the heat from the primary heating within the dwelling from being lost up the chimney. This work was requested by David Woodman of The Chimney Balloon Company with the following objectives:

1. To develop a test procedure to produce robust test data that can be used to determine the Energy and CO_2 savings from the use of this device.
2. To conduct a series of laboratory test in accordance with the methodology developed in item 1 to quantify the reduction in the air flow rate up the chimney from the use of the Chimney Balloon.
3. To produce a detailed report including calculations to determine the energy and CO_2 savings in accordance with the procedure developed in item1 above.

This report describes the test procedure used in the laboratory tests and the methodology to calculate the energy and CO_2 savings. Three types of dwellings are considered to determine the energy and CO_2 savings which are included in this report. These are given in table 1:

Any marketing information, which is produced using the results contained within this report, must be submitted to a Director at BSRIA for approval prior to release.

Table 1 Estimates of annual energy consumption

Building type	Total Floor Area m^2	Primary Heating			Secondary Heating
		Appliance type	Sedbuk Efficiency %	Annual Energy Consumption kWh[1]	
3 Bedroom semi detached	88.8	Gas condensing boiler	89.6	9270	DFE fire, Output 3.0 kW, efficiency 20%
Large 4 Bedroom detached	148.6	Gas condensing boiler	89.6	14960	DFE fire, Output 3.0 kW, efficiency 20%
Large 4 Bedroom detached	148.6	Gas condensing boiler	89.6	14960	Open fireplace burning wood logs, output 6.5 kW efficiency 47%

1 Annual energy consumption data taken from BRE report 27/04/2009 “Research project: Analysis of energy use and carbon emissions from high consumption households”

2 EXPLANATION OF HOW THE CHIMNEY BALLOON WORKS

The manufacturer claims that the Chimney Balloon is designed to block the bottom of a chimney when the fire is not in use to prevent the heat from the primary heating being lost due to induced draughts. This is generally dependent upon external wind conditions , the adventitious ventilation of the dwelling which depends on the permeability of materials and inadvertent gaps and openings in the structure of the dwelling, internal/external temperature differences, the size of the builders opening of the fireplace, chimney diameter and chimney height.

According to manufacturer, the Chimney Balloon is made in a laminate of three plastics to make it airtight, tear resistant and long lasting. The special shape allows a small amount of ventilation in the two corners to keep the chimney dry.

The balloon is installed above the fireplace opening and partially inflated to block the chimney opening. See Figure 1 for schematic of installation and figure 2 for examples of installation. The Chimney Balloon may also be used in applications where there is a canopy for an open solid fuel fire as illustrated in diagram 23 of AD-J of the building regulations
http://www.planningportal.gov.uk/uploads/br/AD_J_wm.pdf

Figure 1 Schematic showing installation of the Chimney Balloon

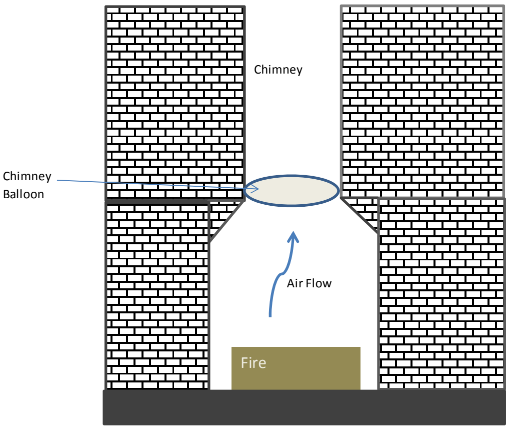


Figure 2 Examples of installation

For the purposes of calculating the energy and carbon savings from the use of the Chimney Balloon, the applications considered are:

1. Open fireplace fitted with decorative fuel effect gas fire (DFE)
2. Open fireplace fitted with solid fuel grate burning wood logs

3 TEST FACILITY

The tests to determine the reduction in air flow rate from the use of the Chimney Balloon were carried out in BSRIA's laboratory which has a purpose - designed fireplace and chimney approximately 4.5 m high (Figure 3).

Figure 3 Purpose - design fireplace and test chimney

The fireplace and chimney is typical of those in dwellings. The masonry flue is constructed using concrete flue liners and is encased in LBC facing bricks. The internal diameter of the flue lining is 200 mm (minimum requirement in AD-J) and will accommodate the vast majority of solid fuel burning appliances (whether or not a fireback is installed). These include decorative and inset living flame effect gas fires as well as most domestic stoves. This flue design is suitable for all domestic fuels including coal and properly seasoned wood. The flue liner complies with the requirements within AD-J, BSEN 1857 for appliances using solid and gaseous fuels.

The fireplace opening is sized in relation to the flue height and the flue internal diameter. See Appendix A. The fireplace is constructed with a builder's maximum recess opening of 610 (H) by 600 mm (W).

4 TEST PROCEDURE

The tests are designed to measure the reduction of the air flow rate resulting from the installation of the 'Chimney Balloon' when it is installed in the chimney. The measured reduction in the airflow rates is used in the calculations to determine the energy and costs savings.

Before commencement of the tests, the chimney and flow measuring system was tested for gas tightness to check compliance against the gas tightness requirement within BSEN 14471: 2005 of 2.0 litres/sec m^{-2} at a test pressure of 40 Pa.

A suction fan installed within the airflow measuring system (Figure 4) was used to provide an airflow over the range 0-80 m^3/hr through the test chimney and the static pressure recorded with and without the Chimney Balloon. The reduction of the airflow rate was determined from the graphs at the reference pressure corresponding to 40 m^3/hr (see Figure 5 for illustration). This value of the reduced air flow rate was used to determine the energy and carbon savings.

The airflow rate of 40 m^3/hr was obtained from the Government's Draft SAP 2012 document (Table 2.1) 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

Figure 4 Schematic of Test Facility

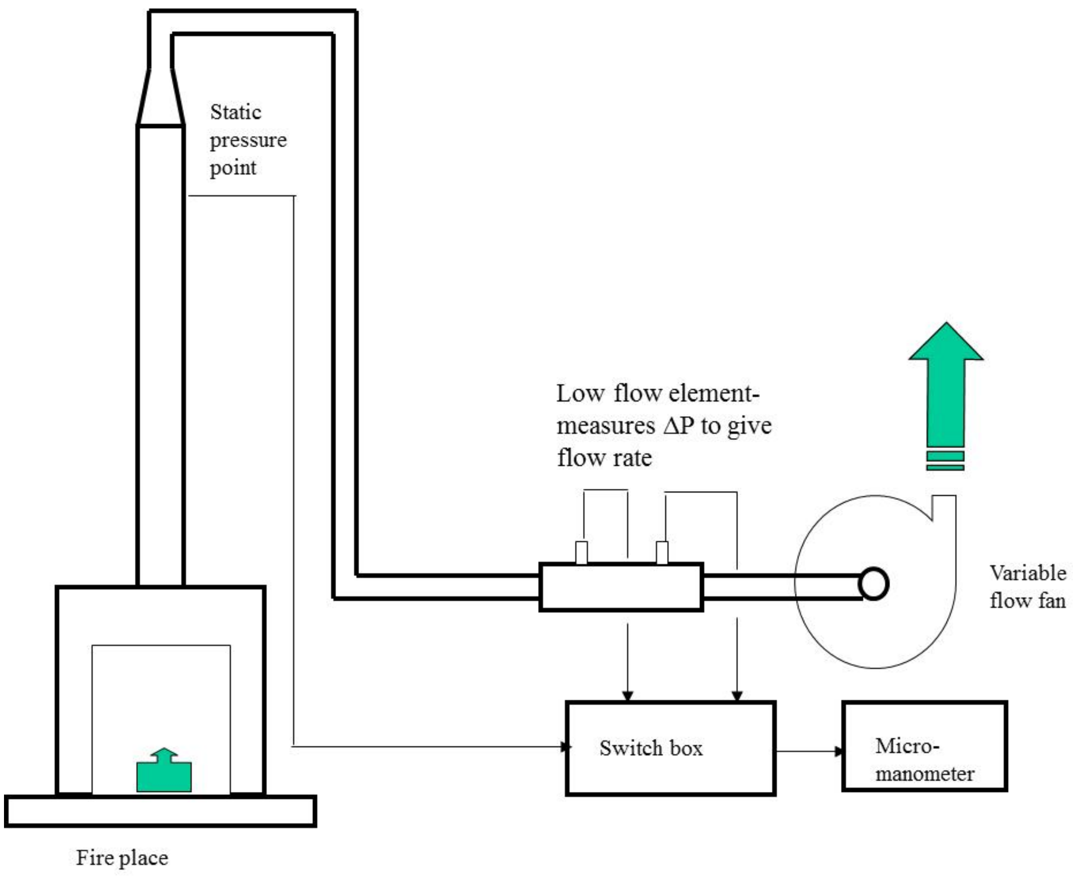
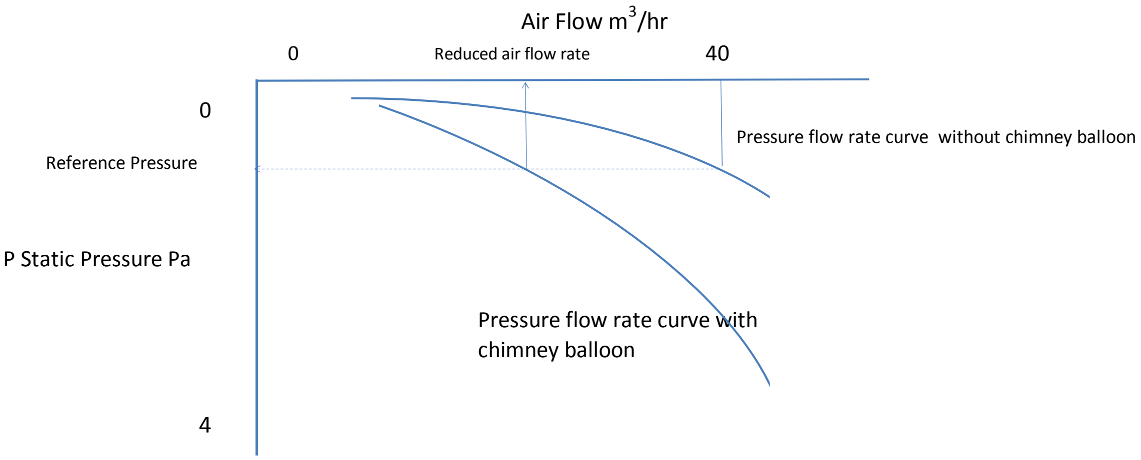


Figure 5 illustrates how the reduced air flow rate with the Chimney Balloon was determined from the laboratory results

Figure 5 Determination of reduced airflow rate



5 CHOICE OF AIR FLOW RATE

The actual air flow rate or ventilation rate through a chimney without the operation of the fire is dependent upon the following factors:

- The permeability of materials and inadvertent gaps and openings in the structure of the dwelling
- External wind conditions
- Internal/external temperature differences
- The size of the builders opening of the fireplace, chimney diameter and chimney height

In the absence of actual data for the ventilation rate through a typical chimney, the tests used the generic value of 40 m^3/hr given in the SAP 2012 calculations. It is not clear how representative this is of the actual air flow rates up a chimney. In practice, the actual ventilation rates through a chimney could be significantly higher, particularly during the heating season when temperature differences between the inside of the building and outside will result in density differences. Warm air which is heated by the primary heating will be less dense that cold air causing it to rise through the chimney.

6 CALCULATION OF THE COSTS SAVINGS

The total costs savings due to the Chimney Balloon is given by the following relation.

Total costs savings = Savings from primary heating + Savings from secondary heating.

The savings from the primary heating is a result of the reduced airflow rate up the chimney by the use of the 'Chimney Balloon'. The reduced airflow is referenced to the ventilation rates of 40 m^3/hr as given in SAP 2012

The savings from the secondary heating is obtained by not using the fire, but the boiler instead i.e. the primary heating. This is to make up for the deficit in the secondary heating which is no longer available due to the installation of the 'Chimney Balloon'. These savings would result because boilers are generally far more efficient than DFE gas fires and solid fuel open fires. A condensing gas boiler would have an efficiency of between 85-90%. A DFE gas fire in comparison would have an efficiency of around 20% and a solid fuel open fire burning wood logs would have an efficiency around 47%.

6.1 CALCULATION OF THE PRIMARY COST SAVINGS:

The primary costs savings per annum due to installation of the Chimney Balloon is calculated from the relation.

Primary Costs savings (Chimney Balloon) =(reduced mass flow rate of air through chimney with Chimney Balloon × specific heat capacity of air × ΔT × (P- S)× pence/kWh)/appliance Sedbuk efficiency. *(1)*

Where ΔT is the temperature difference between the inside and outside air of the dwelling. In accordance with SAP 2012, the average external temperature corresponding to a base temperature of 15.5°C and 2130 degree days was taken as 6.5 °C. Hence ΔT =9.0°C.

The term P-S represents the time in the heating season the secondary heating is not operating.

Where P = heating season length × 24 hrs.
S = hours of operation of the secondary heating

The number of hrs/annum the secondary heating operates is obtained by determining the total kWh over the heating season and dividing by the output of the appliance. SAP 2012 assumes that 10% of the total annual heating requirements is provided by a secondary heating appliance.

6.2 CALCULATION OF THE SECONDARY COST SAVINGS

The secondary costs savings = kWh of secondary heating (1/efficiency of secondary heating - 1/efficiency of primary heating)"× pence/kWh *(2)*

The total costs savings per annum = (1) + (2) *(3)*

6.3 CALCULATION OF THE CO_2 SAVINGS

CO_2 emissions (tonnes) per annum = Total energy savings per annum (kWh) × Fuel emissions factor (kg CO_2/kWh) × 0.001 *(4)*

The fuel emissions factor for the combustion of natural gas is 0.206 and for wood logs is 0.386- source http://www.bre.co.uk/filelibrary/SAP/2009/STP09-CO201_Revised_emission_factors.pdf

6.4 ASSUMPTIONS

The following assumptions were made in the calculations:

1. The open DFE fire (secondary heat source) is rated around 3.0 kW (output) and the gross efficiency is around 20%.
2. The heat output for an average size solid fuel open fire burning wood logs with grate to fit into the builders opening is around 6.5 kW with an efficiency of around 47%
3. The Sedbulk efficiency of a condensing gas fired boiler is 89%
4. The total heating season length is 238 days (SAP 2012)
5. The calculations assume a gas price of 4.6 pence per kWh
6. The cost of burning wood logs is 10 pence per kWh (based on a 50 kg bag) http://www.confusedaboutenergy.co.uk/index.php/domestic-fuels/fuel-prices

7 TEST RESULTS

7.1 CHIMNEY AIR FLOW RATE TEST RESULTS

The air flow performance curve showing the reduction of airflow in the chimney with and without the Chimney Balloon is shown in figures 6-9. Five separate tests were conducted with the Chimney Balloon inserted randomly within the bottom of the chimney. Results are shown for two of the 5 tests conducted. In general the average reduction of the airflow rate was around 87%. This is equivalent to a reduction of the air flow rate from 40m^3/h to around 5.0 m^3/h. This value was used in the calculations to determine the energy and CO_2 savings.

Figure 6 Chimney airflow rate performance curve –test 1

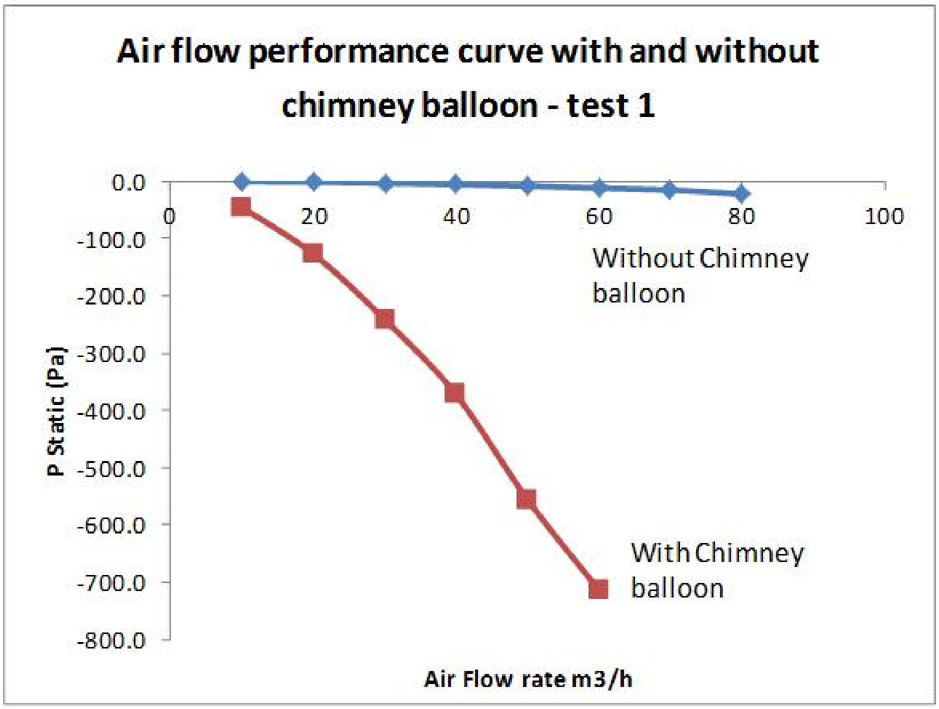


Figure 7 Chimney airflow rate performance curve (zoomed)

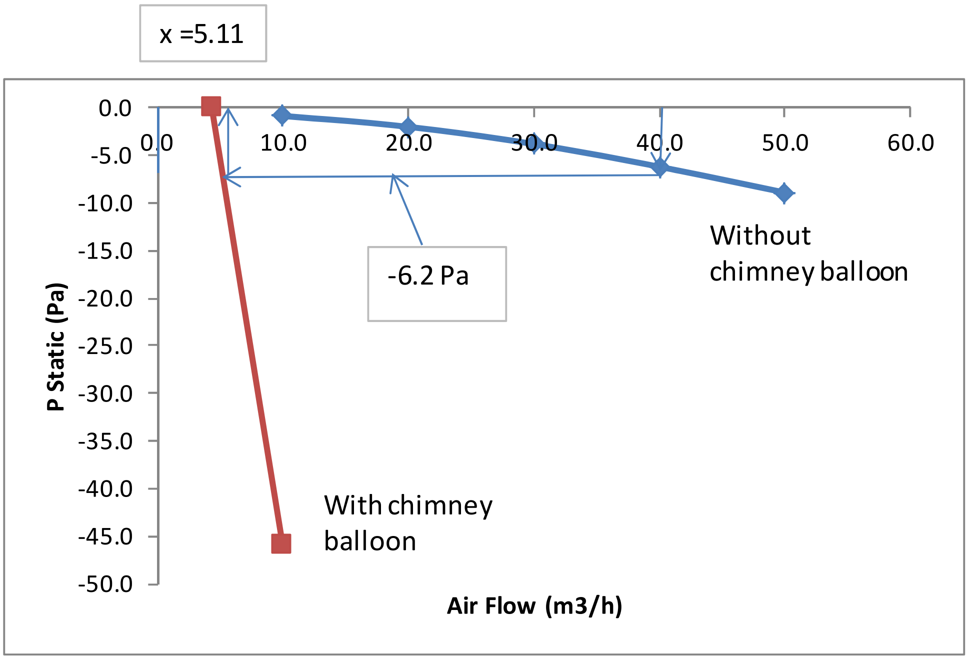
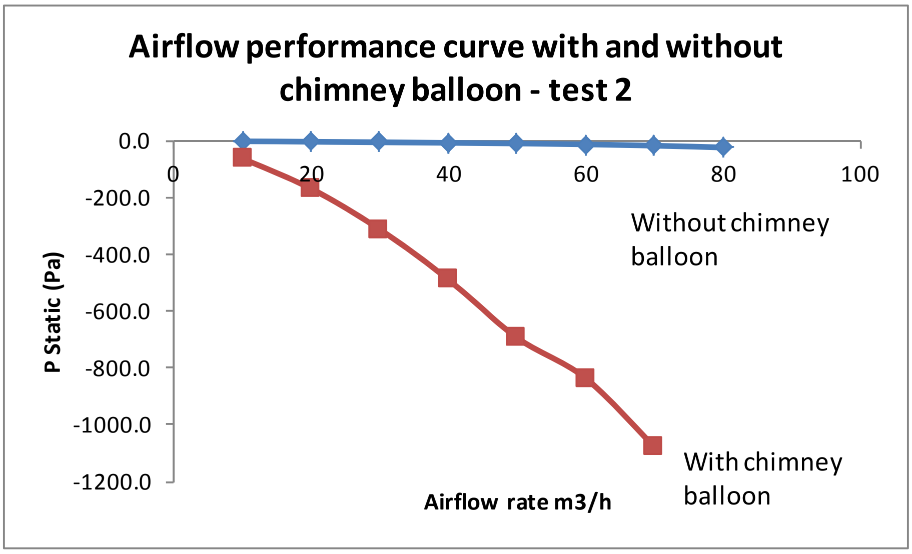
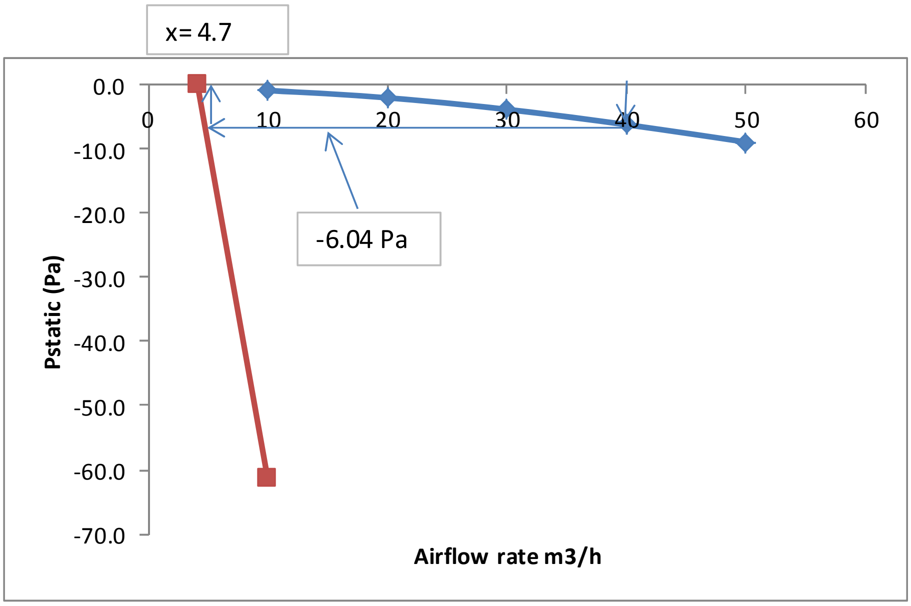


Figure 8 Chimney airflow rate performance curve –test 2



Reduction in chimney airflow rate with Chimney Balloon = 40.0-5.11 =34.89 m^3/h

Figure 9 Chimney airflow rate performance curve (zoomed)



Reduction in chimney airflow rate with Chimney Balloon = 40.0-4.7 =35.3 m^3/h

Table 2 Air flow test results with and without Chimney Balloon

Air Flow rate m3/hr	Air Flow rate L/min	ΔP (Pa)	P Static without Chimney balloon (Pa)	P Static with Chimney Balloon (Pa) test 1	test 2	test 3	test 4	test 5
10.0	166.70	5.78	-0.9	-46.00	-61.40	-55.50	-37.60	-64.25
20.0	333.30	11.58	-2.0	-127.50	-167.50	-136.50	-125.40	-180.00
30.0	500.00	17.37	-3.8	-242.00	-311.00	-268.00	-221.00	-325.00
40.0	666.70	23.16	-6.2	-373.00	-488.00	-450.00	-354.40	-525.00
50.0	833.30	28.95	-8.9	-556.00	-693.00	-649.00	-509.00	-711.00
60.0	1000.00	34.75	-12.6	-714.00	-836.00	-816.00	-672.00	-1008.00
70.0	1166.70	40.54	-16.0		-1078.00	-1044.00	-935.00	
80.0	1333.30	46.33	-22.7					

7.2 ENERGY AND CO_2 SAVINGS

The energy and CO_2 savings were calculated for the following cases.

Case 1

- 3 Bedroom semi-detached. Insulated wall cavity with double glazing and 270 mm loft insulation.
- Total floor area 88 m^2, gas heated, annual energy consumption 9270 kWh, DFE providing secondary heating.
- DFE output – 3.0 kW, efficiency 20%, Sedbuk efficiency for non-condensing gas boiler = 89.6%.
- Occupancy – two person household with all day heating.

Case 2

- Large 4 bedroom detached. Insulated wall cavity with double glazing and 270 loft insulation.
- Total floor area 148.6 m^2, gas heated, annual energy consumption 14,960 kWh, DFE providing secondary heating.
- DFE output = 3.0 kW, efficiency 20%, Sedbuk efficiency for condensing gas boiler = 89.6%
- Family occupancy with standard heating hours.

Case 3

- Large 4 bedroom detached. Insulated wall cavity with double glazing and 270 mm loft insulation.
- Total floor area 148.6 $m^{2,}$ gas heated, annual energy consumption 14,960 kWh, log burning open fire providing secondary heating.
- Output of log fire = 6.5 kW, efficiency 47%, Sedbuk efficiency for condensing as boiler = 89.6%.
- Family occupancy with standard heating hours.

Table 3 Estimates of the total energy and CO_2 savings

Installation	Primary Energy savings/annum kWh	Secondary Energy savings/annum kWh	Total energy savings/annum kWh	Primary cost savings/annum £	Secondary cost savings/annum £	Total cost savings/annum £
Case 1	667	3600	4267	31.0	166.0	197.0
Case 2	644	5810	6454	30.0	267.0	297.0
Case 3	677	1513	2190	31.0	151.0	182.0

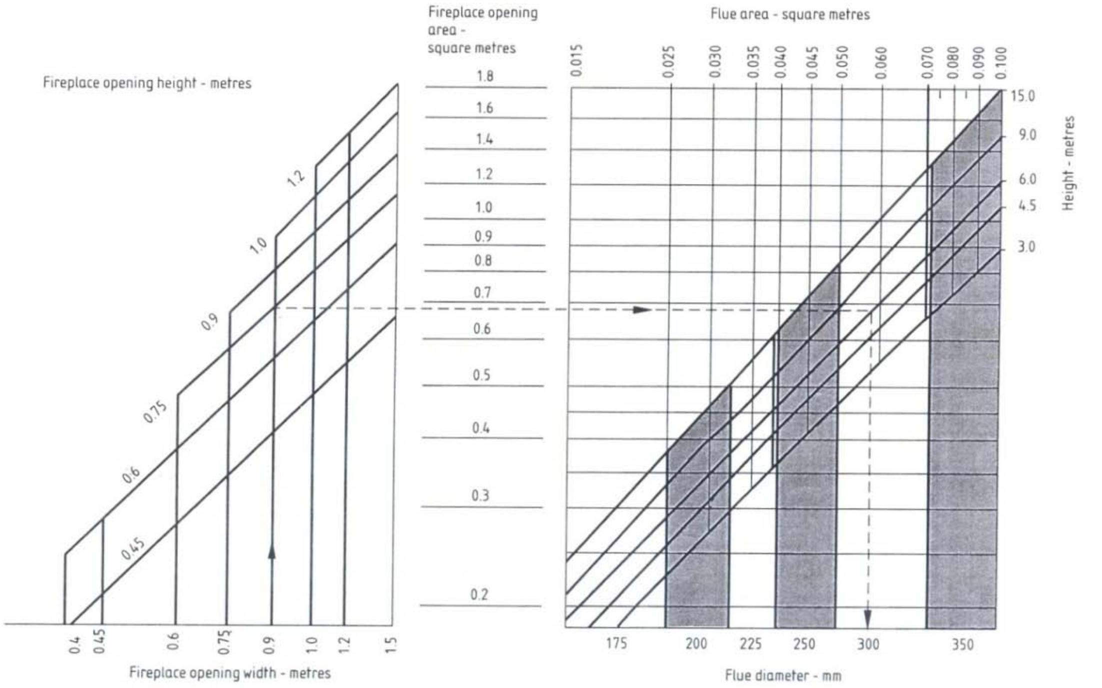
Installation	Primary CO_2 Tonnes/annum	Secondary CO_2 Tonnes/annum	Total CO_2 Tonnes/annum	Total CO_2 kg/m^2 Tonnes/annum
Case 1	0.13	0.74	0.89	7.3
Case 2	0.13	1.19	1.33	8.9
Case 3	0.14	0.58	0.72	4.8

8 CONCLUSIONS

Laboratory tests were carried out to determine the potential energy and carbon savings from the use of a Chimney Balloon. The manufacturer claims that the Chimney Balloon is a simple and effective method of blocking the chimney on open fireplaces (when not in use) to prevent the heat from the primary heating within the dwelling from being lost up the chimney. Estimates of the energy and CO_2 savings are made based on 3 types of dwelling with the primary heating provided by a condensing gas boiler and secondary heating by a DFE fire and an open log fire respectively. The main findings are given below.

1. The average reduction of the airflow rate within the chimney when the Chimney Balloon was inserted was around 87%. This is equivalent to a reduction of the air flow rate from $40m^3/h$ to around $5.0\ m^3/h$. The value of $40m^3/hr$ is the ventilation rate used for a chimney in SAP calculations to calculate the overall heating requirement of a dwelling. In actual practice, the ventilation rate is dependent upon a number of factors e.g. gaps and openings in the building structure (adventitious ventilation), permeability of the building materials, pressure difference across the chimney pots and temperature differences between the inside and outside of the dwelling.
2. The total energy and cost savings per annum is dependent upon both the primary heating consumption and the secondary heating consumption. The analysis shows that the total energy savings (primary and secondary) for a 3 bedroom semi-detached dwelling with a total floor area of $88\ m^2$ and all day heating for a two person household; when fitted with a DFE providing secondary heating was 4267 kWh. This gives a total cost savings/annum of £197.0 which is made up of a primary cost saving of £31.0/annum and secondary cost savings £166.0/annum.
3. For a large 4 bedroom with a total floor area of $148.6\ m^2$, family occupancy and standard heating hours; when fitted with a DFE, providing secondary heating, the total energy savings (primary and secondary) was 6454 kWh. This gives a total cost savings/annum of £297.0 which is made up of a primary cost saving of £30.0 /annum and secondary cost savings £267.0/annum.
4. For the same 4 bedroom house with a total floor area of $148.6\ m^2$, family occupancy and standard heating hours; but when fitted with a log fire, providing secondary heating, the total energy savings (primary and secondary) was 2190 kWh. This gives a total cost savings/annum of £182.0 which is made up of a primary cost saving of £31.0/annum and secondary cost savings £151.0/annum.
5. The total CO_2 savings/annum for the three cases considered were respectively, 7.33, 8.95 and 4.87 kg/m^2 per annum based on the total floor area of the dwelling. The total CO_2 savings expressed in tonnes per annum is given in Table 3 of this report.

APPENDIX: A DETERMINATION OF CHIMNEY HEIGHT



EXAMPLE Fireplace opening is 0.9 m wide × 0.75 m high = 0.68 m²

Then for flue height 6.0 m, use a 300 mm diameter flue.

NOTE 1 Where choice is possible, the smallest diameter flue should be used. Large diameter flues, particularly of short length, will be conducive to downdraught and therefore spillage.

NOTE 2 In the case of fireplace openings served by the above chart, a fireplace opening of greater width (*W*) than height (*H*) will be less likely to spill than one of width (*H*) and height (*W*), despite their having the same fireplace opening areas (*W H*).