

Nanoparticle emissions from combustion of biomass and anthracite in a domestic multi-fuel stove

Introduction

In many areas of the world, solid fuels are used for both space heating and cooking.

In the UK these fuels have largely been replaced in the domestic arena with natural gas, oil and electricity, but recent years have seen increasing use of solid fuel stoves, usually as supplementary heating and with a strong emphasis on aesthetic considerations.

In the 1950s, London UK suffered particularly from chemically active smogs, caused by heavy coal consumption combined with weather conditions that allowed the products of coal combustion to accumulate rather than being dispersed. These smogs had significant health effects, and smokeless zones were introduced to restrict coal burning and reduce emissions of particulates and sulphur compounds.

The latter half of the 20th Century saw a continued fall in consumption of solid fuels in cities, and air quality continued to improve. As multi-fuel stoves are increasingly installed in urban homes, often fired by unskilled operators, an examination of the emissions from such stoves is appropriate to consider their effect on local pollutants.

DMS500 Fast Particulate Spectrometer

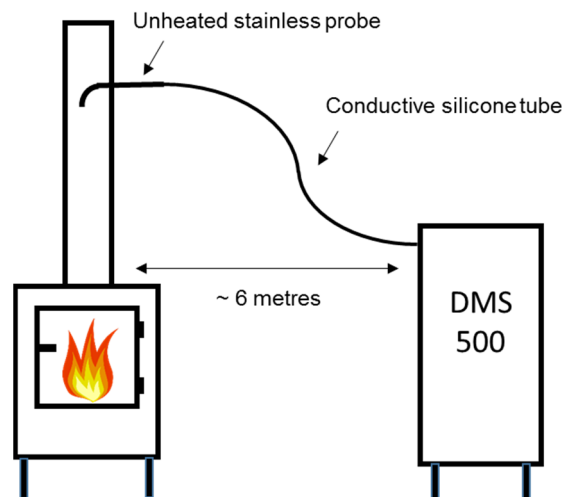
The DMS500 Fast Particulate Spectrometer uses unipolar corona charging and parallel detection of particles of varying electrical mobility (using electrometers) to offer real-time measurement of the particle size spectrum between 5 and 2,500 nm.

Various design features allow the instrument to offer 10Hz data with a $T_{10-90\%}$ of 200 ms, which is well suited to the short transient nature of emissions.

Sampling Arrangements

A small domestic multi-fuel stove of 6kW rated output was installed with a 125 mm diameter flue of approx. 3 metres length. It is noted that this is shorter than may be optimal for good draught, and further that the use of single skin flue will result in cooler exhaust gas and further reduce draught.

A DMS500 measuring between 5nm and 2,500nm at 10Hz was connected to the flue, initially using stainless steel tube and then conductive silicone tubing. The overall length of the sampling pipe was around 6 metres. This will have resulted in significant particle losses which were not compensated for. More careful siting of the measurement equipment would allow much shorter sample lines.



Example Data

The following contour plots show various stages in the operation of the stove over around 30 minutes.

Lighting:

The stove was lit using dry kindling and kerosene-based firelighters at $T \sim 120$ s. Particles of around 20 nm are observed (associated with the firelighters) but this is rapidly surpassed in concentration by ~ 250 nm particles as the kindling starts to burn. As the wood begins to burn, the concentration of particles falls, up to $T \sim 135$ s when the stove door is opened and the kindling moved to cover more fully the firelighters. This produces a rapid increase in particle concentration, and a slight increase in particle size. Closing the door at ~ 160 s significantly improves the combustion and the concentration of 250 nm particles significantly falls, although the relative concentration of 60 nm particles increases.

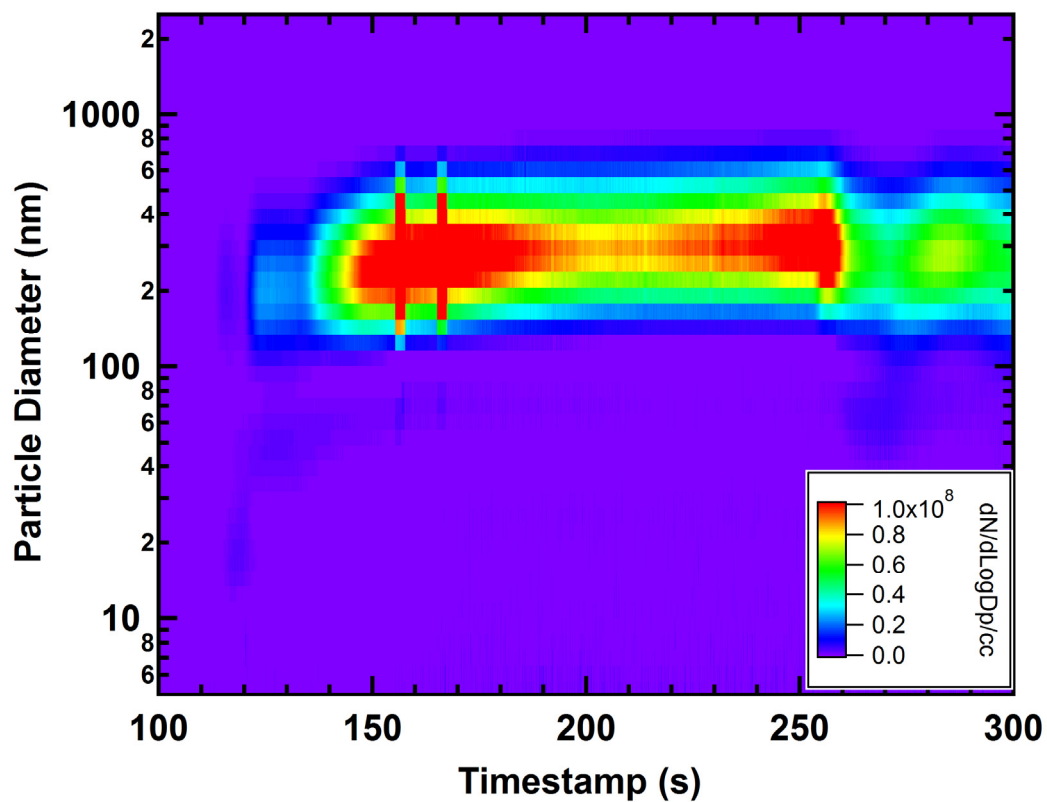


Figure 1: Lighting

Running with the door open

At around 320 s, the door was opened to allow extra air into the stove. Although the available controls on the stove were set to allow maximum combustion air, the short length of flue is presumed to have created a lack of draught for efficient combustion.

This transient produces a short-lived increase in concentration of the 250 nm particles, and a subsequent but transient appearance of ~ 60 nm particles.

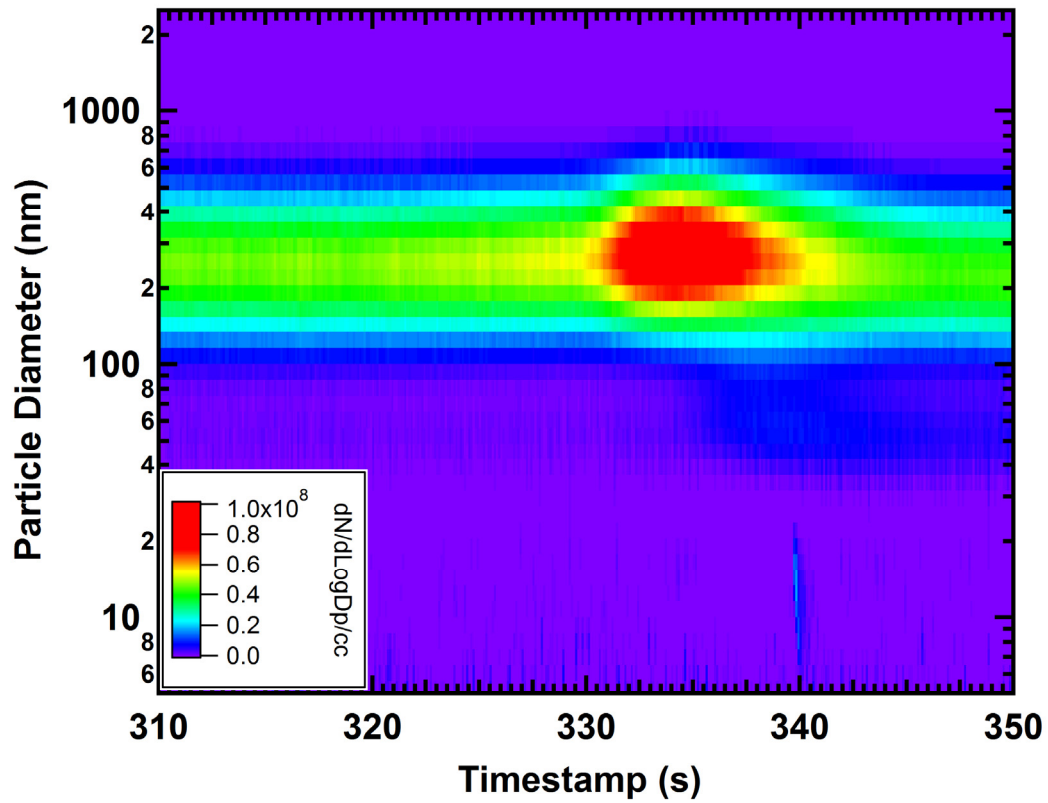


Figure 2: Running with the door open

Adding fuel

Around 400 s, the door was fully opened and further dry wood added. The door was then closed fully again. The main particle mode shrinks from ~250 nm to below 200 nm, and associated with this is the appearance of 60 nm particles in significant concentration.

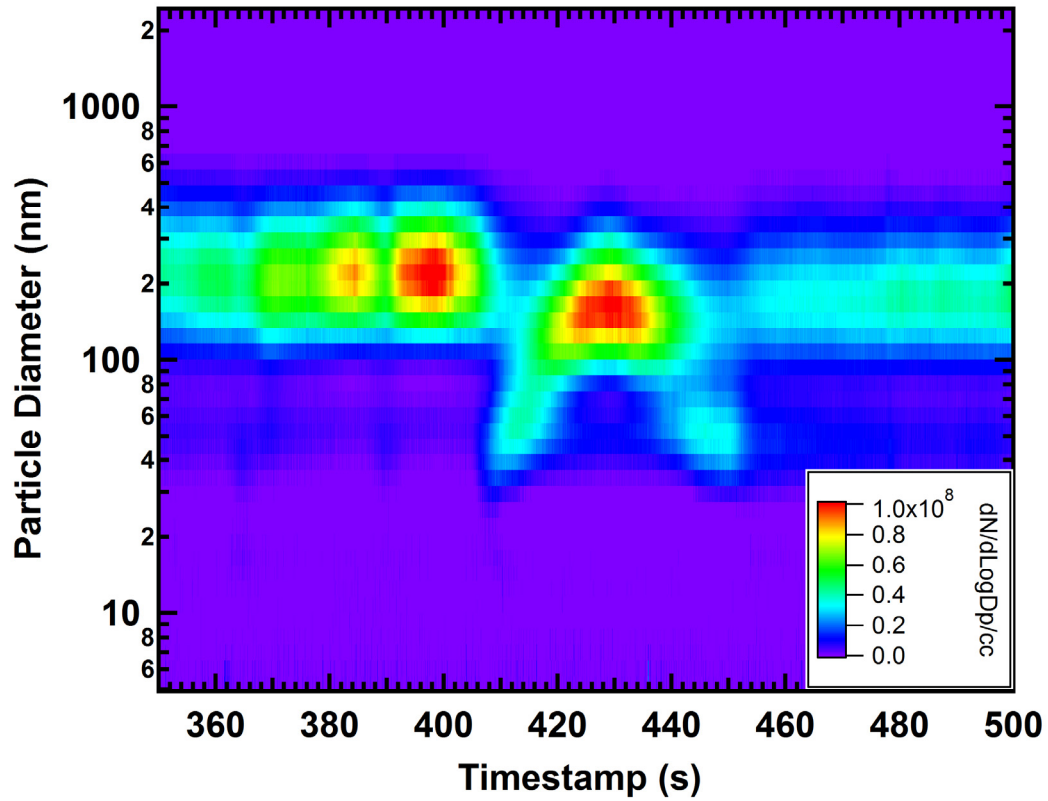


Figure 3: Adding fuel

Use of poker

Around 625 s the door was opened and consistent with earlier in the experiment, a large number of 60 nm particles are seen, replaced by much higher concentrations of 150 – 200 nm particles as the existing wood is agitated with a poker. Closing the door again rapidly re-establishes comparatively stable and clean combustion.

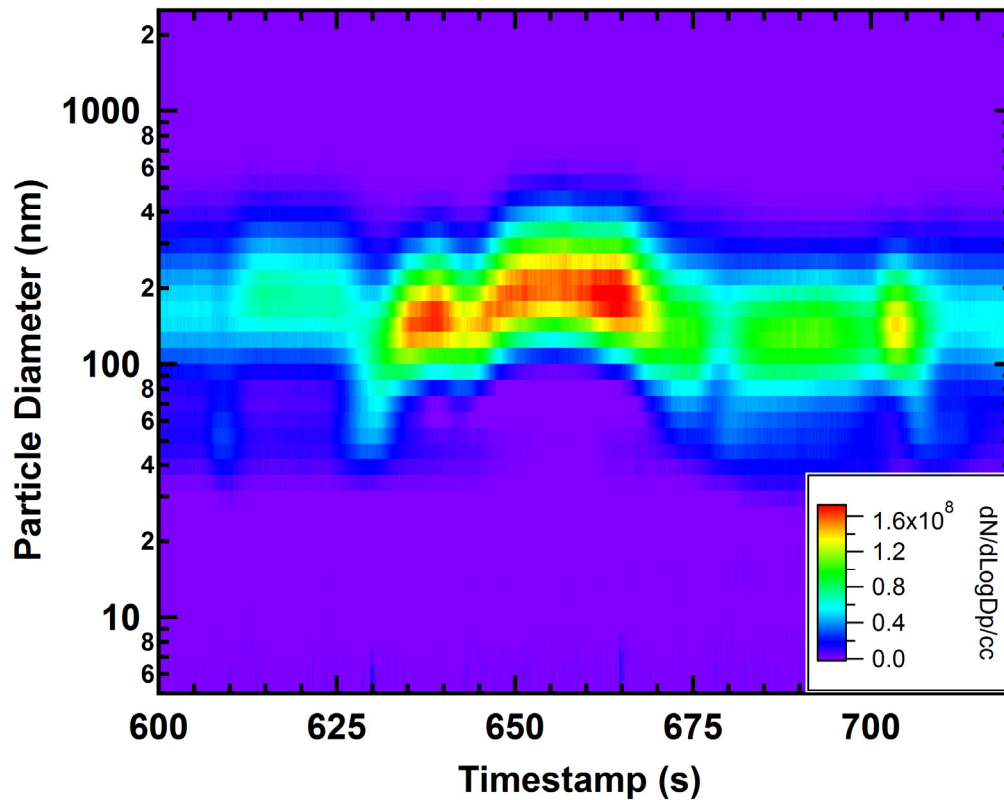


Figure 4: Use of poker

Adding anthracite

With a hot burning wood fire well established, the door was opened and anthracite nuts were added at around 825 s. As in previous agitation of the burning wood, this action is associated with an immediate increase in concentration of the 200 nm particles, although a 50 nm mode which unlike previous behaviour persists after the door is closed. It is surmised that this may be associated with the volatile components driven off the anthracite.

Although the wood fire was burning well, the addition of coal significantly impairs combustion, and after 975 s the effect of the coal is seen clearly, as the particle size rapidly increases (albeit with falling concentration) up to a CMD of 500 nm, with the distribution extending over 1000 nm.

This can be argued to be the result of overloading the fire with anthracite, but is perhaps not unrepresentative of non-skilled operators.

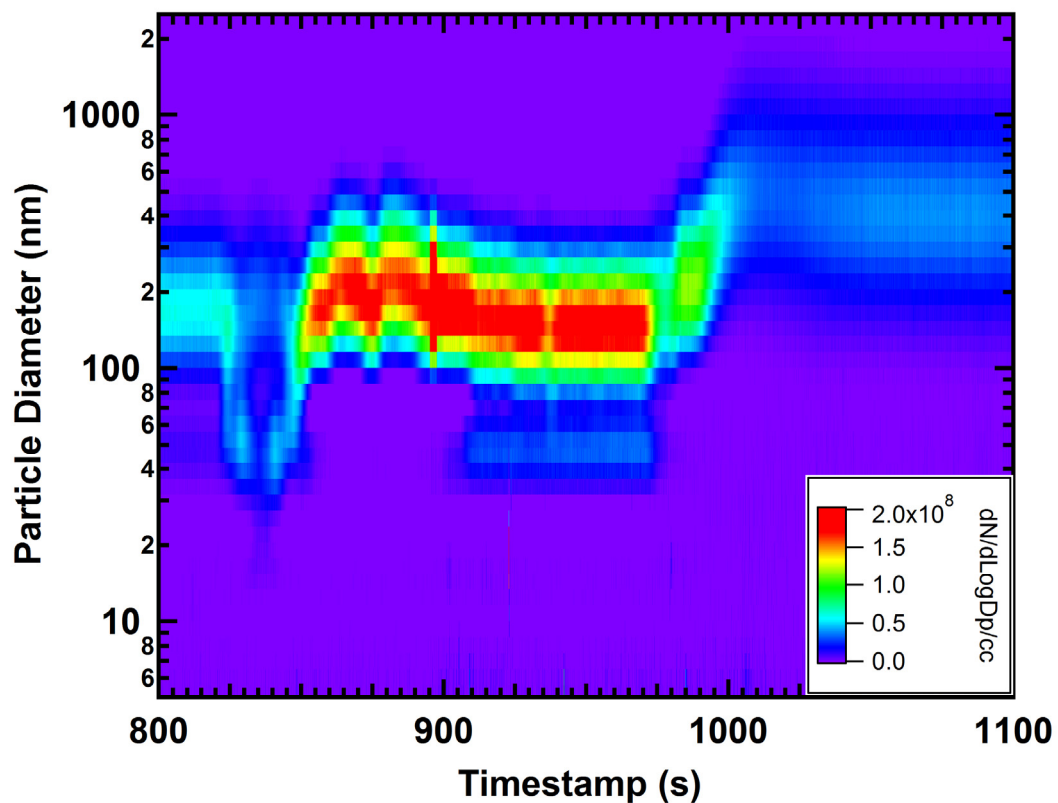


Figure 5: Adding anthracite

Conclusions

The DMS500 is able to accurately resolve the wide range of particle sizes produced by a multi-fuel stove, both at steady state, and during the transients associated with lighting, fuelling, and tending the fire.

The DMS500's high time resolution (the above data was logged at 10 Hz) provides excellent opportunities to look at these transient events in greater detail.

The appearance of much smaller particles during periods when the door is opened is of interest. These measurements were of raw exhaust gas, so the temperature at the sample point would have fallen significantly during the period when the door was open allowing excess air into the flue. Future measurements of the flue gas after dilution (arguably more representative of the pseudo-stabilised aerosol in the environment) would be helpful to understand this process.

Further Reading:

DMS500: www.cambustion.com/products/dms500/aerosol