Ventilation and Filtration Unit Effectiveness Study

at

The Bakers Arms, Waddesdon

8th - 9th October 2004

Report by:

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1. Executive Summary

A ventilation and filtration unit study was carried out at The Bakers Arms from the 8th – 9th October 2004.

Levels of carbon dioxide, as an indicator of ventilation effectiveness, and carbon monoxide and airborne particulates, both constituents of Environmental Tobacco Smoke, were recorded with the ventilation off and on, and with the filtration units off and on.

The results indicate that with the ventilation and filtration units on, there is a substantial reduction in the levels of the contaminants being monitored.

In conducting the study a number of limitations were identified, and suggestions made to improve the reliability and robustness of any future studies.

2. Introduction

This report presents the findings of a ventilation effectiveness study carried out at the Bakers Arms Public House, in Waddesdon, on the 8th and 9th October 2004.

The Bakers Arms is a brick-built community pub located in quiet road in a small village near Aylesbury and so benefits from relatively good outdoor air quality. The floor area is approximately 70 m^2 and in addition to seating areas there is a games area with table football and a pool table. The total volume of the outlet is c. 225m^3.

The pub benefits from an over bar ventilation system designed to provide 750m^3/hr of fresh outdoor air, via high level fabric diffusers. With a room volume of approximately 225 m^3 this equates to a little over 3 air changes per hour. Extract ventilation was via three through-wall extract fans fitted at high level. Using a figure of 8 litres/second/person, as recommended for non-smoking rooms in buildings by CIBSE and the Health and Safety in the Workplace Regulations, this supply rate would be suitable for 26 occupants. This number is representative of the busier periods in the pub. Rather than increasing the ventilation rate to accommodate smoking, with associated heating energy costs, ceiling mounted filtration units have been installed in the customer areas.

The approximate costs of upgrades to the ventilation for this test were £3200.

The customer area also benefitted from five Honeywell air filtration units. Three of these were F90B units, each with an airflow rate of 770m^3/hr and two were F90C units, each with an airflow rate of 453m^3/hr.
There were no restrictions on smoking in the premises at the time of the research.

The aim of this report is to quantify the effectiveness of the ventilation system and filtration units, using real time data recording of a sample of air quality and Environmental Tobacco Smoke (ETS) markers. The ventilation rate was lower than would be used if there were no filtration units fitted. The innovative use of fabric diffusers allowed the total air volume to be delivered to the bar serving area, optimising air quality in the serving area. These diffusers can deliver higher air volumes than conventional metal diffusers whilst avoiding noise and draught problems.

The airborne contaminants that were measured can be harmful in high concentrations. The levels of acceptable worker exposure are set out in Workplace Exposure Limits set by the Health and Safety Executive. There are also further levels at which discomfort can occur, these have been noted below.

3. Methodology

The monitoring was conducted on a Friday and Saturday as these days were identified as busy days of the week, so avoiding periods of decreased activity. For a brief period during the Saturday afternoon the ventilation and filtration equipment was turned off.

Continuous real-time monitoring was carried out to ensure that peak exposure conditions were captured and to measure baseline levels of markers during the overnight period of no occupancy. The sampling devices were located behind the bar counter at a height approximating to the breathing zone. Additionally, readings for some markers were taken in a customer area on a continuous basis.

This pub was similar in layout to pubs monitored in previous studies. A traditional domestic style of construction provided modest ceiling heights, a particularly challenging situation for the ventilation system. Smoking levels were similar to those in previous studies. A televised England match on the Saturday afternoon provided an example of a very busy period, during which different permutations of system operation were used.

The sampling devices used were the Dustrak Aerosol Monitor Model 8520 by TSI Inc, using the 2.5 µm inlet conditioner and a flow rate of 1.7 l/min, and the Q-Trak Plus IAQ Monitor Model 8554 by TSI Inc.

During the busy periods an hourly cigarette count was taken. Levels of carbon dioxide, carbon monoxide and respirable suspended particles (PM 2.5) were recorded. Temperature and relative humidity were also recorded.

A number of other particle phase or vapour phase markers may be monitored when assessing ventilation performance in dealing with ETS, but to do so in this study would have extended the timescale and costs unacceptably. The aim of this study was to demonstrate the effectiveness of a ventilation system in dealing with ETS by monitoring a solid (PM 2.5) and a gaseous (CO) constituent. From these results it is possible to indicate the likely effectiveness of the system for a wider range of ETS constituents.

3.1 Carbon Monoxide

Carbon monoxide is a constituent of Environmental Tobacco Smoke (ETS) but is sometimes considered unsuitable as an ETS marker, as it has other sources such as gas fires. The advantages of

ease of real-time recording and the existence of recognised occupational exposure standards for Carbon Monoxide outweighed this concern. Additionally any carbon monoxide from other sources will make the test conditions more onerous, not less.

The long-term exposure limit (8 hour time weighted average) for carbon monoxide is 30 parts per million (EH40/2004 Health and Safety Executive).

3.2 Carbon Dioxide

Carbon dioxide is a product of respiration and occurs naturally in the atmosphere. It is therefore usual to use carbon dioxide as an indication of the effectiveness of the ventilation system in occupied buildings. For the purposes of this study it is important to establish that the ventilation is performing effectively.

A figure of 12000 ppm is identified by the World Health Authority as the level of concern (BSRIA Technical Note 2/2002). This is very unlikely to be reached in a building in normal occupation. The long-term exposure limit (8 hour time weighted average) for carbon dioxide is 5000ppm (EH40/2004 Health and Safety Executive). For comfort and adequate odour dilution, a CO_2 level of 1000 ppm is recommended.

It is also worth noting that carbon dioxide is present in fresh air at around 400ppm and so, unlike other indicators, carbon dioxide levels will not tend towards zero.

3.3 Particulate (PM 2.5)

Respirable Suspended Particles (PM 2.5) are a constituent of Environmental Tobacco Smoke and serve as a marker.

The long-term exposure limit (8 hour time weighted average) for respirable particles is 4 mg/m^3 (EH40/2004 Health and Safety Executive). However, figures for traffic related airborne particles currently under review by DEFRA suggest annual exposure limits of a mean value of 0.04 - 0.05 mg/m^3. It should be noted that this figure relates to “fresh air” rather than indoor air and is an annual rather than an 8 hour average.

3.4 Temperature

There are requirements under Health Safety legislation relating to the provision of a satisfactory thermal environment. Monitoring of these parameters satisfies two objectives, firstly to establish that in improving the air quality the ventilation is not having a negative impact on thermal comfort, and secondly to establish whether it is actually enhancing thermal comfort. Ideally temperatures should be maintained between 19 ^{o}C and 24 ^{o}C, and relative humidity between 40 and 70%, (CIBSE Guide A, 1999).

3.5 Cigarette Count

The number of cigarettes consumed was measured on an hourly basis through a count of the cigarette butts collected in ashtrays to produce a measure of cigarettes/hour. To gain a fair comparison with other studies in venues of different sizes the cigarette count has been divided by the volume of the premises, to provide a measure of cigarettes/m^3/hour. The highest level of smoking to date measured in these field trials was 0.66 cigarettes/m^3/hour, which represented very heavy smoking late on a very busy night.

4. Results (Staff Area Measurements)

4.1 Carbon Monoxide

The results of the monitoring for CO can also be seen in figures 1 and 2. Figure 1 shows that, with the ventilation running, the CO levels rarely register on the instruments. Figure 2 shows that when the ventilation and filtration units are out of service, the CO levels rise rapidly, on this occasion to approximately 7 ppm behind the bar and approximately 4 ppm in the customer area, but when the ventilation is re-instated, the readings return very quickly to their earlier levels. Figure 6 indicates that CO levels overnight remain at zero.

The workplace exposure limit noted above is an average of 30 ppm over an eight-hour period.

4.2 Carbon Dioxide

The results of the monitoring for CO_2 can be seen in Figures 1 and 2. Figure 1 shows that, with the ventilation running, the CO_2 levels are normally limited to less than 710 ppm behind the bar and less than 760 ppm in the customer area. Figure 2 shows that when the ventilation and filtration units are out of service, the CO_2 levels rises, on this occasion to approximately 2800 ppm behind the bar and approximately 3100 ppm in the customer area, but when the ventilation is re-instated, the readings return very quickly to their earlier levels, demonstrating the effectiveness of the ventilation system. Figure 5 indicates that CO_2 levels overnight fall to ambient levels in fresh air as would be expected in a rural location.

The workplace exposure limit noted above is an average of 5000 ppm over an eight-hour period as a cause for concern and 1000 ppm being the accepted level for comfort and odour control.

4.3 Particulate (PM 2.5)

The results of the monitoring for Respirable Suspended Particles (PM 2.5) can be seen in Figures 3 and 4. Figures 3 shows that with the ventilation and filtration units running particulate is generally limited to below 0.5 mg/m^3 behind the bar counter and less than 1.0 mg/m^3 in the customer area. Figure 4 shows that when the ventilation and filtration units are out of service, the particulate level rapidly rises, on this occasion to approximately 3.9 mg/m^3 behind the bar and approximately 3.2 mg/m^3 in the customer area. When the systems are re-instated, the readings return very quickly to their earlier levels. Figure 6 shows that overnight the particulate levels fall below 0.01 mg/m^3 as would be expected in a rural location.

The workplace exposure limit noted above is an average 4mg/m^3 over an eight-hour period.

4.4 Temperature

The results of the monitoring for temperature can be seen in Figure 5 seen in Figure 7. Temperature is reasonably constant during the monitoring period and is within the acceptable range for comfort. During the period when the equipment is off on the 9th, there is a marked increase in temperature. If this increase in temperature were maintained the room would become uncomfortably warm.

4.5 Cigarette Count

The level of smoking was relatively high for the venue and peaked during the football international at a rate of 55 cigarettes an hour (0.25 cigs/m^3/hour). This is likely to be at, or close to, the maximum smoking rate for the outlet. For the remainder of the monitored period smoking was in the range of 0.1 to 0.2 cigs/m^3/hour, which is the normal level of smoking on busy nights in the outlets surveyed to date.

5. Analysis of Results

5.1 8th October 2004

The three air quality constituents recorded appear to fluctuate in tandem with both levels of smoking and ventilation and filtration intervention.

The results from the 8th October when the equipment was running all evening show that contaminant levels are being controlled for the markers recorded. During this monitoring period, all parameters are well within recognised HSE occupational exposure levels.

5.2 9th October 2004

The results show that the equipment is still controlling the growth of contaminant levels for the markers recorded and that when the equipment is turned off the levels steadily increase until the equipment is re-instated. When the equipment is re-instated the levels fall very quickly to the earlier position. This appears as a very steep curve on the graph. This rapid decay represents a decrease of 80 to 90% in the case of the particulates, 80% in the case of carbon dioxide, and in the case of Carbon Monoxide, with the levels falling to zero (subject to the precision of the instrument), a decrease of almost 100%.

6. Conclusions and Recommendations

This study clearly demonstrates the ability of the ventilation system and filtration units in this building to limit and control the concentrations of the parameters under consideration.

This result is particularly interesting as the ventilation system is designed at the relatively low rate of 8 litres/person/second (l/p/s) for the whole building (CIBSE and HSE), but with all the air being delivered behind the bar using a high level fabric diffuser. This is designed to provide bar staff with good air quality. The customer area receives fresh air via the bar area, and ceiling mounted filtration units are used in lieu of higher fresh air rates that would otherwise be required to accommodate smoking in the customer areas.

It does appear that the levels of airborne particulates and carbon monoxide are greater behind the bar when the systems are not operating, perhaps due to enclosed nature of the bar counter preventing the air from circulating. With the systems running the conditions behind the bar are significantly better than in the customer area, confirming the benefit of the high volume over bar ventilation flushing the stale air away from staff.

Although the contaminant levels are higher in the customer areas, they are still within recognised limits for the markers recorded, and this is the area where smoking was actually taking place. It should be noted that the steep reductions in carbon monoxide readings to effectively zero when the ventilation was used would be closely matched by reductions in all other gases in the ETS/indoor air mixture according to Dalton's Law of Partial Pressure etc.

The results of a single short term study such as this whilst not being conclusive, provide positive encouragement for further studies with higher ventilation rates and with filtration units in tandem with ventilation. The results are consistent with similar earlier studies and add weight to the argument that appropriately designed ventilation systems, both with and without the support of filtration units, significantly improve the air quality in buildings where smoking is taking place, meeting all available Health and Safety Executive Occupational Exposure Limits.

The study has a number of limitations both in terms of the range of markers recorded and the duration of the test period. It does however support the argument for the development of a more comprehensive study to determine the parameters for an acceptable standard for ventilation systems in

buildings where there is smoking in or near the building. It is recommended that the following issues be considered in any such study:

- Determination of an appropriate range of ETS markers to be measured
- Determination of an appropriate number of monitoring points
- Determination of an appropriate smoking regime to test against
- Determination of appropriate short term and long term exposure standards.

Dr Andrew Geens

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for and on behalf of UGCS Ltd

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Fig. 1 Bakers Arms Staff vs Customer areas Gases Friday 8th October 2004

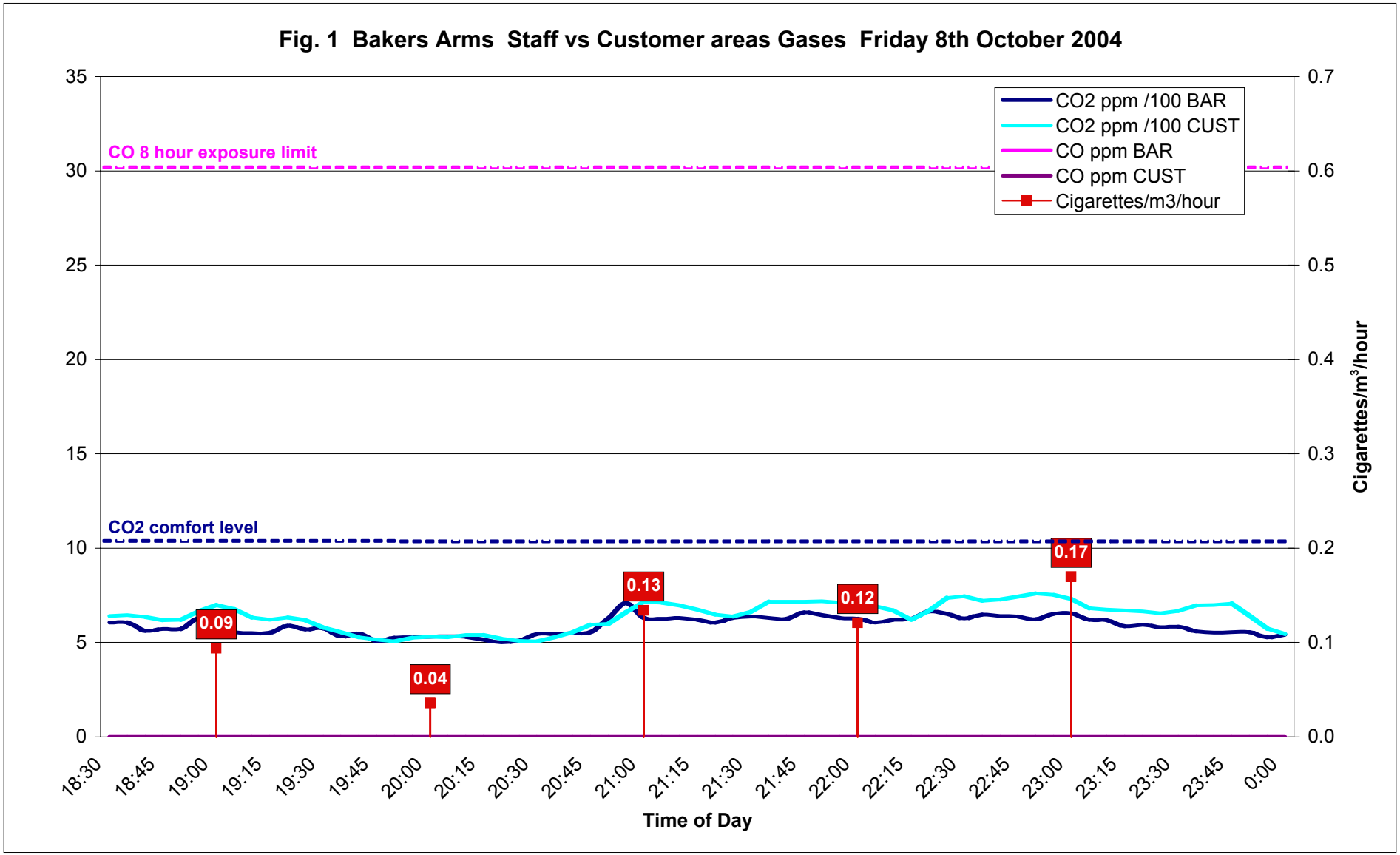

Fig. 2 Bakers Arms Staff vs Customer areas Gases Saturday 9th October 2004

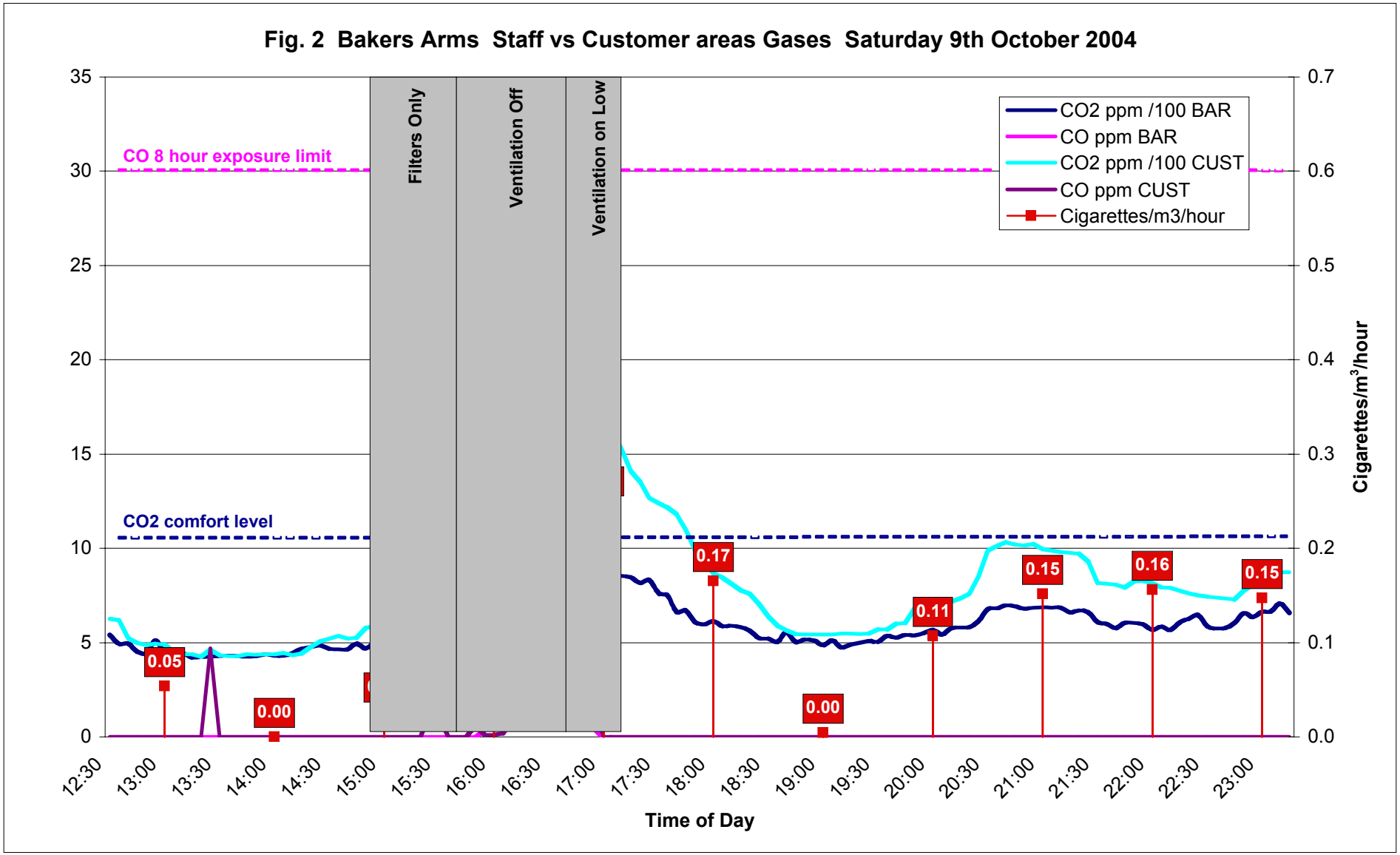

Fig. 3 Bakers Arms Staff vs Customer areas Particulate Friday 8th October 2004

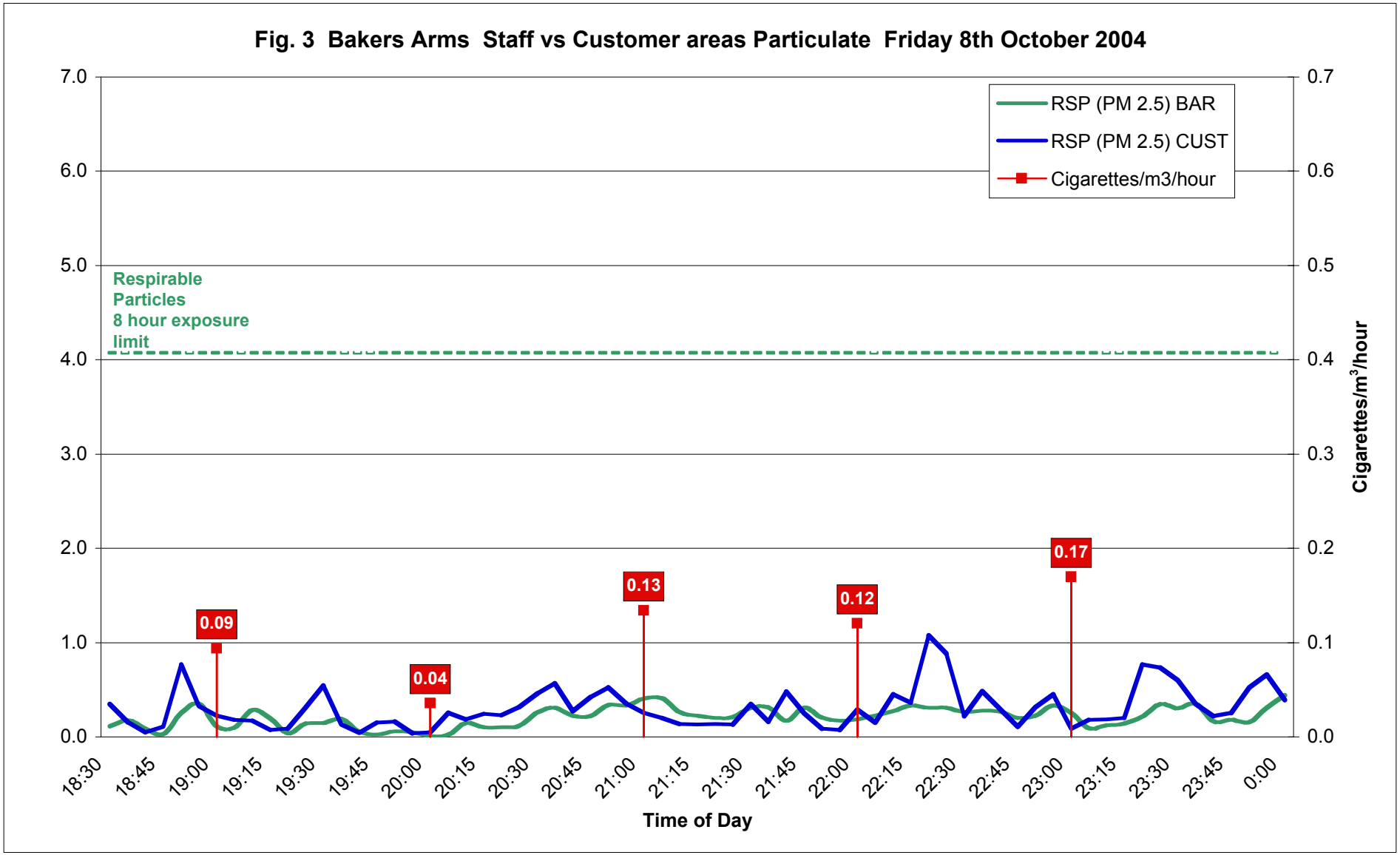

Fig. 4 Bakers Arms Staff vs Customer areas Particulate Saturday 9th October 2004

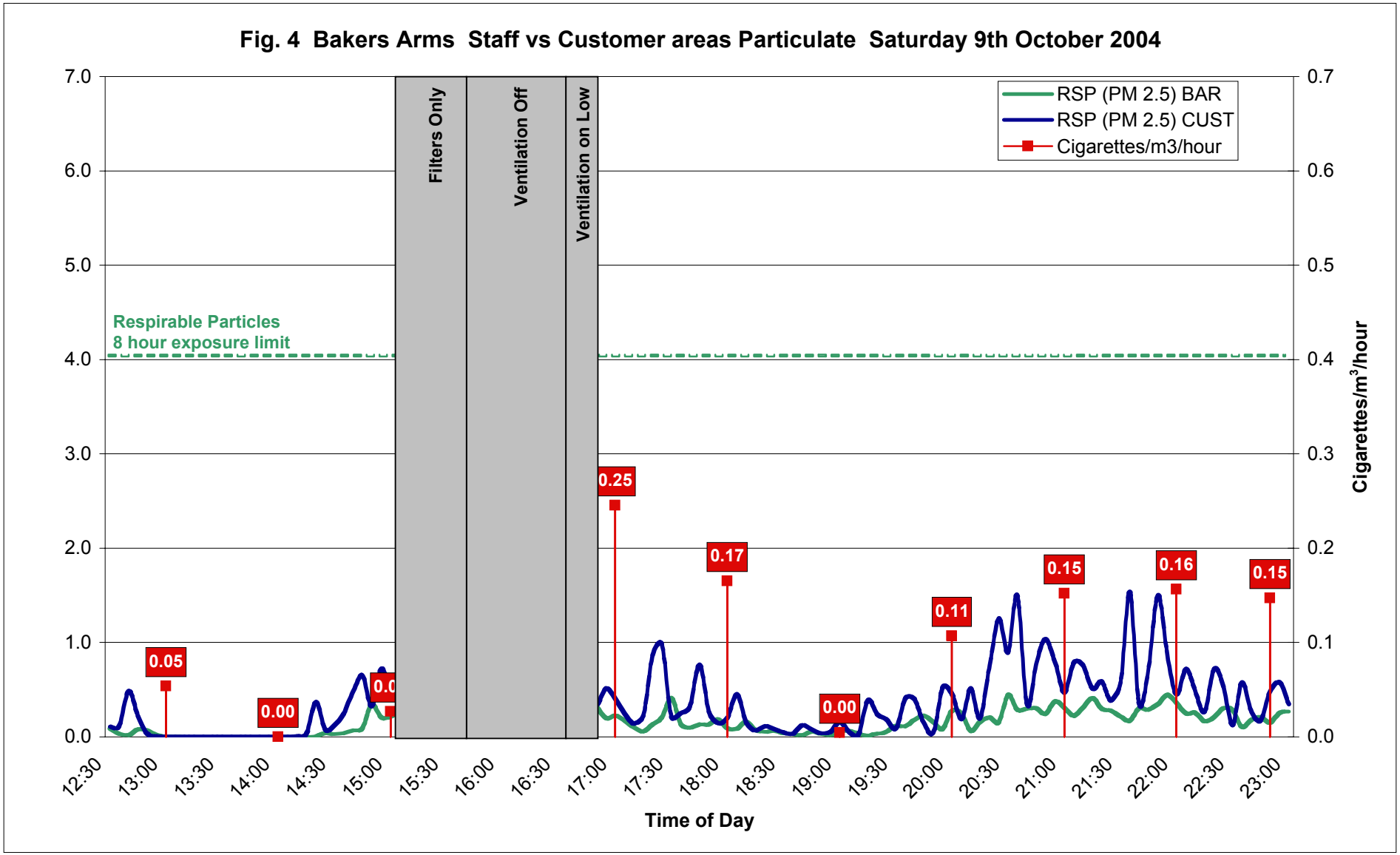

Fig. 5 Bakers Arms 8th and 9th October 2004

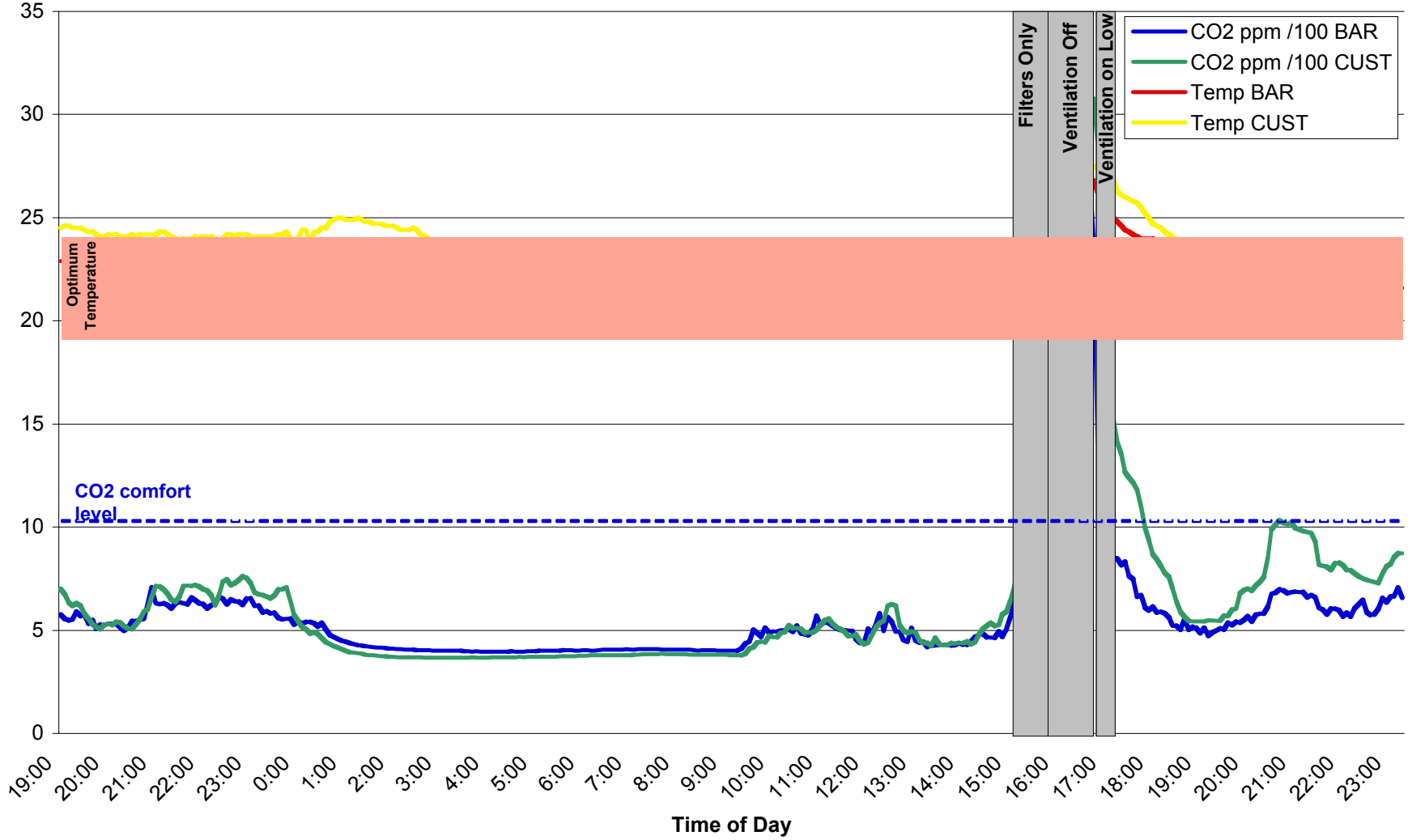

Fig. 6 Bakers Arms Carbon Monoxide and Particulate 8th and 9th October 2004

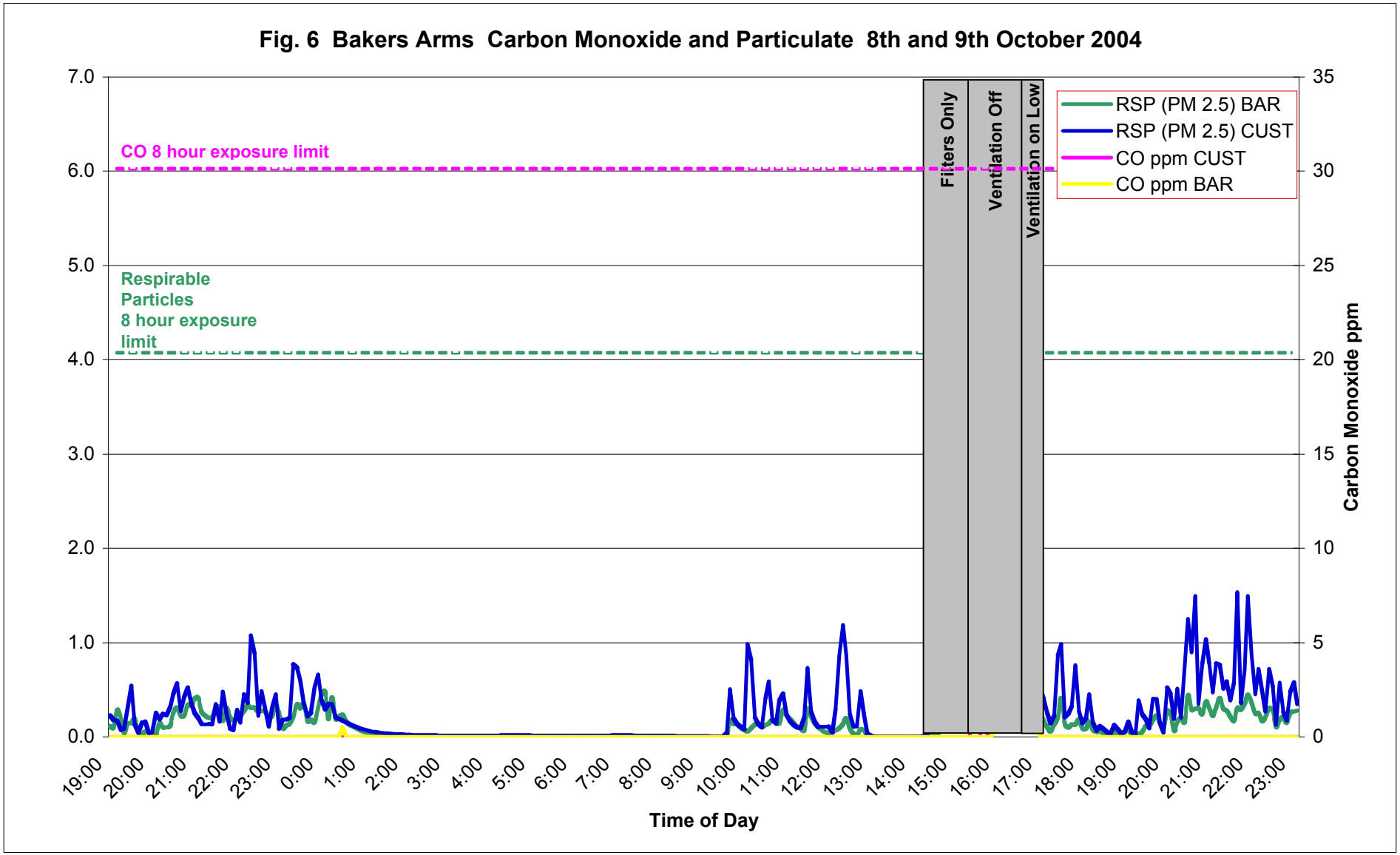

Fig. 7 Bakers Arms Relative Humidity 8th and 9th October 2004