
C2 Sensor Application Testing

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CO₂ LEVELS IN CARS

Background

When driving in a car, the driver and passengers are in an enclosed space. If the car's air conditioning system or air circulation system is in recirculation mode, air from inside the car is redistributed around and the CO₂ levels inside the car rise.

This is an issue because CO₂ is a dangerous gas. It can cause drowsiness at low concentrations and at higher concentrations, it can become an asphyxiant and cause loss of consciousness, even death. Both the Occupational Safety and Health Administration (OSHA) and the European Agency for Safety and Health at Work limit CO₂ concentration levels in the workplace to 5000ppm for a prolonged period of time, normally eight hours. The U.S. National Institute for Occupational Safety and Health limits brief exposures (up to ten minutes) to 30,000ppm, or 3% concentration, and considers CDPL exceeding 4% as "immediately dangerous to life and health".

People who breathe 5% for more than half an hour show signs of hypercapnia, which can result in symptoms of flushed skin, muscle twitches and high blood pressure. If breathing 7-10%, this can result in serious hypercapnia with symptoms of panic, hyperventilation, unconsciousness and eventually death.

For a driver in a car, even slight drowsiness can become a problem so rising CO₂ levels inside cars is a serious issue.

Test 1

To show the levels of rising CO₂ in a car over time, tests were carried out using the C2 sensor. Three adults travelled in an enclosed car for 30 minutes then stationary for 30 minutes. Measurements were obtained using eight C2 sensors. They showed the CO₂ levels rise quickly to 2000ppm when the car is in motion and when stationary, 4000ppm levels were measured (see Figure 1).



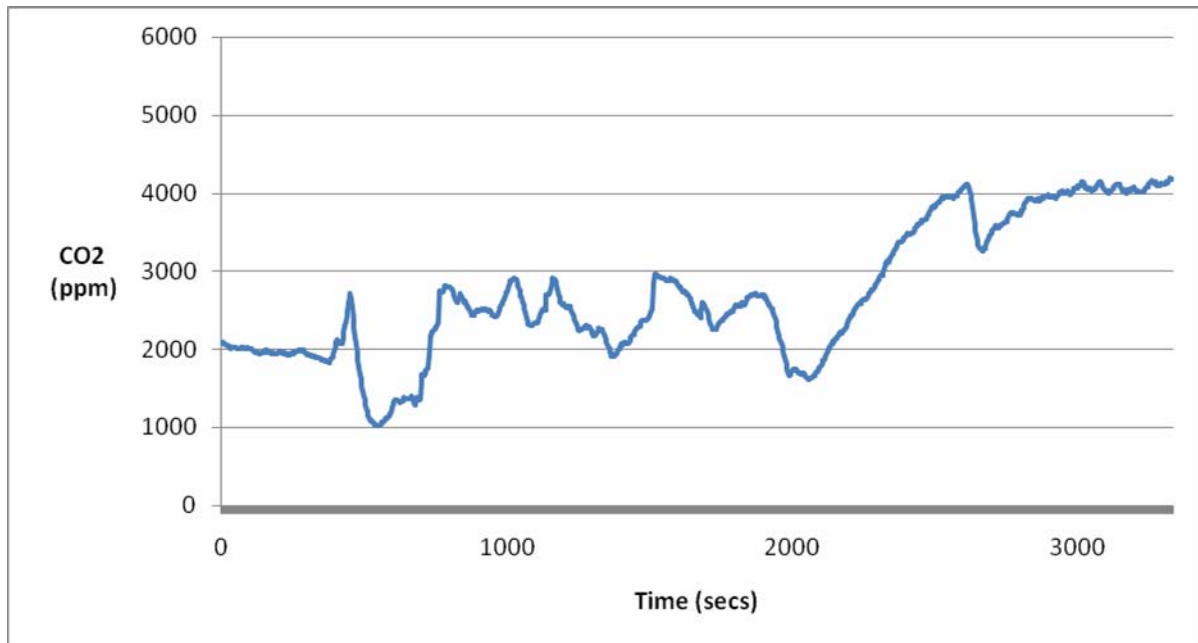


Figure 1 – CO₂ levels from test 1

This test shows levels quickly rise from zero (fresh air) at 400secs to 2000ppm, driving at an average speed of 30mph (48kmph). The readings fall to 1000ppm at 1700secs when the speed increases to an average of 60mph (96kmph). The levels rise again when the car is stationary, to simulate traffic conditions. There is then a sudden drop in reading as the doors are opened and two passengers leave – 2500secs. The reading rises as the single passenger remains in the car.

Test 2

To simulate long periods of stationary traffic, four adults were positioned in a car with eight C2 sensors measuring the CO₂ level. This test was performed in a Ford Mondeo 5-door family saloon car (see Figure 2).



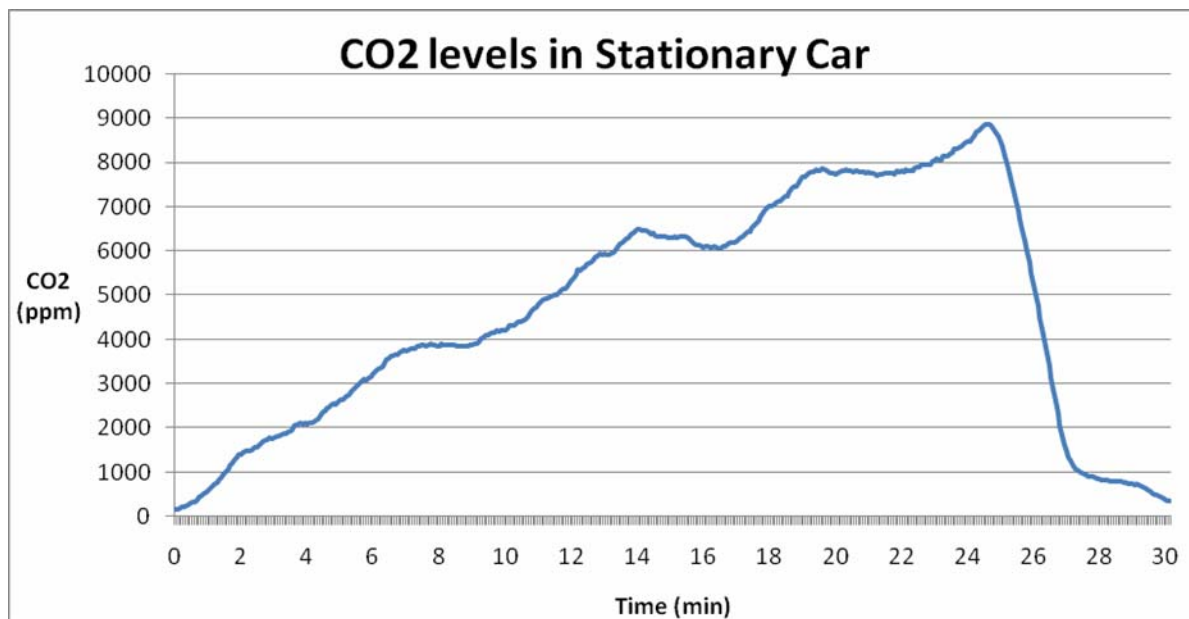


Figure 2 – CO₂ levels from test 2

Initially all doors were opened for 5 minutes to allow CO₂ to stabilise. Four adults entered the car and sat with the sensors on the back parcel shelf in an open topped container. The air vents and all the doors and windows were closed. Figure 2 shows the results from one of the sensors averaged over 8 seconds. The readings start at approximately 450ppm (fresh air) then steadily rise over 25 minutes to almost 9000ppm. At 20 minutes the passengers started to feel uncomfortable and at 25 minutes, the conditions were getting oppressive so the test was stopped at this point. The doors were then opened and all passengers left. After 3 minutes, the concentrations had dropped to 800ppm and after 5 minutes, they had returned to the initial value of 450ppm.

Test 3

Test 3 incorporates a full journey and 4 different driving conditions. These conditions are:-

- Condition 1 - Driving with air vents closed – 40 mins
- Condition 2 - Doors open, passengers exit, CO₂ normal
- Condition 3 - Three passengers in stationary car, with one window half open, to simulate sitting in traffic
- Condition 4 - Driving with vents open – 40 mins



Condition 1 Fig 3

For this test, there were 4 passengers in the car. The car was driven at different speeds over the course of 40 minutes. The peaks on the graph show the points when the car is travelling slower. With the vents shut, the variation in speed of the car changes the concentrations of CO₂. The CO₂ levels rise to 3000ppm.

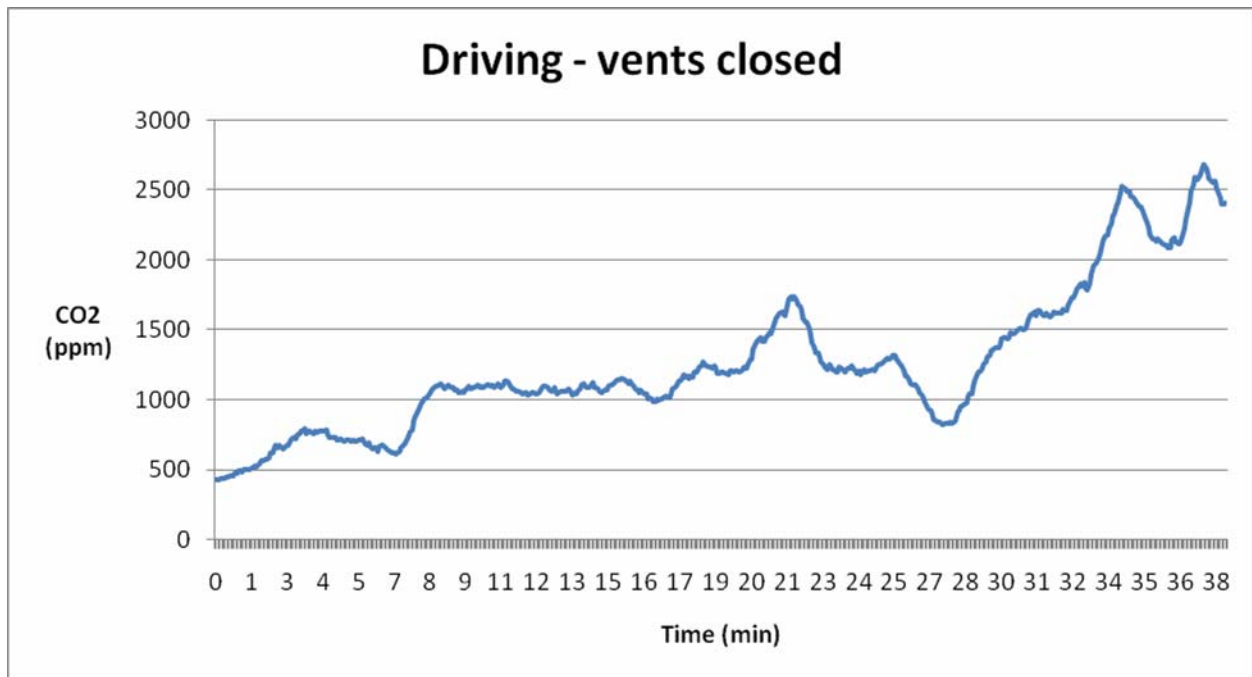


Figure 3 – CO₂ levels in car, driving with vents closed



Condition 2 Fig 4

Fig. 4 shows the effect of the passengers opening the doors and leaving the car, then closing the doors behind them. It takes approximately two and a half minutes for the CO₂ levels to drop to 300ppm where the levels are that of ambient.

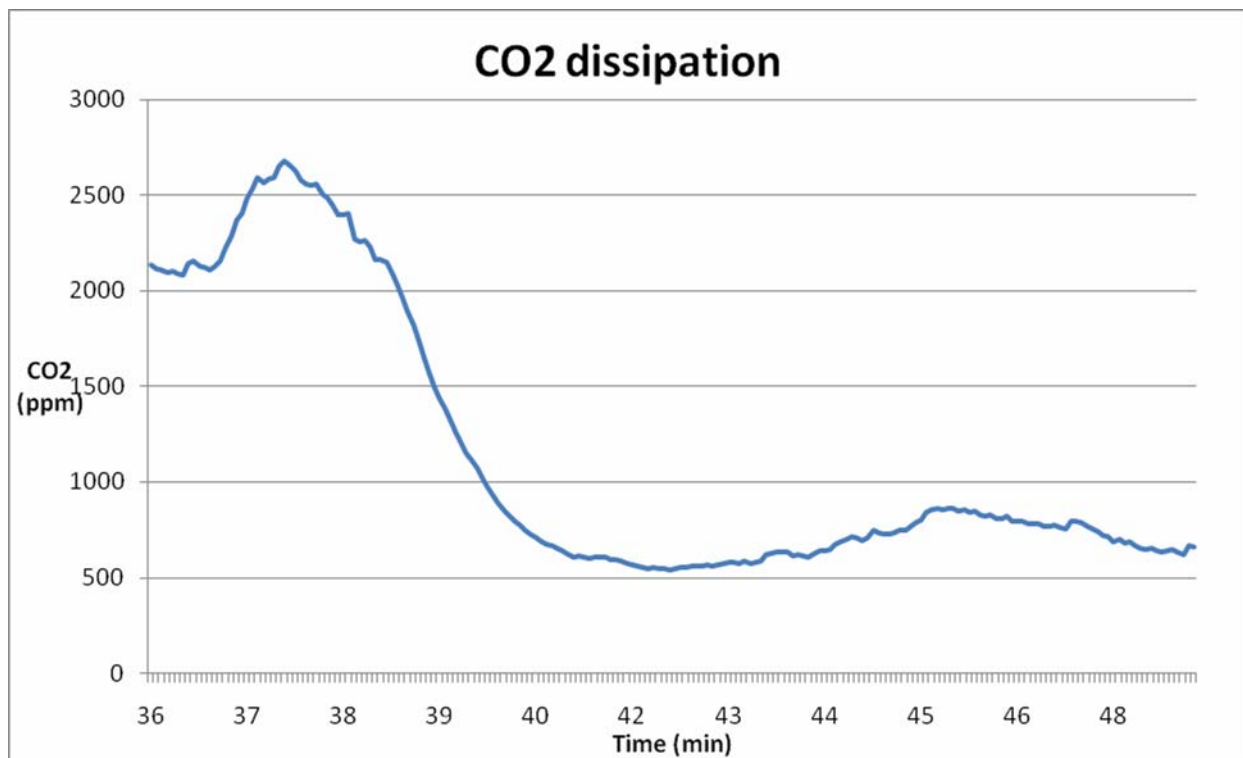


Figure 4 – CO₂ dissipation when doors open and passengers leave



Condition 3 Fig 5

This test is to simulate the effect of sitting in traffic with one window half open. The effect of rising CO₂ levels can still be seen even though a window is open due to the three adults inside the vehicle. In Fig. 5 the CO₂ levels reach 6500 ppm. The drop at 73 minutes is the door being opened.

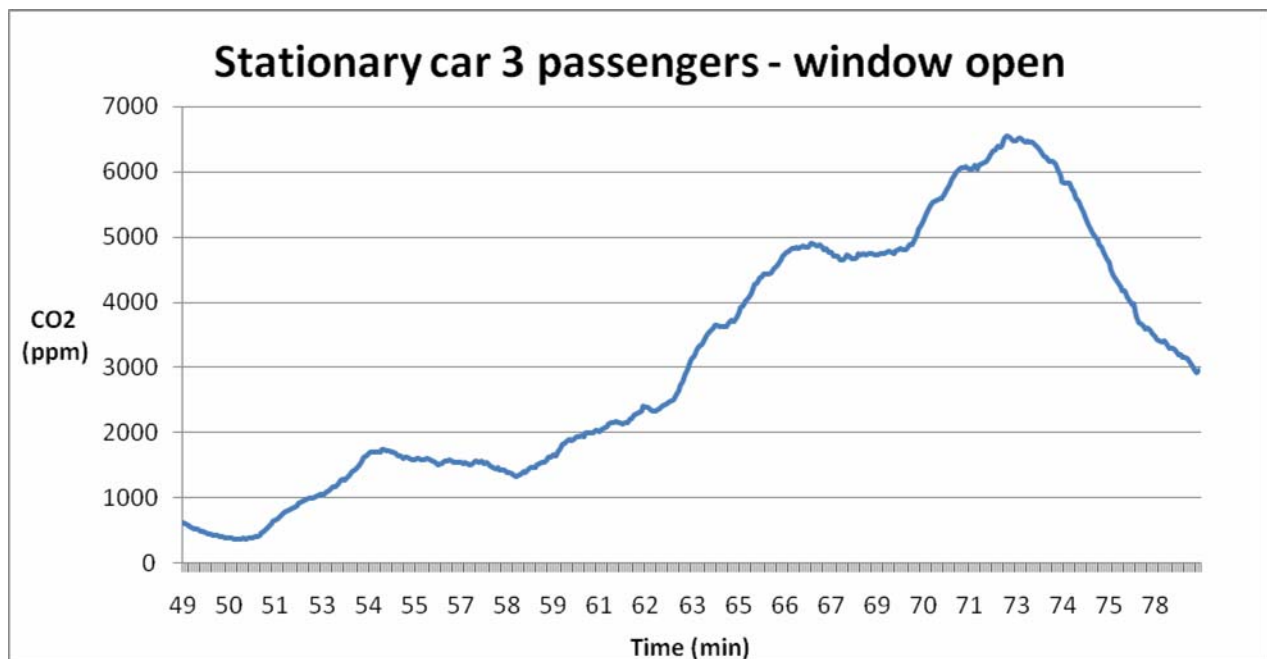


Figure 5 – CO₂ levels in stationary car to simulate traffic



Condition 4 FIG 6

On the final stage of the journey, the car was driven with the air vents open. There is still some residual CO₂ in the car; hence the readings are slightly higher than in condition 1. The troughs in the graph correlate with increased speeds. The CO₂ levels are lower with the vents open.

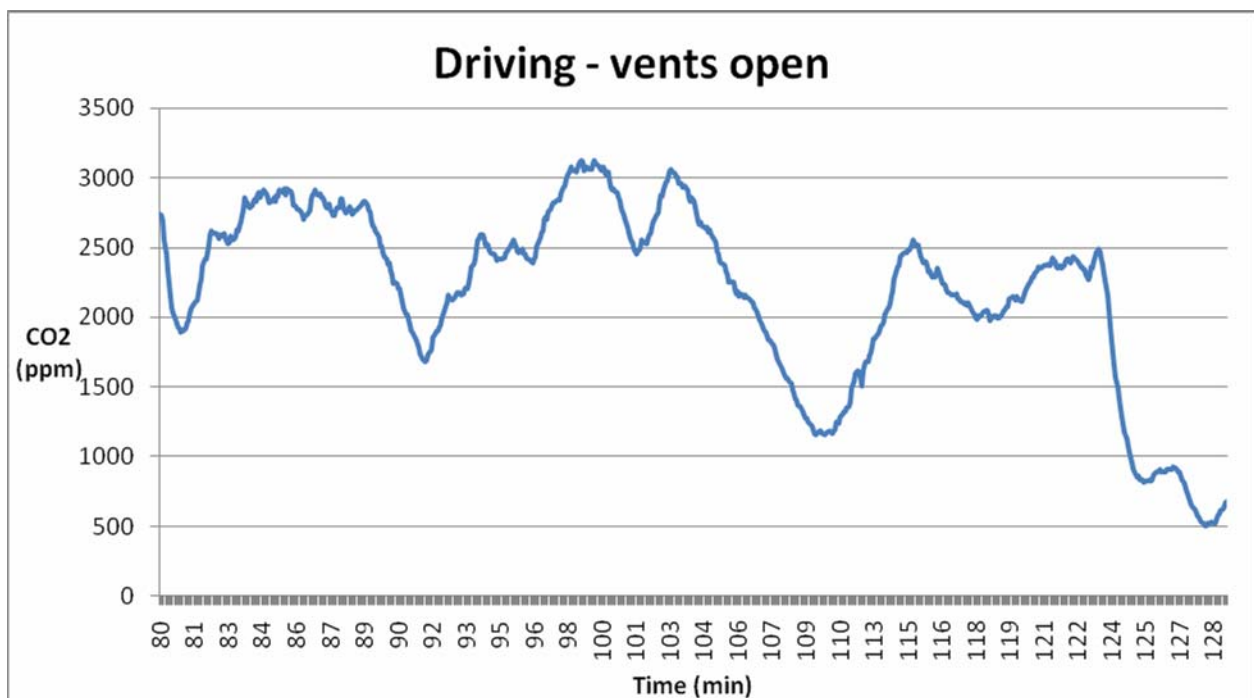


Figure 6 – CO₂ levels of car driving with vents open



CO2 LEVELS AT SOFT DRINKS MANUFACTURER

Measurement of Carbon Dioxide at a Soft Drinks Manufacturer

Test No. 01000

Tests Conducted

The following tests were conducted over a two-day period.

The initial measurement was conducted at 1m height at the point where drink is carbonated (filling station). As detailed in graph 01001, the concentration in CO₂ rises from 15,000ppm to 22,000ppm. The rise in reading was the result of the access doors to the filling station being opened.

The tests conducted the following day were again initially conducted at 1m height but on further investigation, the levels varied from “head height” to ground level. A fixed concentration test gas was used before the measurement to check calibration. The variation of CO₂ levels of concentrations were measured by the C20 sensor at different heights. The results shown in Graph 01002 illustrate at 1.8m height the levels of CO₂ are 6000ppm. At 1m height, this rises to 15,000ppm and when moved to 30cm from the ground, the levels rise to 30,000ppm.

The European Agency for Safety and Health at Work limit for CO₂ concentration levels in the workplace is 5000ppm for 8 hours exposure. When measurements are reaching levels of 40,000ppm, this can become an immediate danger to health.

Test No. 01001

Background

Following previous tests carried out at soft drinks manufacturers, more testing was required to determine levels of CO₂ at different heights around the canning station.



Tests Conducted

The following tests were conducted over a period of approximately 2 hours.

Eight sensors were placed at different heights around the canning station. The levels of CO₂ were measured and recorded over a time of 2 hours 20 minutes. The canning station was not operating over the complete measurement period. The product contained lower levels of CO₂ for the carbonation process. Approximately half the CO₂ concentrations were used in the carbonisation for the product compared with the previous tests conducted.

The sensors were placed at three different heights around the workstation desk at the C4 canning station. The positions were as follows:-

- D323, D577 – height approximately 200mm
- D670 – height approximately 400mm
- D715, D579 – height approximately 800mm
- D194, D589 – height approximately 1450mm
- D699 – at door of canning station, height approximately 200mm

D323 and D527 showed peak levels of 15,000ppm when the machinery is working at full capacity. When the station stops production, the level of CO₂ falls to 1000ppm. During a previous test at a similar height, the peak concentration levels were 30,000ppm when the machinery was running. These results can be seen in graph G-01006 and G-01007.

The readings from D670 show peak levels of 6,000ppm (graph G-01008). D715 and D579 reached peak levels of 4,500ppm (graphs G-01009, G-0110) and D194 and D589 both reached a peak of 3,500ppm (graphs G-01011, G-01012).

D699 was placed at the door of the canning station. The peak concentrations seen by the sensor was 12,000ppm (graph G-01005).



CO2 LEVELS AT MEAT PACKAGING FACILITY

Measurement of Carbon Dioxide at a meat packing facility

Test No. 01002

Tests Conducted

The following tests were conducted over a period of approximately 45 minutes.

The tests were carried out at several areas around the packing machine, where CO₂ is used in packaging to increase the shelf life of the meat.

One sensor was placed at ground level beneath the conveyor belt. Levels of 4000ppm concentration were measured. The results are shown in graph G-01013; this was typical of the other sensors which were also stationed around this area.

The second test area was adjacent to the packaging machine at a height of approximately 1.3 m from the ground. The results from D699 show the concentration levels rise to 3000ppm, 0.3%, shown in graph G-01014.

The final area tested was next to the gas inlet pipe near the base of the machine. The results from the sensors placed around this area show that the concentration levels of 5000ppm or 0.5%. The results are shown in graph G-01015.



Human breath, when exhaled, contains a Carbon Dioxide concentration of approximately 45,000ppm. The C2 sensors can provide fast response to breath.

The test was carried out in an office environment with a background of approximately 500ppm. The sensor was exposed to exhalation of breath from a distance of 30mm for 5 seconds. The results are shown below.

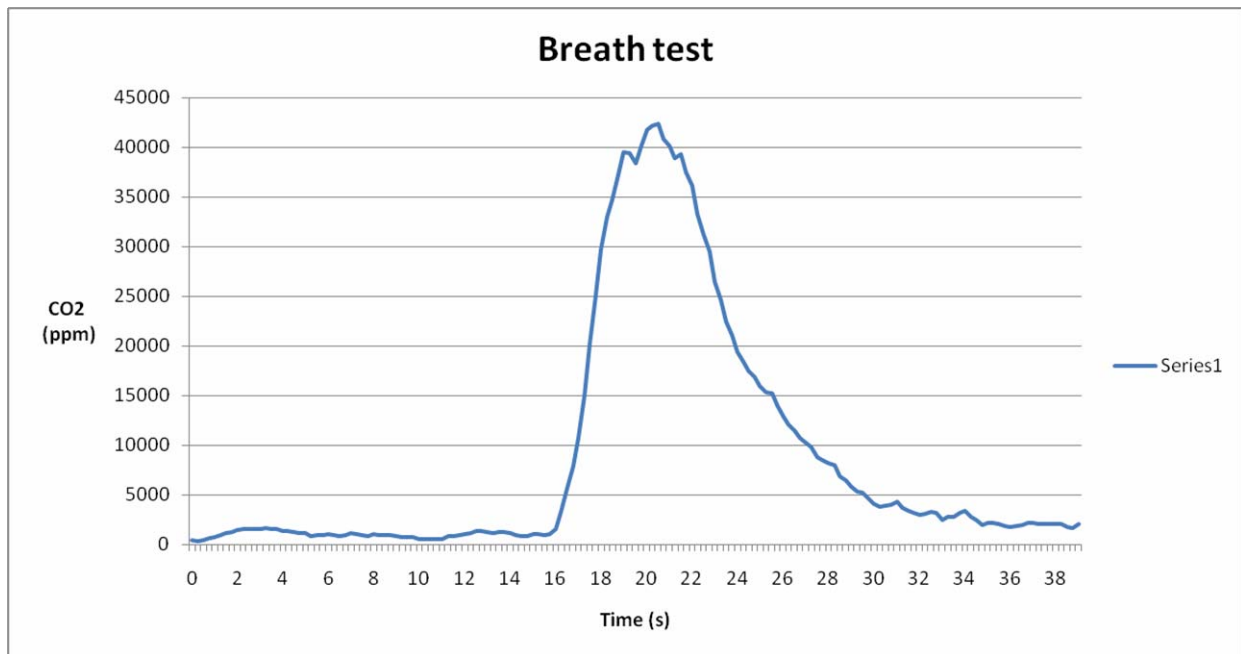


Figure 7 Breath test

Fast response

Note the speed of response of the C2 sensor. This can be used for many applications including safety. To show the quick response of the sensor, the sensor sat in ambient atmosphere of 500ppm then shown 50,000ppm for 5 minutes. This measurement was averaged over 8 seconds.



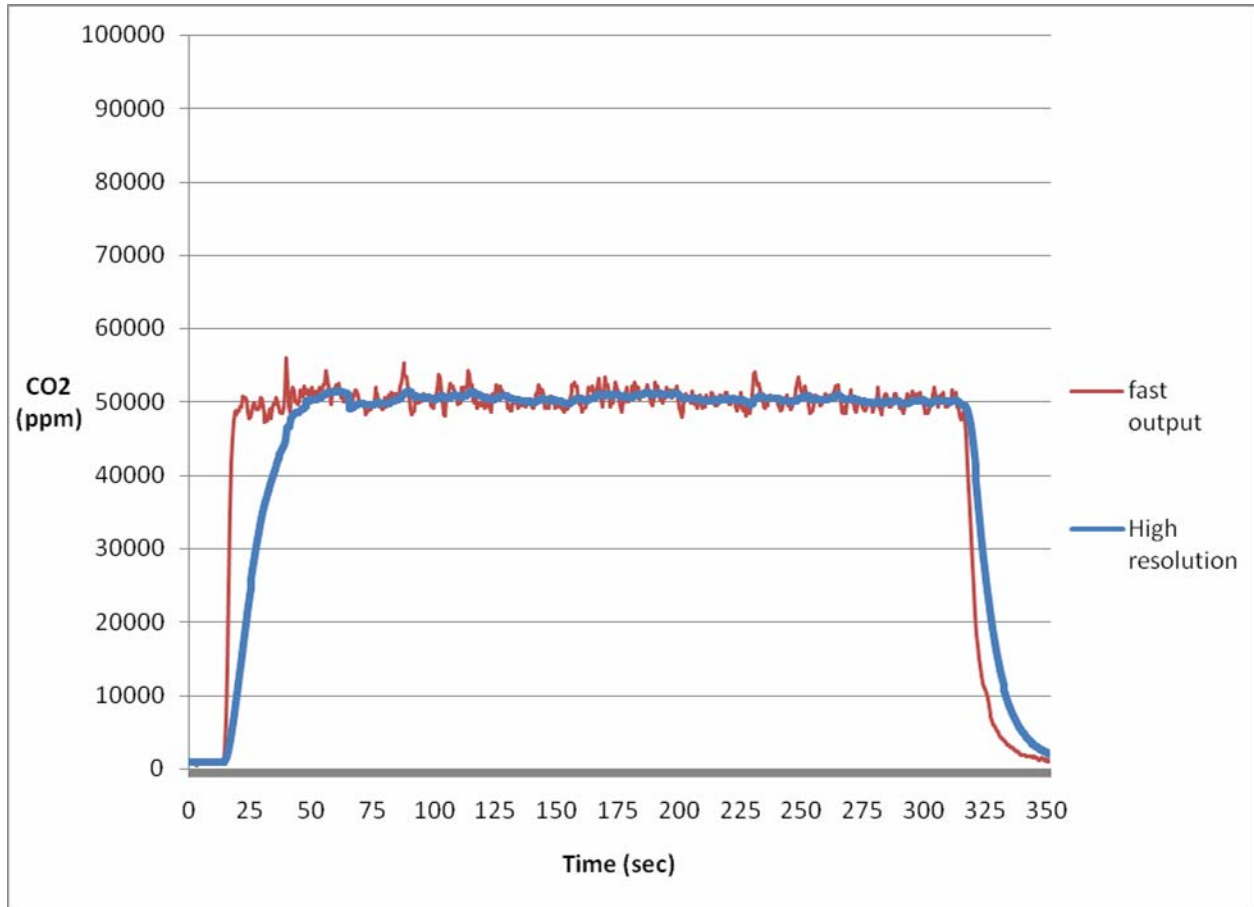


Figure 8 - speed of response raw and filtered outputs

Safety Applications

The red line shows the fast output and the blue line shows the slower high resolution reading which takes a filtered reading over the previous 8 seconds.



INTERNAL AIR QUALITY/HVAC

The C2 sensor is also very capable of being used in internal air quality and HVAC applications. A longer integration time can be set to optimise resolution and stability.

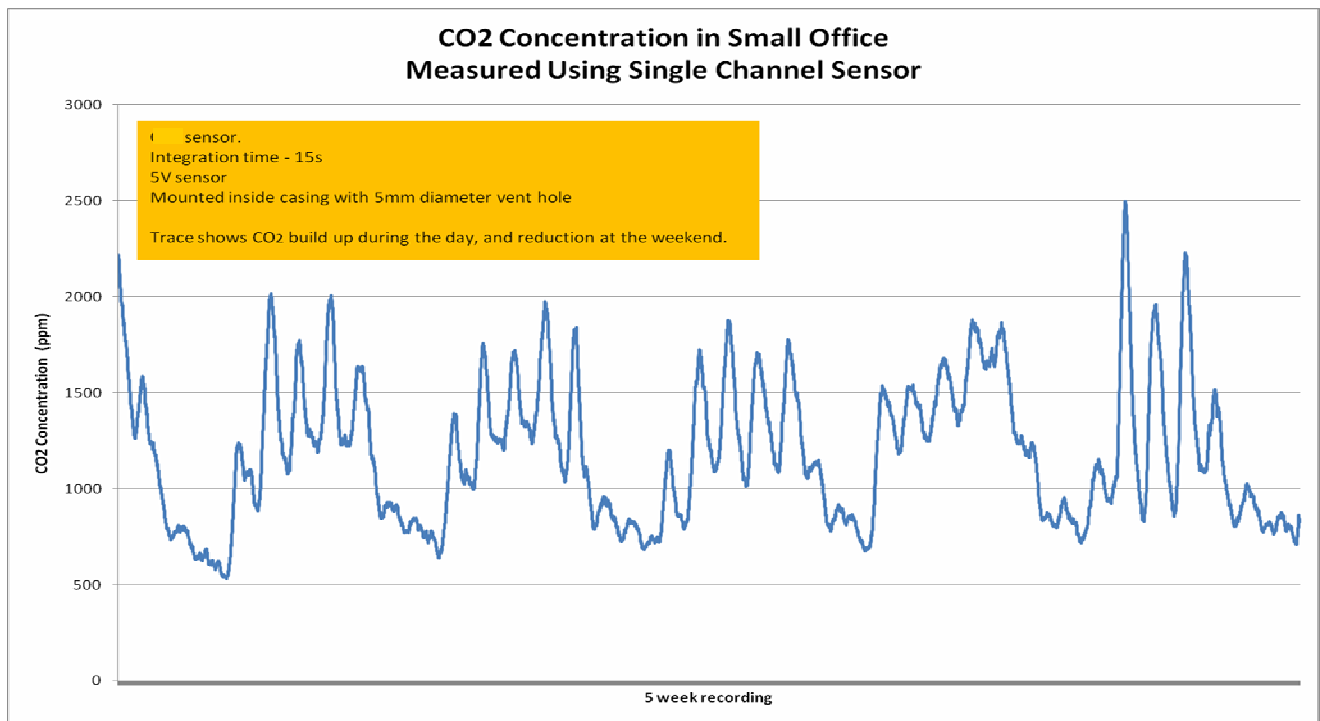
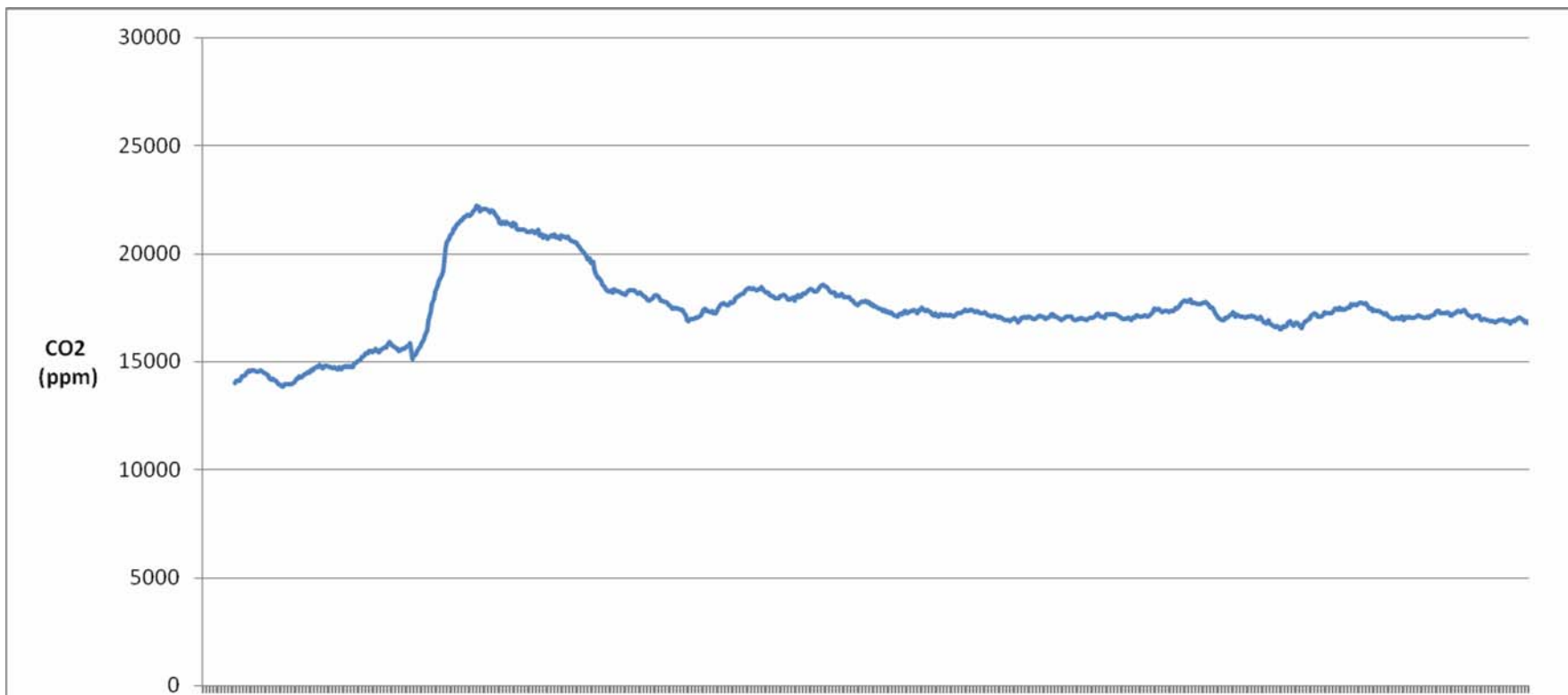


Figure 9 - Internal Air Quality/HVAC

Figure 9 shows the CO₂ readings from a sensor placed in an office environment. The volume of the office is approximately 10m³. The graph shows CO₂ profile over a normal working day/week during a 5 week period.





Description Graph G-01001

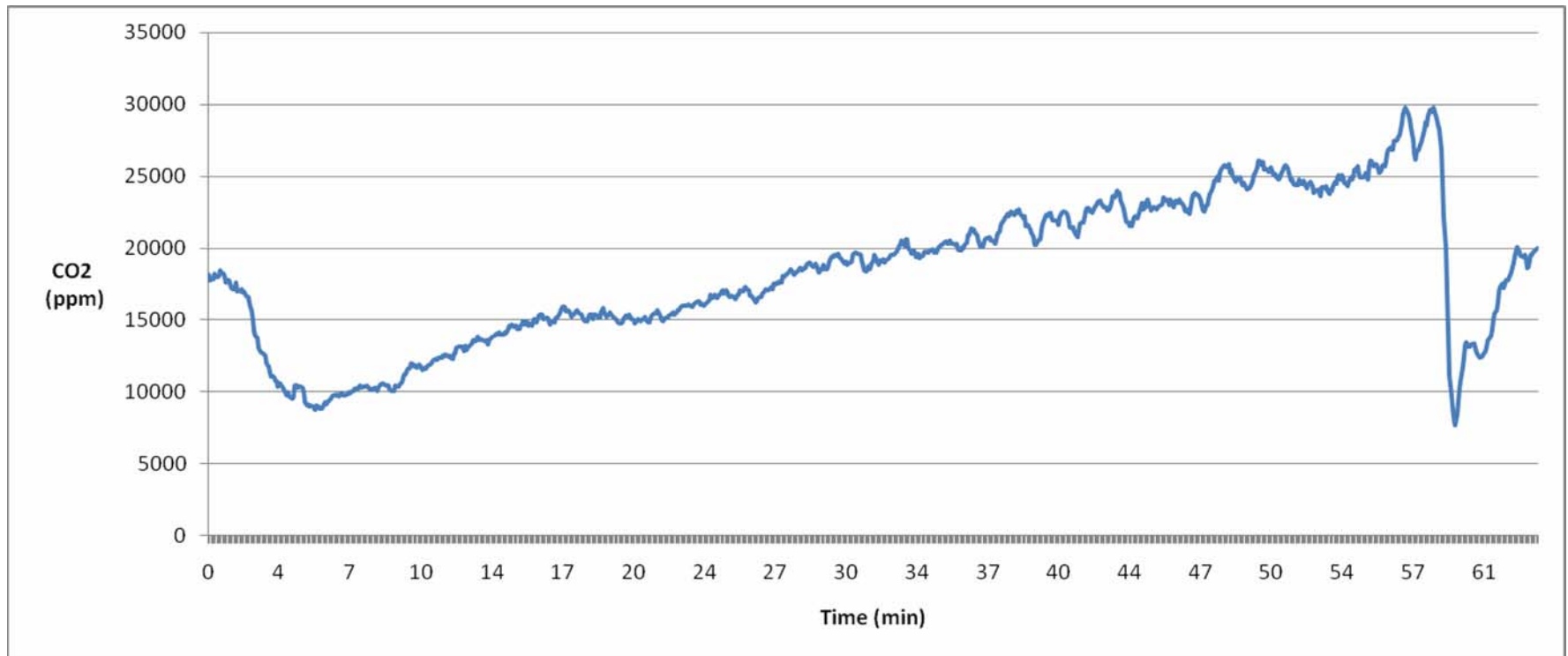
Sensor 1m from floor level with a further 8 sensors measuring CO2 levels in facility, situated near filling station for soft drinks. The peak of 23,000ppm shows the point when the door of the station opened.

Application/location– Soft drinks factory filling station

Board number– D426

Date – 22/04/08

Time– 10:00 -11:00



Description Graph G-01002

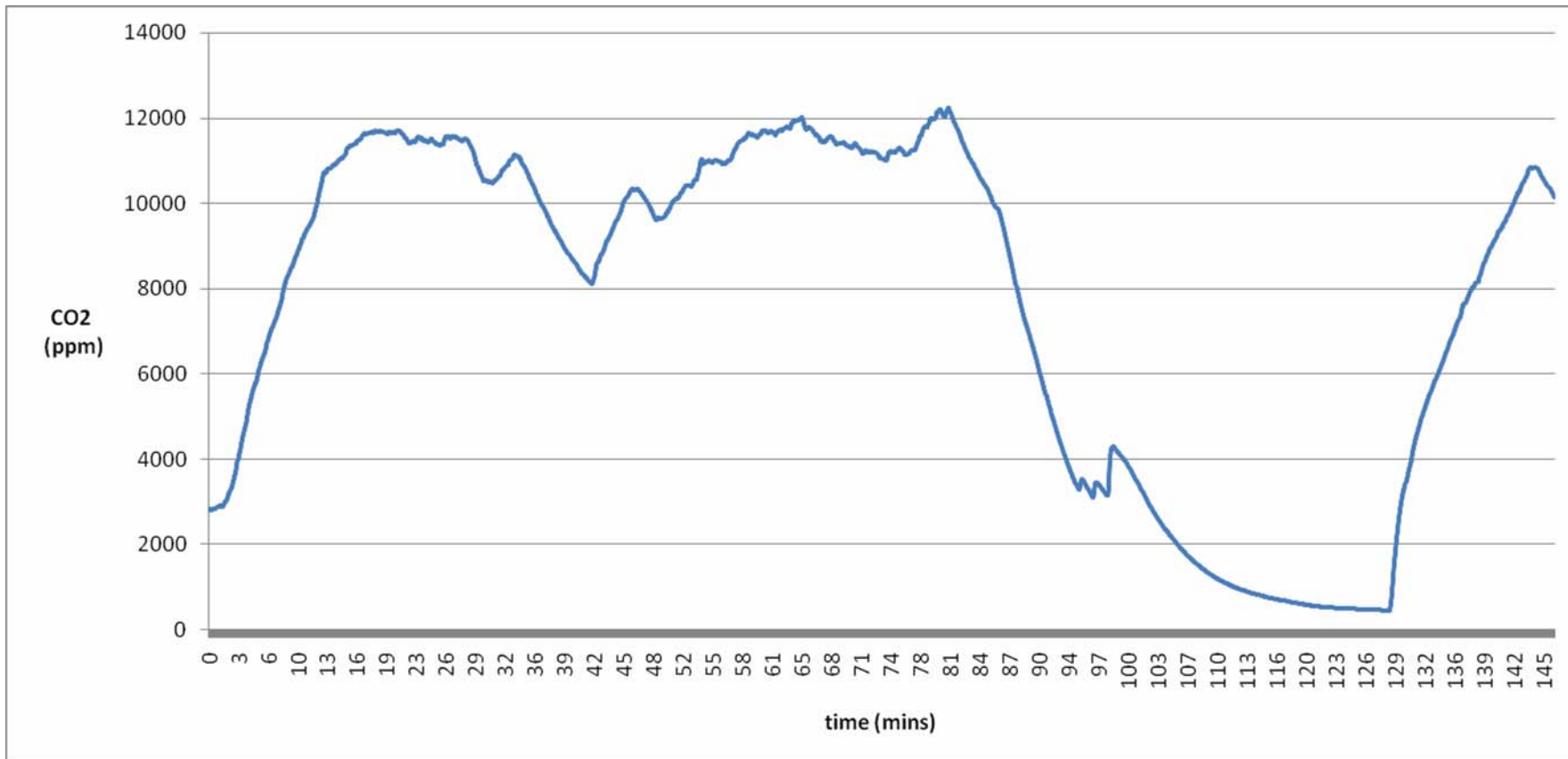
8 sensors measuring CO₂ levels in factory setting near Canning station for soft drinks. For first 3 minutes the sensor is measuring on the table 1m from ground level next to the canning station. A calibration gas of 10,000ppm is then shown to the sensor. The sensor is then moved to a lower height (30cm from ground level). The readings rise to 30,000ppm at 57mins. The sensor is then lifted to 2m where the reading drops to 7000ppm and sharply rises when it is put back to the table where the test was initiated.

Application/location– Soft drinks factory filling station

Board number–D432

Date 21/04/08

Time– 13:30 – 14:30



Description Graph G-01005

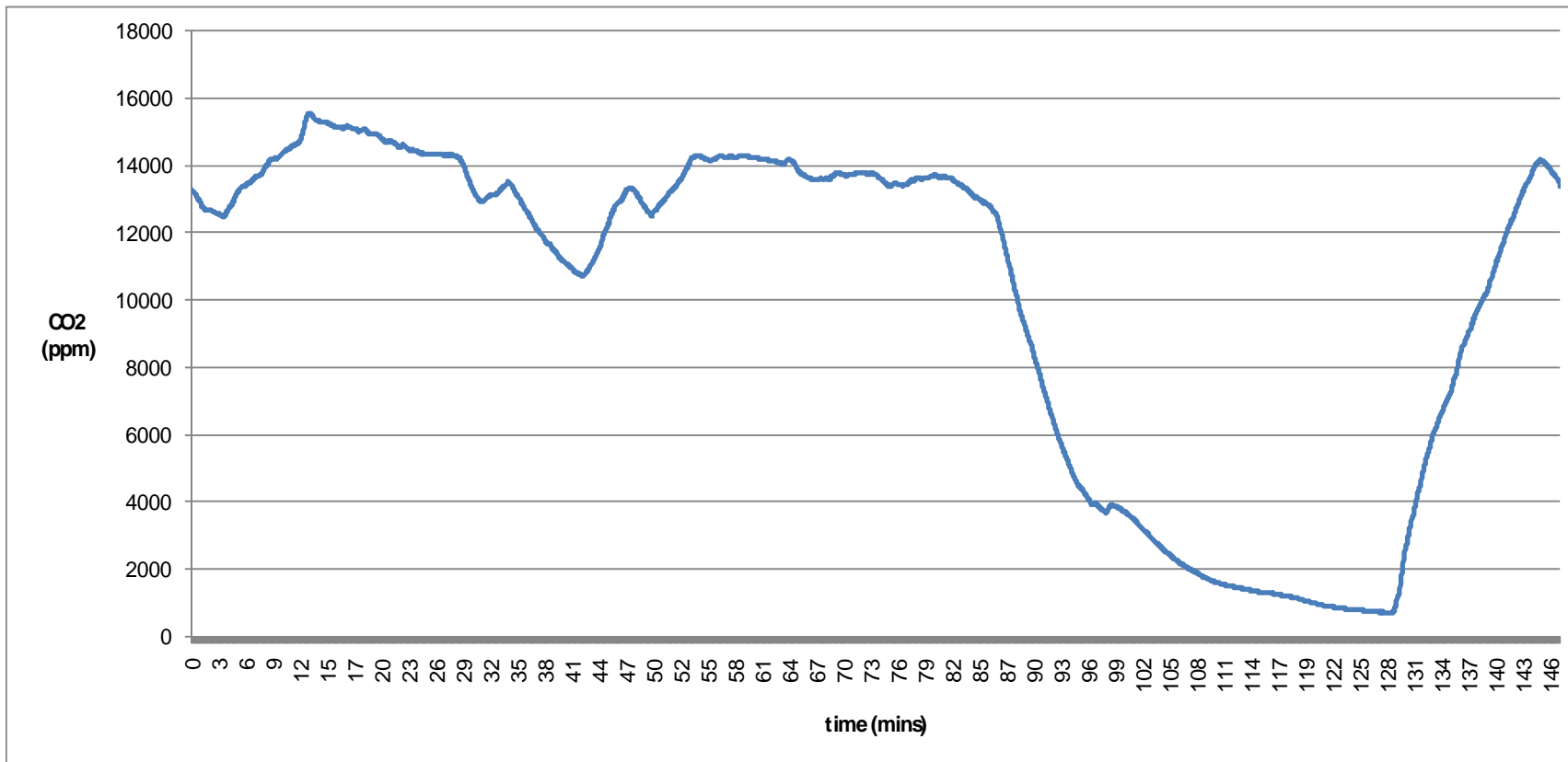
Sensor at door of canning station. Height of approximately 200mm from floor.

Application/location– Soft drinks Factory filling station

Board number– D699

Date 09/05/2008

Time– 13.30



Description Graph G-01006

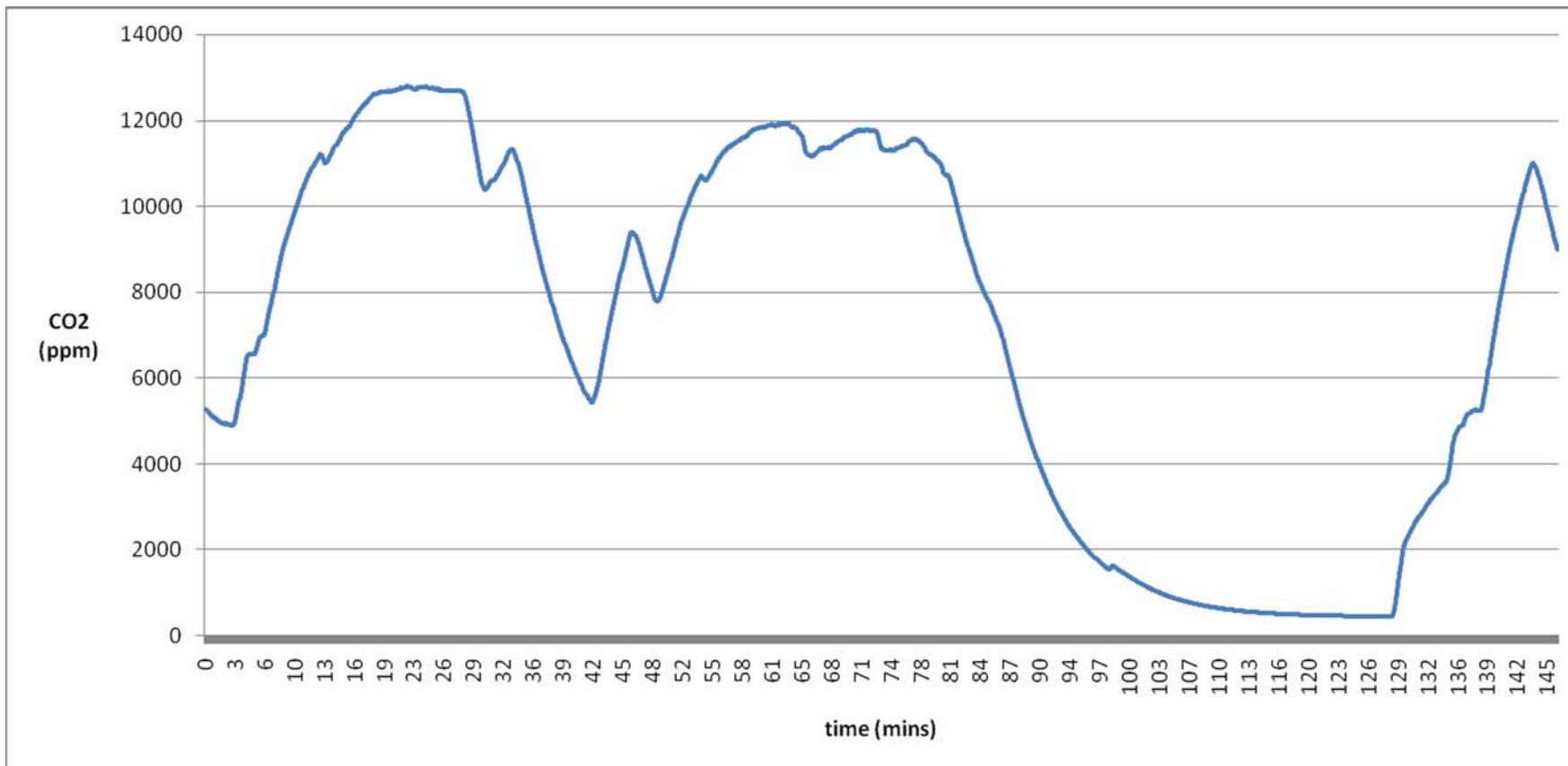
Height - approximately 200mm from floor.

Application/location– Soft drinks Factory filling station

Board number– D323

Date 09/05/2008

Time– 13.30



Description Graph G-01007

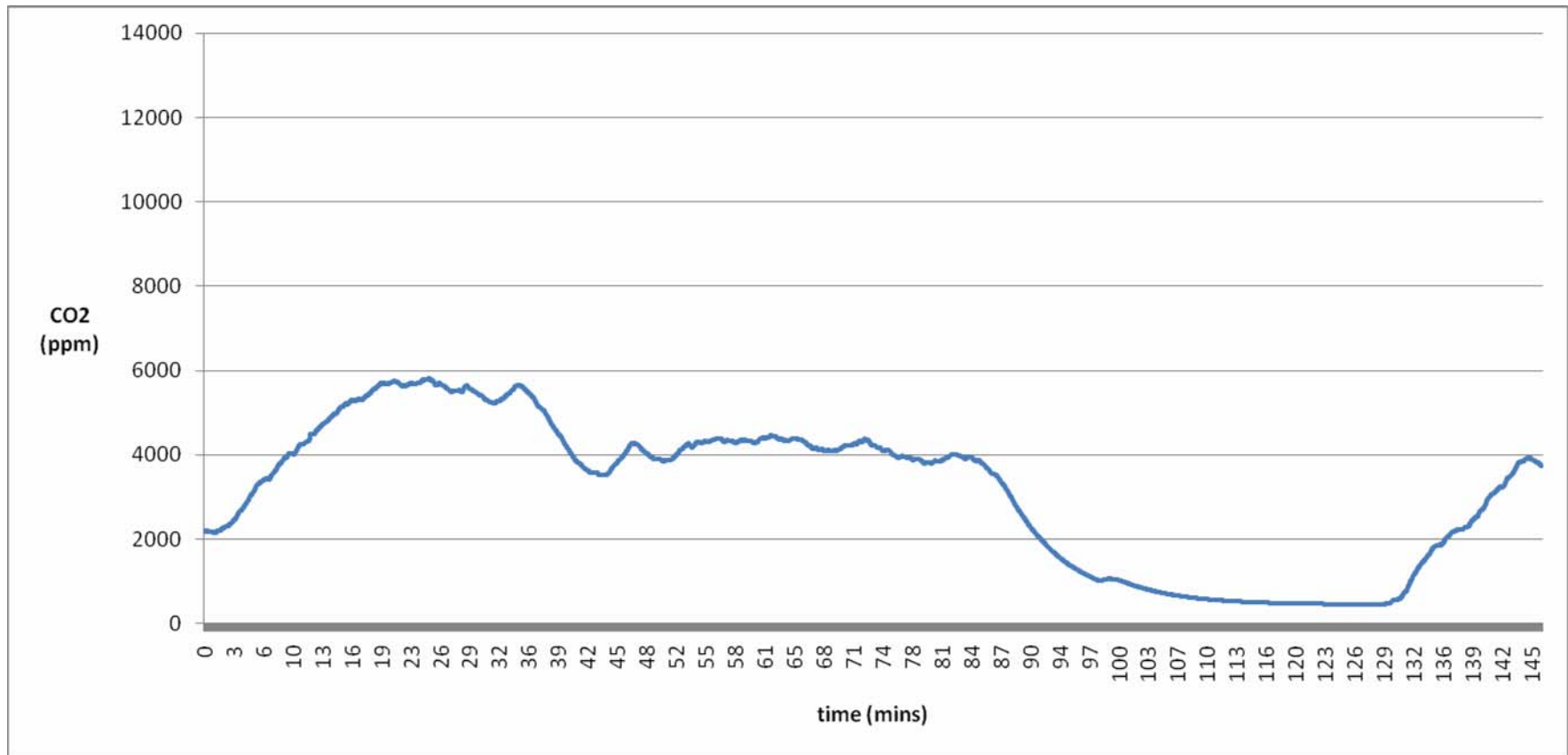
Height - approximately 100mm from floor.

Application/location- Soft drinks Factory filling station

Board number- D577

Date 09/05/2008

Time- 13.30



Description Graph G-01008

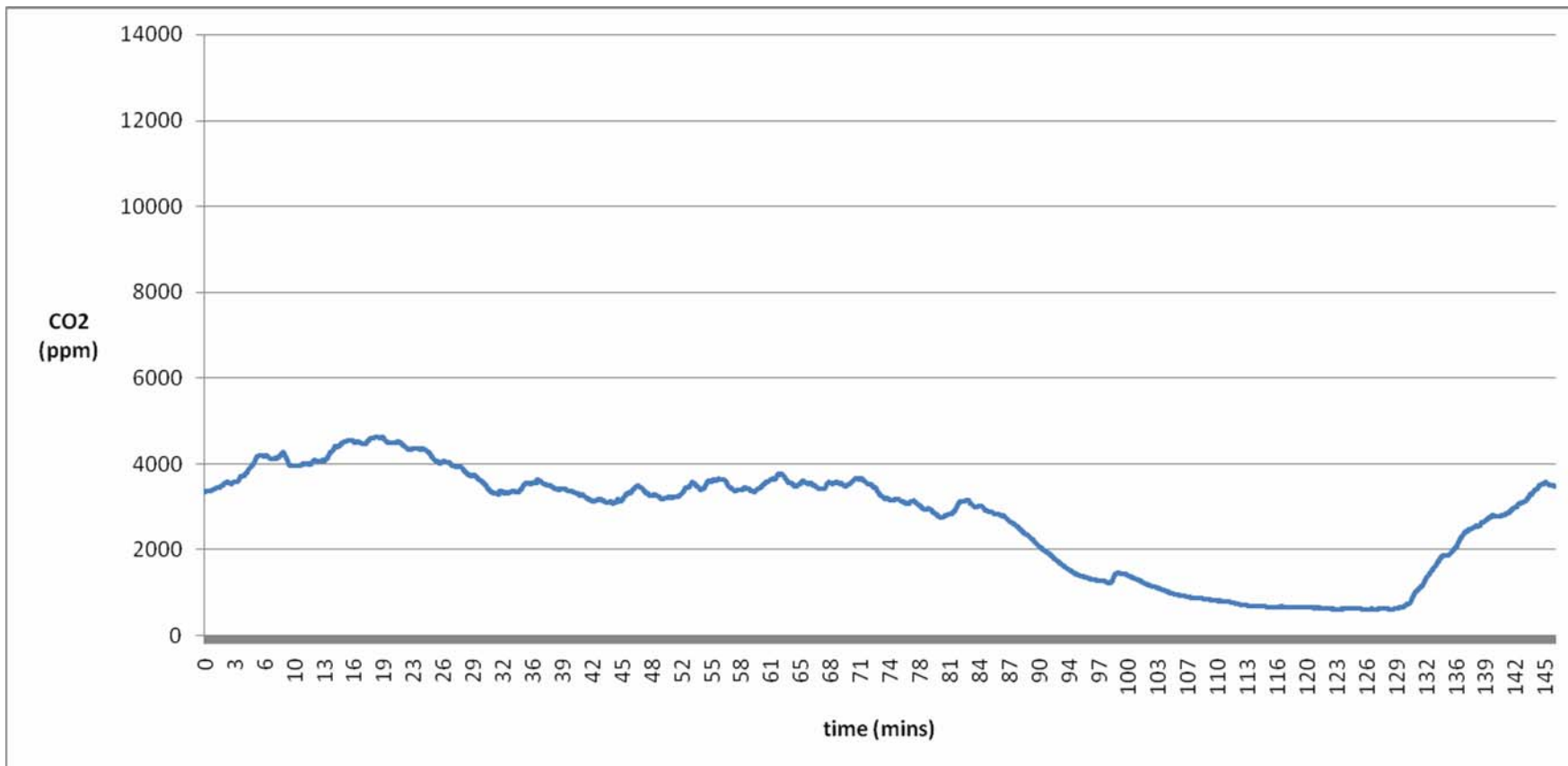
Sensor attached to table leg. Height - approximately 400mm from floor.

Application/location- Soft drinks Factory filling station

Board number- D670

Date 09/05/2008

Time- 13.30



Description Graph G-01009

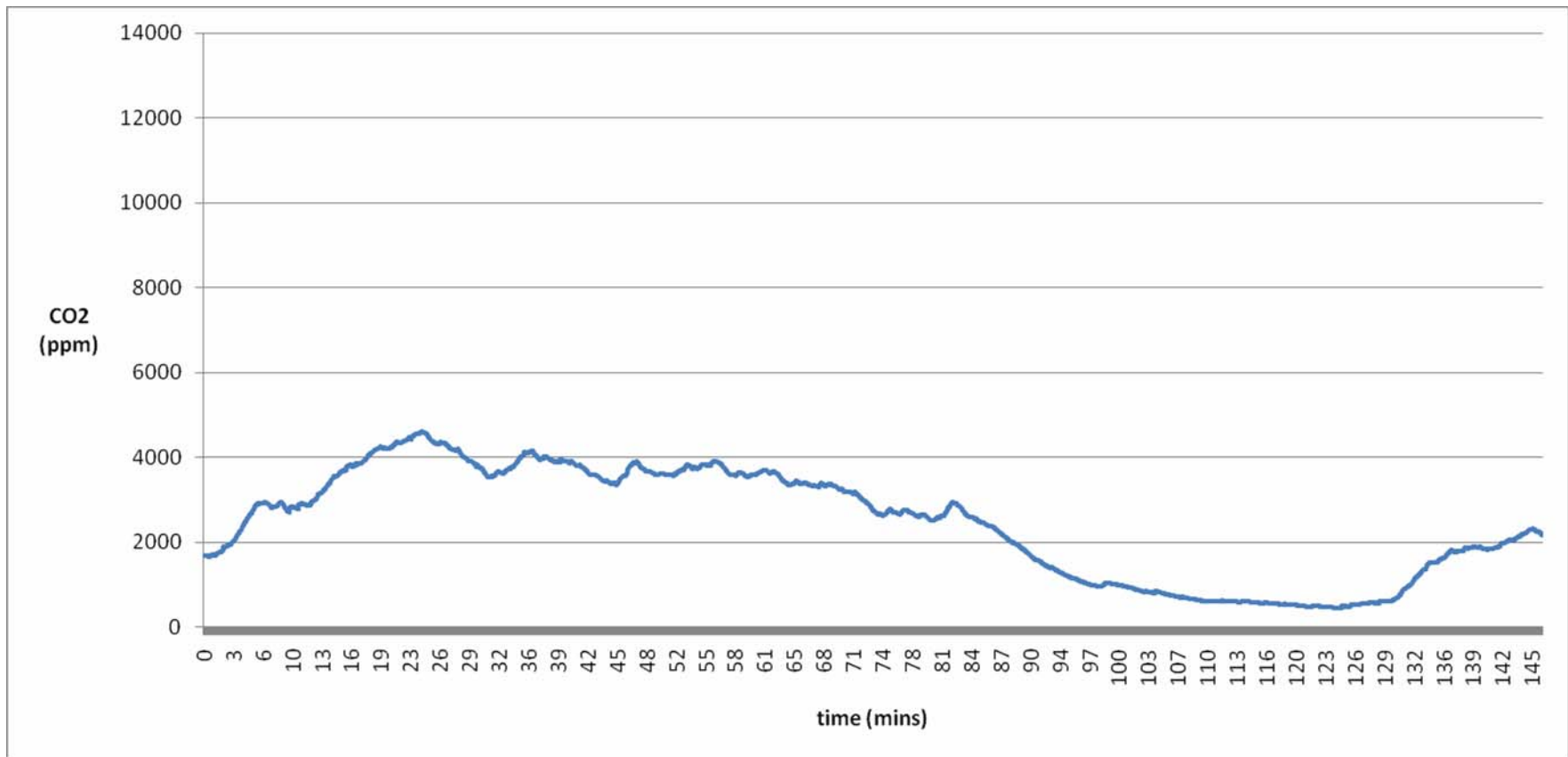
Sensor on table. Height - approximately 800mm from floor.

Application/location– Soft drinks Factory filling station

Board number– D579

Date 09/05/2008

Time– 13.30



Description Graph G-01010

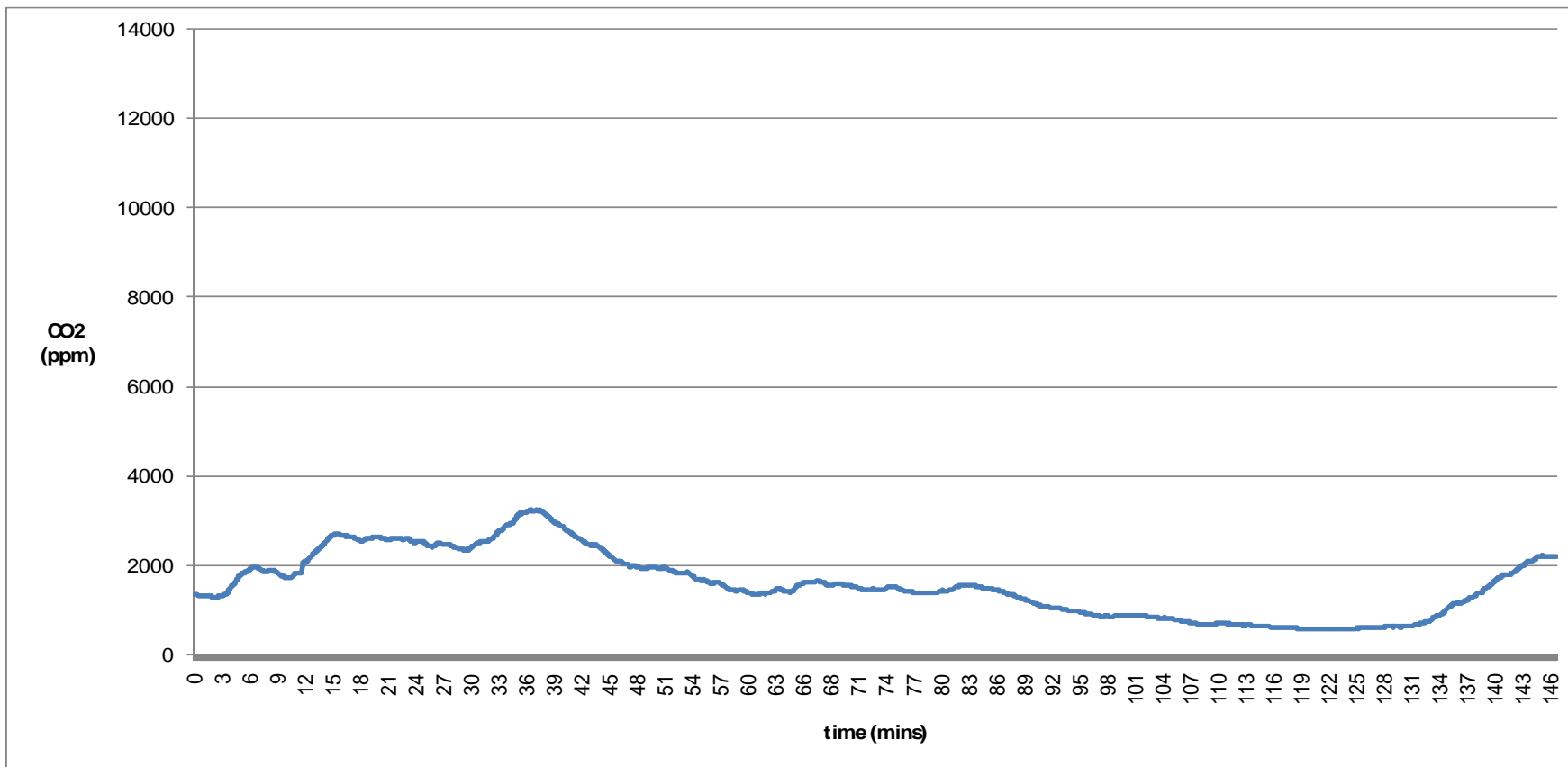
Sensor on table. Height - approximately 800mm from floor.

Application/location– Soft drinks Factory filling station

Board number– D715

Date 09/05/2008

Time– 13.30



Description Graph G-01011

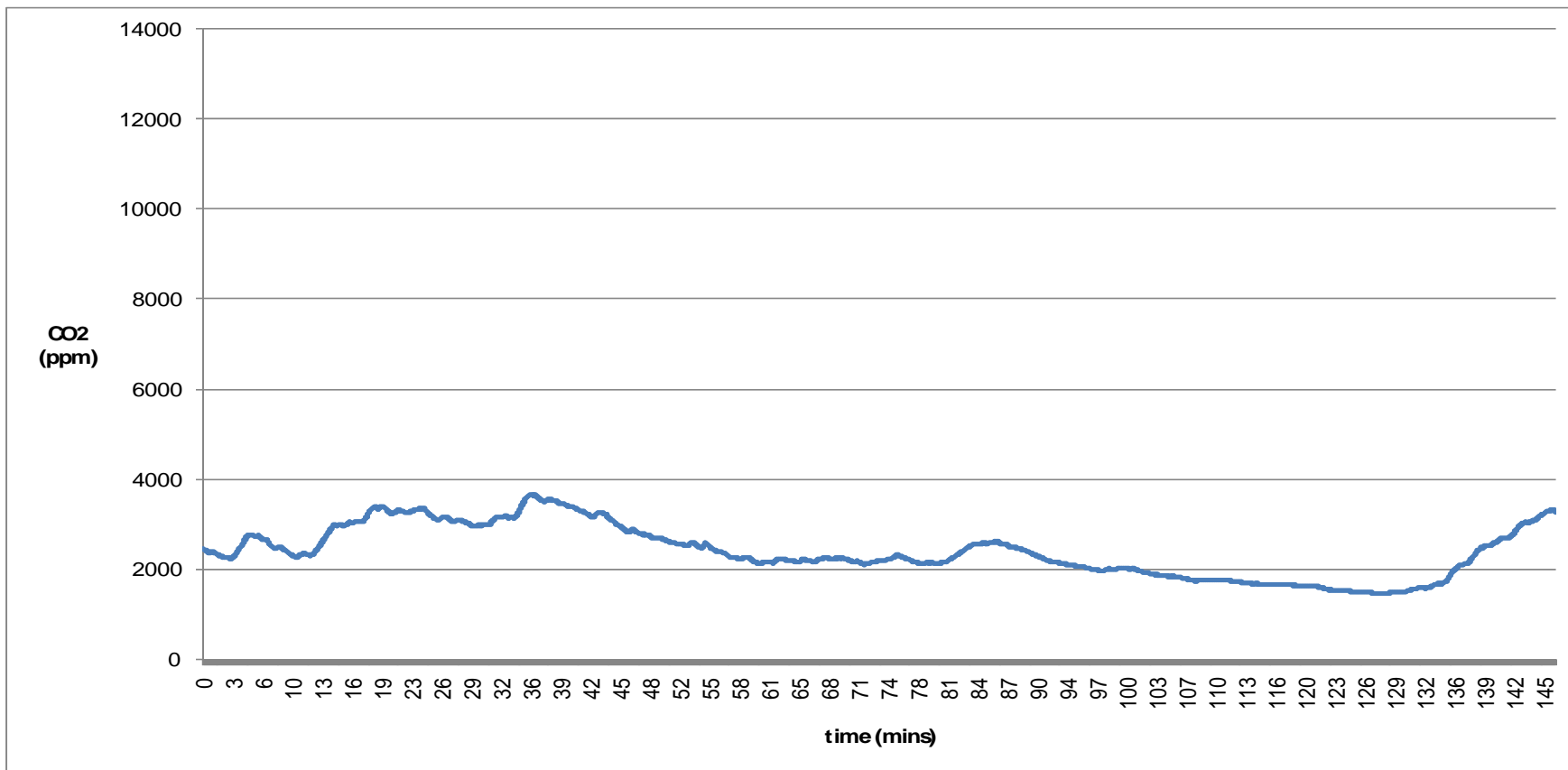
Sensor on railing. Height - approximately 1500mm from floor.

Application/location– Soft drinks Factory filling station

Board number– D589

Date 09/05/2008

Time– 13.30



Description Graph G-01012

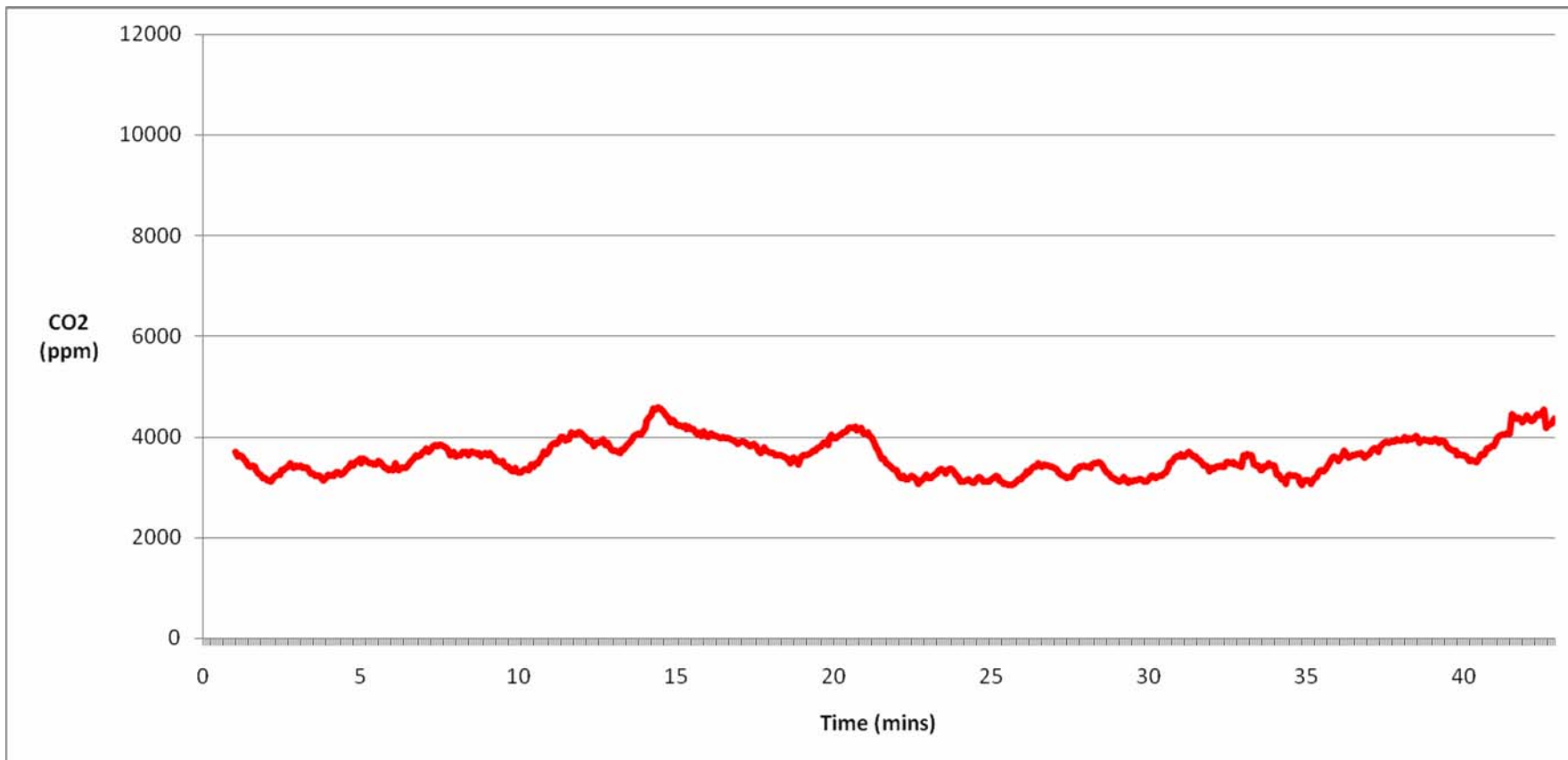
Sensor on railing. Height - approximately 1500mm from floor.

Application/location– Soft drinks Factory filling station

Board number– D194

Date 09/05/2008

Time– 13.30



Description Graph G-01013

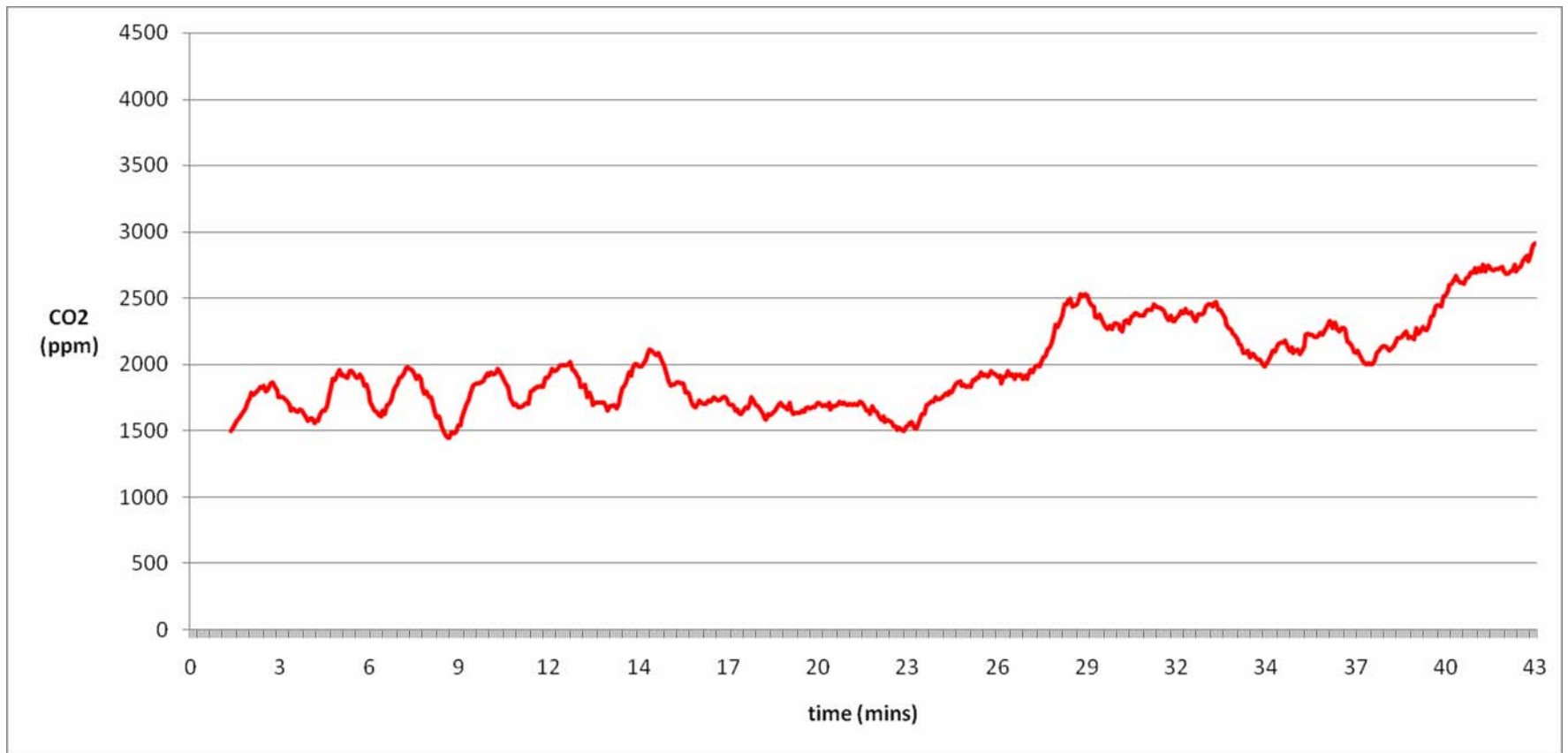
The sensor was placed underneath the conveyor belt at a height of 300mm over a period of 45 minutes when the packing machine was running

Application/location– Meat Packaging plant

Board number– 194

Date 23/04/08

Time– 09.50



Description Graph G-01014

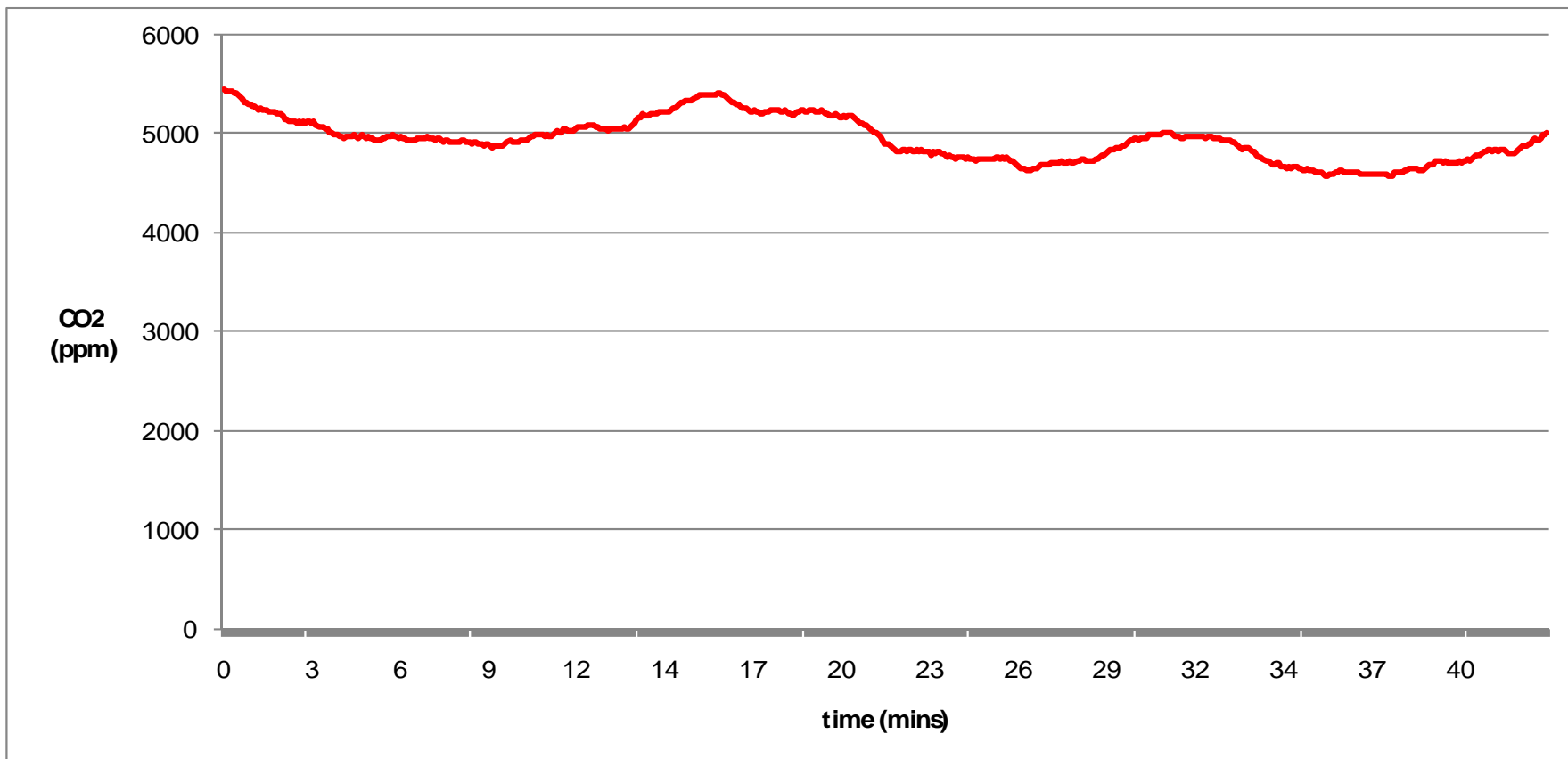
Sensor placed at door of canning station, height approximately 200mm

Application/location– Meat Packaging plant

Board number– 699

Date 23/04/08

Time– 09.50



Description Graph G-01015

The sensor was placed on the gas inlet pipe which feeds into the machine near its base.

Application/location– Meat Packaging plant

Board number– 323

Date 23/04/08

Time– 09.50