Demand-controlled ventilation in a garage, Kv. Cedern in Malmö

Investigation of CO and CO_2 emissions during the period 20/2-17/3 2001

by

Doc. H. Martin and J. Lindfors, SenseAir AB

Introduction

The property company AB Ragne manages a garage in Malmö, in the Cedern block, Disponentgatan 19-23. In december 2000 a simple demand-controlled ventilatilation system was installed there based on a CO/CO_2 combination sensor of model *mSENSE II* from Senseair. An induction fan is steered intermittently on/off based on CO and CO_2 level measurements in the garage. The levels chosen for on/off switching are 35/30 ppm CO or 1500/1400 ppm CO_2. The purpose of this ventilation solution is to ensure a good garage environment for users while at the same time maintaining low energy-use and low investment costs.

After an official inspection on 2000-12-13 the function of the existing solution was questioned. The inspectors were not convinced that the building regulation BBR was satisfied with regard to air quality. This was the reason for the decision to conduct this investigation. By means of six measuring points distributed through the garage area, emissions of CO and CO_2 have been studied continuously for an unbroken period of 26 days.

Description of the garage

The object of study is a typical Swedish basement garage for the use of building residents. It contains 77 parking places covering an area of 17 x 85 metres. Almost all the parking spaces are rented out. Ceiling height is 2,15 metres. This gives the garage a volume of 3100 m^3. This volume of air is ventilated by means of upper induction air and an extraction fan (FF) with a capacity of 9000 m3/h. The supply air duct (SA) is located at the innermost end of the garage, and fresh air is sucked from it through the garage and out throught the outflow duct which is placed on the opposite wall beside the garage entrance. The climate sensor which controls the ventilation (G1) is located in the middle of the locale. A stylised plan of the garage is shown in figure 1.

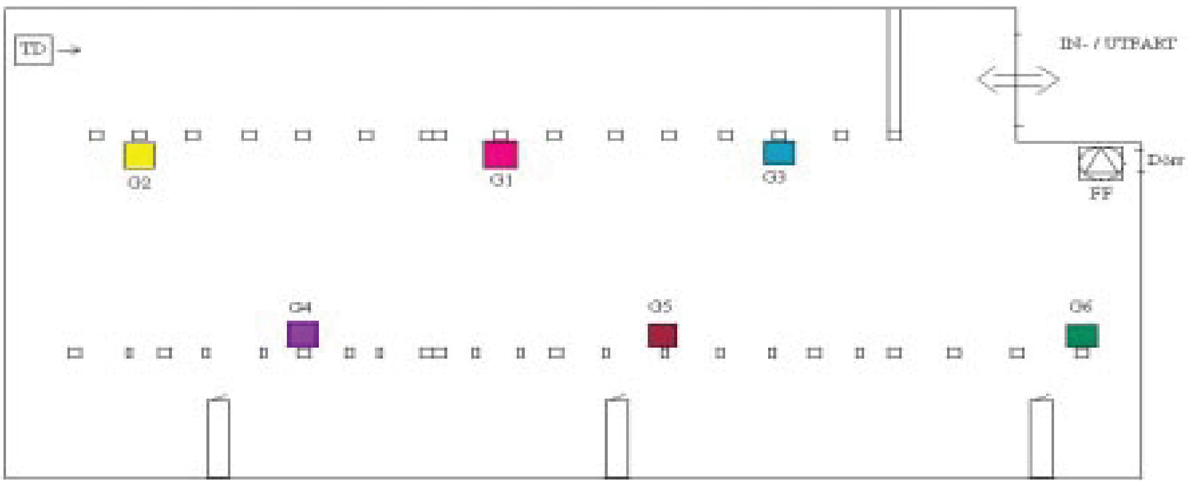

Figure 1: Sketch of the garage with sensor stations G1 – G6 colour-marked. The same colours represent the individual sensors' readings in coming diagrams. Sensor G1 steers ventilation during the period of measurement. Sensors G2 and G3 were also connected to the control-system after the end of the period, while G4 – G6 were only temporarily installed to provide extra information about the garage environment during the measurement period.

Description of measurements

The locations of the 6 separate climate sensors are shown in figure 1. They are distributed at 13 to 22 metre intervals in order to cover the whole garage area for registration of climate data. Each sensor makes localised measurements of the parameters carbon monoxide (CO), carbon dioxide (CO_2), tmperature and relative humidity. A detailed description of the sensor type can bee downloaded from our home page www.senseair.com.

The sensors individual serialport (RS485 interface) were connected in a 140 metre long communication loop (G2-G4-G1-G5-G3-G6), which terminated at an adjacent caretaker's office. There a PC was connected, which in this simple 2-cable network acted as network master and data gatherer.
The collection of data functions as follows. A Visual-Basic programme (*mSENSE II* networklogger - free software from Senseair) is started in the Windows environment. During the start-up sequence one chooses the number of sensors in the system (in this case 6), the time-interval at which one requires to collect data, (we chose a three-minute interval), and the file name desired for the data file. The programme then creates these files (one for every sensor under the desired file name + sensor number) and starts the collection process. At every collection point the computer calls up each sensor in turn, reads off the four measurement parameters digitally, opens the appropriate loggerfile and writes in a new item of information consisting of the time and the recorded values. Then the sensor's loggerfile is closed until the next collection time, when the procedure is repeated.

Climate conditions

Figures 1, 2 and 3 show the registered climatic conditions in the garage. Clearly the temperature remains relatively constant at 12 – 13 degrees C, with a 24-hour variation of about 1 degree. The outdoor temperature, however, varied considerably during the measured period. A cold front moved in over Malmö during the last week in February (22/2), and held outdoor temperatures at around -13 degrees C. After two weeks the weather turned milder, and a Spring peak temperature (+11 °C) was reached in the middle of March (10 – 12/3). These weather conditions are reflected in the recorded temperature and humidity; dry continental air during the cold spell and humid Atlantic air during the warm spell (figure 3).

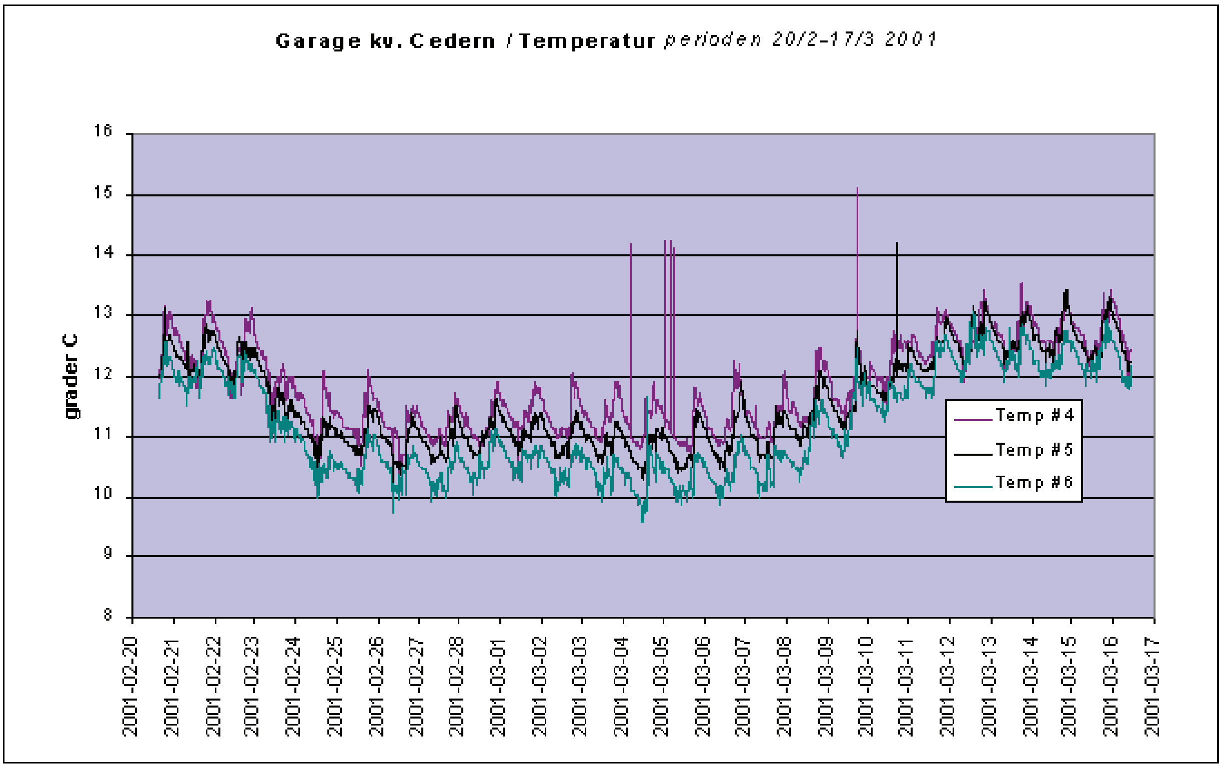

Figure 2:Registration of temperature in the garage during the measurement period by sensors G4, G5,G6.

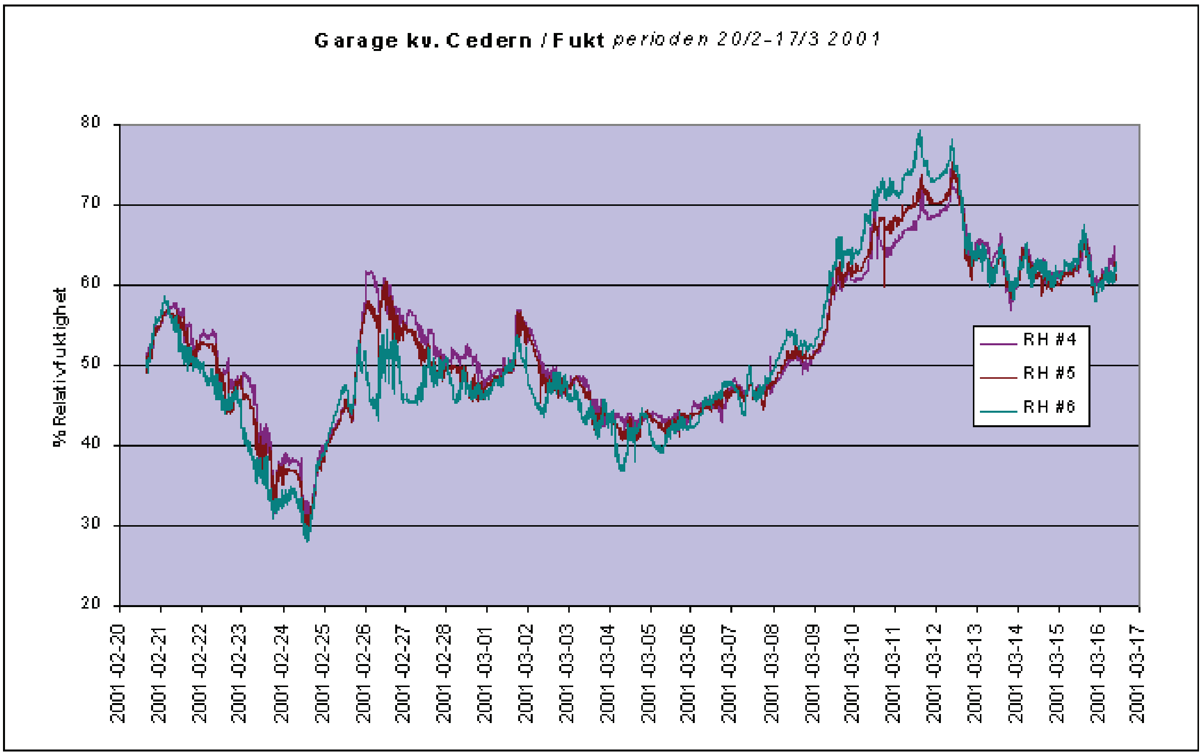

Figure 3: Registration of humidity in the garage by sensor G4 (farthest in in the garage), G5 and G6, (closest to the entrance), during the period of measurement. The time variations probably follow variations in outdoor weather conditions. The shorter periods of deviation for sensor G6 can be explained by extra air-exchange from the garage entrance under certain wind conditions. Farther into the garage the values are more stable.

In figure 3 , a comparison between the values for sensor G4, placed farthest in in the garage, and sensor G6, placed nearest to the entrance, shows that the latter was exposed more frequently to the outdoors air. This is indicated by the fact that during the cold spell of the first weeks G6 registered drier air than the other sensors, whereas during the warm spell of 10/3 – 13/3 G6 registered higher humidity. This exposure of G6 to outside air is probably a result of extra ventilation through the garage entrance under certain wind conditions.

Observation and interpretation of emissions

Figures 4 and 5 show the registration of CO and CO_2 respectively for all sensors over the whole measurement period. Generally speaking, it is clear that the diurnal variations at all measuring points are in phase with each other, and that different sensors, roughly speaking, register the same emission values. As expected there is a high correlation between CO and CO_2 variations.

It is also interesting to note that the quotient between the amplitude variations for CO and CO_2 is very high; ca 35 ppm CO per 100 ppm CO_2 , if one disregards individual emission peaks. This means that the CO/CO_2 volume quotient is about 0,3 , which converted to mass quotient is equal to 0.2 . This indicates very 'dirty' car engines, engines that emit very high levels of CO. Consequently in this garage the level of CO has been the ventilation-steering parameter. A check of the carpark at 10 am, Friday 16/3, revealed that at this time half of the parking spaces were occupied. The distribution of various types of vehicle was then : 21 cars with catalytic converters, 13 cars without catalytic converters, 3 motorbicycles and 1 diesel vehicle. An explanation of these high CO-levels must be that almost all the cars in this garage start with a cold engine (long parking times), and that more than a third of them lack catalytic converters. The pattern of use seems to be that, perfectly naturally in the case of a residential garage, users drive out of the locale within a couple of minutes, before any catalytic converter has started to function.

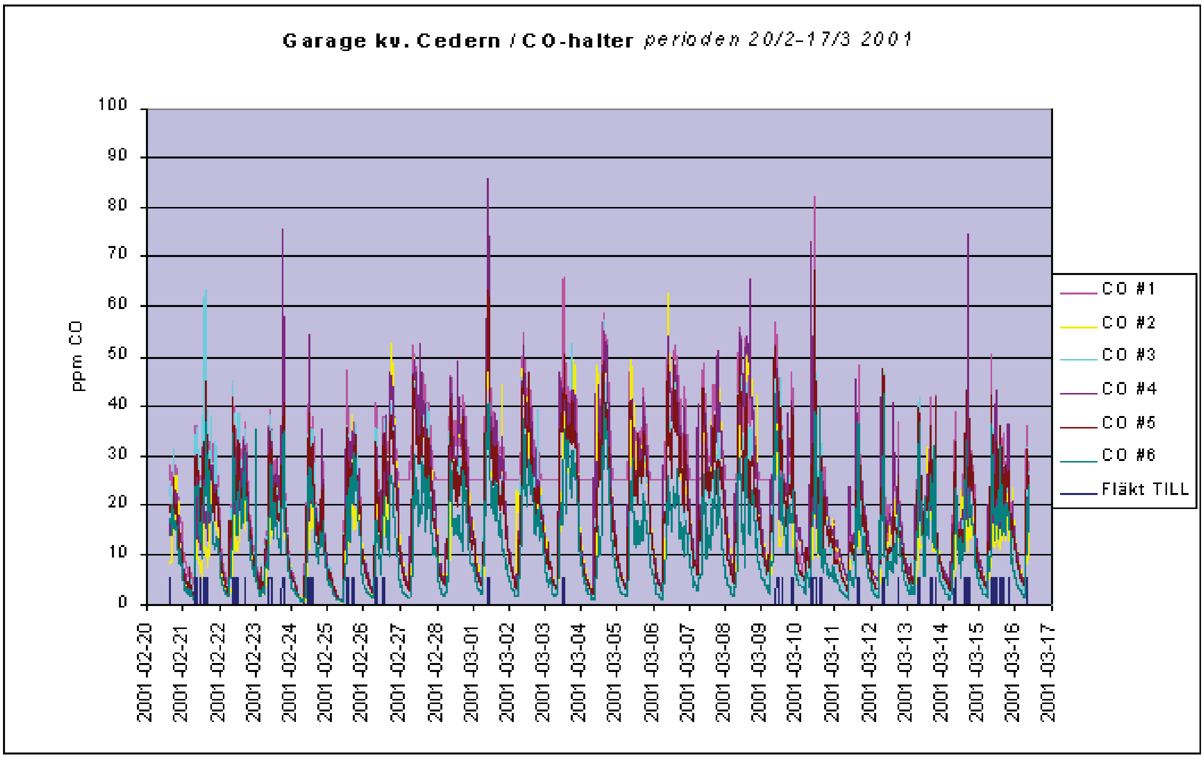

Figure 4: Variations in CO registered over the whole garage area (sensors G1 – G6) during the measurement period. The lower readings show when the fan has been switched on as a result of demand-control. During the middle period, when the fan had mostly been inactive, the value for fan-activation was temporarily increased from 35 ppm to 60 ppm CO.

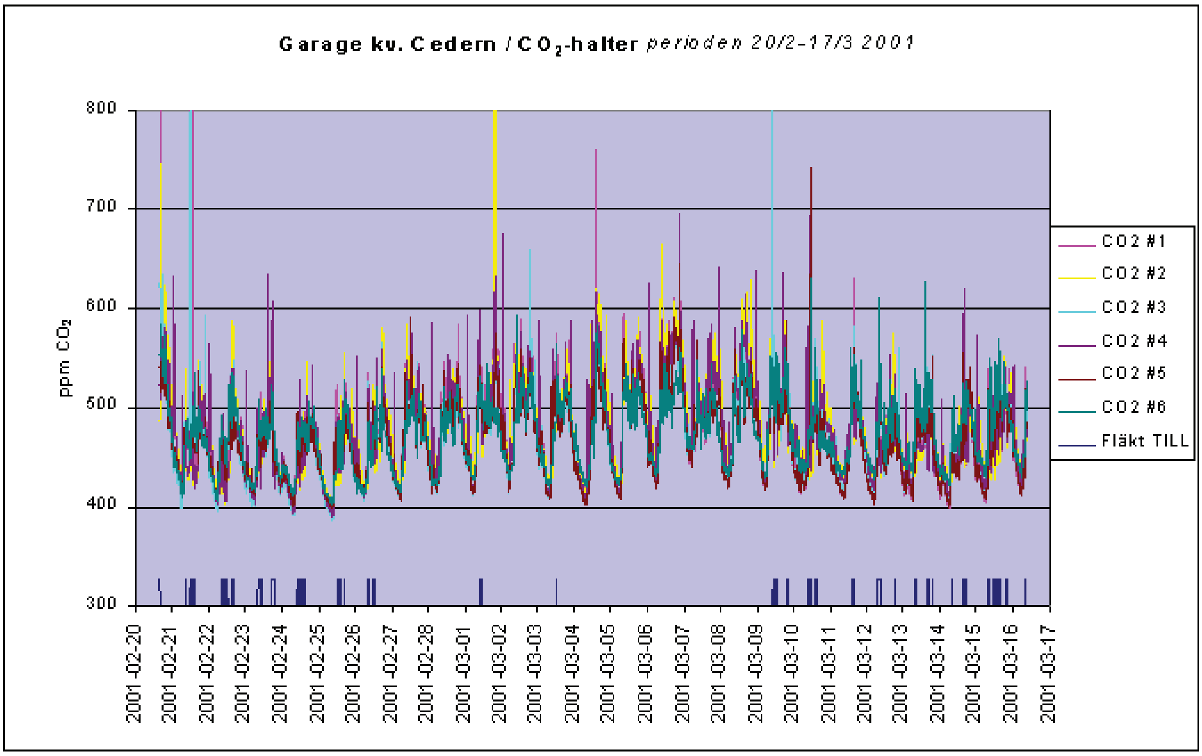

Figure 5: Variations in CO_2 registered over the whole garage area (sensors G1 – G6) during the period of measurement. The lower readings show when the fan was switched on as a result of demand-control.

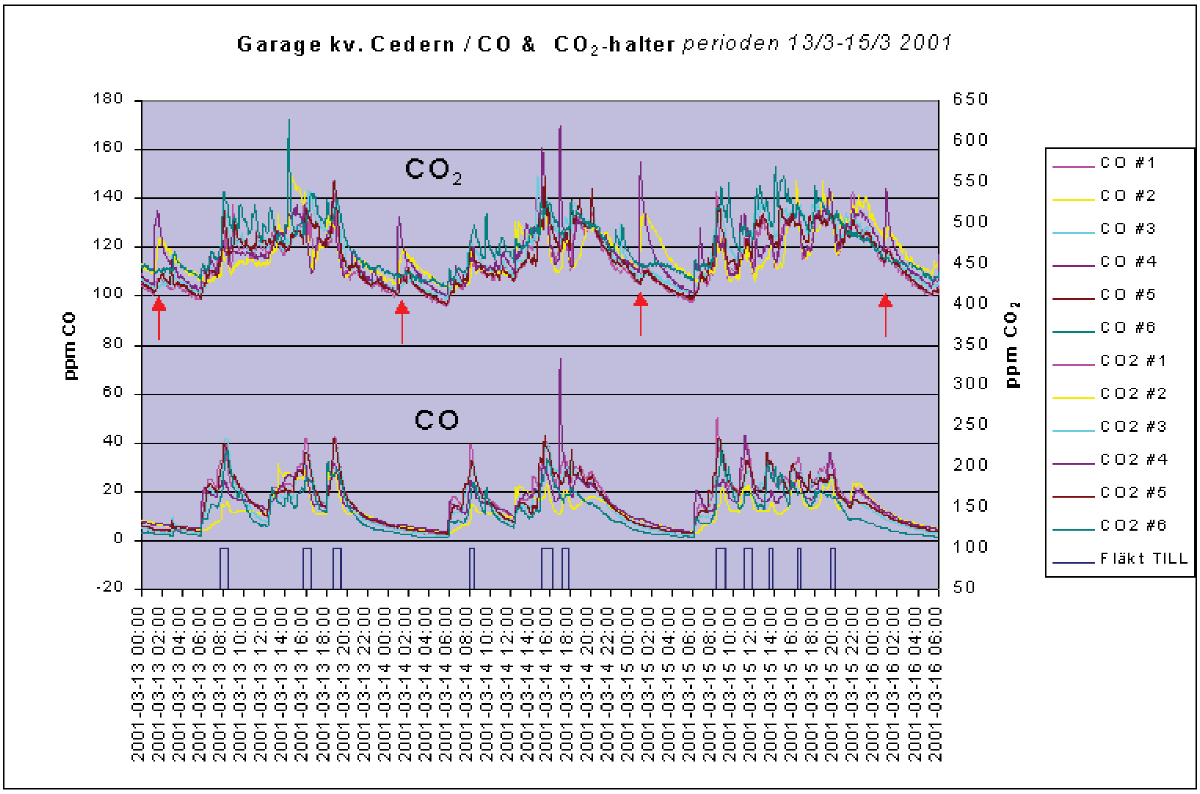

Figure 6: Emission data for a three-day period which show the function of demand-control with a CO-limit value of 35 ppm. On these occasions frequent cold starts are the probable reason for the ventilation demand, to judge by the high CO/CO_2 volume quotient.The arrows mark the opposite conditions – low CO/CO_2 volume quotients - in a number of cases where arriving catalytic converter vehicles are the probable source of emissions

On closer examination of the data a fair amount can be interpreted and different situations can be reconstructed. In figure 6, to provide an example of this, measurement data from a three-day period is shown. The distinct peaks which can be observed in both the CO and the CO_2 curves bear witness to the fact that one or more vehicles have at the time emitted exhaust for a short period. In 11 cases during this period the CO-level for sensor G2 has exceeded the limit value and therefore started the ventilation fan. The demand-control system clearly functions as intended.

A comparison of the CO_2 and CO curves reveals that certain distinct peaks are only to be found in the CO_2 curve: The interpretation of this is that it is a case of one or more cars with catalytic converters returning at the same time to park. For example, figure 6 shows that on four nights in succession, at 1 am, the same occurrence is registered. The CO/CO_2 volume quotient is here less than 1:200, which is a characteristic of engines with functioning catalytic converters.

The registered data also makes it possible in many cases to acquire information about where in the garage a vehicle is or was parked. Let us take the examples marked with an arrow in figure 6: On the whole the same relative deviation was obtained from the different sensors every night at 1 am. This indicates that the same event is being repeated – probably the same vehicle arriving at its own rented space. Sensor G4 gives the fastest and largest reading, followed by G2 after a short lapse of time. Smaller peaks are registered by G1 and G5. Sensor G6 shows a very flat 'bump' with a maximum value which is first reached a couple of hours after the time of parking. A glance at the plan in figure 1 shows that these observations are consistent with a car arriving at its parking place somewhere in the area far to the left beyond G6. G6 then reacts fastest and strongest, after which one can follow the emission spreading and diluting during the following hours. In a simalar way many other individual events can be found in the large mass of data, which by the same reasoning can be traced to other areas of the garage.

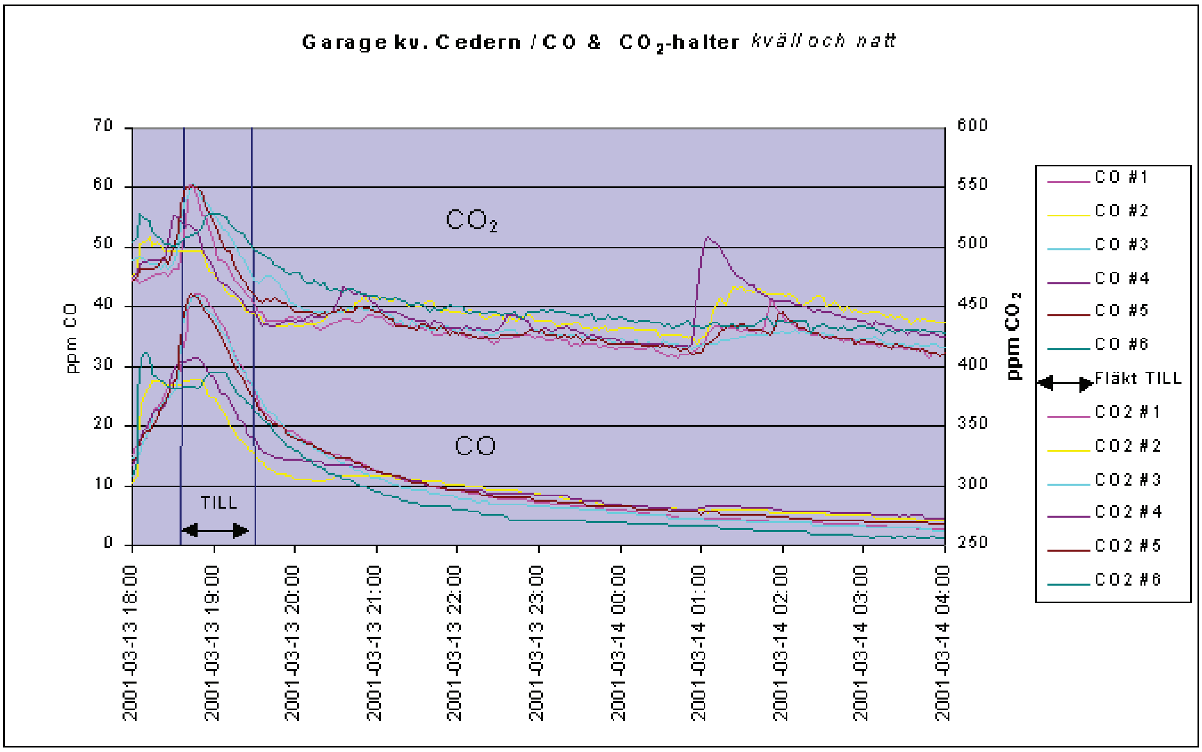

Figure 7: Active ventilation, airmixing and passive ventilation studied via the spread and diminution of emission gases.

When activity starts to decline in the garage, a detailed examination of the environmental conditions can give some insight into the dynamics of air exchange. Figure 7 provides an example of this. Vehicle movements during the evening cause CO-levels to rise above the activation level for the active ventilation. The non-homogenous garage atmosphere is diluted when the fan motors are running and fresh air is sucked into the locale. In all observations the emission-levels at G2 (closest to the induction point) fall somewhat faster than at the other measuring-points, and the opposite is the case at sensor G6. This is logical considering the placement of the in- and outflow ducts in the ventilation system.

When the fan has shut down it takes one to one-and-a-half hours for the non-homogenous atmosphere in the locale to diffuse to a reasonably homogenous mass of air. After this, providing that no new emissions disturb the pattern, a collective diminution follows which reflects the passive garage ventilation. This is best seen in figure 7 in the CO-sensors reading during the night. Analogously with the so-called trace-gas method we can use this diminution time to calculate the air-exchange rate in the garage at around five hours, when the active ventilation is not running. This is the equivalent of about 600 m^3 /h and appears to be pretty much independent of outdoor temperature. Therefore it seems that no significant 'Chimney effect' is present.

A test was also conducted during the period 26/3 – 9/3 in order to study the robustness of the ventilation method. A deliberate calibration error was introduced into CO-sensor G1. An offset of 25 ppm CO was added to the demand - controlling sensor, whereby the ventilation fan's activation point was de facto altered from 35 ppm to 60 ppm CO. As a result of this, while the CO-level is generally higher during this period, it is still by a wide margin well below the regulation limit value of 100 ppm. This in spite of the fact that the active ventilation only started on demand on a few occasions : Clearly the garage's volume is so large in relation to its emission load that the dilution of the exhaust gases, together with the passive ventilation, is almost sufficient without resorting to a compulsion fan. There is of course no guarantee that this will always be the case, so that demand-control does in fact fill an important function. The average level of use of the garage is of course dependent on the differing combinations and habits of the tenants.

Statistics for the running time of the fan during the two weeks when the system was running with the correct CO-value show a 9.3% running time during the first week, and 10.5% during the last week. We can therefore conclude that with the present vehicle load, demand-control of the fan is responsible for a 90% saving in energy.

Conclusion

This analysis of the management of the garage kv. Cedern demonstrates that a good indoor environment is maintained day and night, independently of vehicle load and weather conditions. The locales satisfies the norm BBR-94 by a wide margin with regard to air quality and air exchange, on condition that no other contaminants are introduced. Even the most unfavourable places in the garage show no significant environmental deviations from the places where the sensors are located. The demand-controlled ventilation functions demonstrably to perfection, without adjustments or other special refinements. The logic is simple and the results easy to grasp. No surprises have arisen.

The property managers' interests have been met by, among other things, a cost-effective installation. To this we can add the fact that the running time of the fan has been reduced by 90% (in relation to 24-hour running). The cost of electricity for the property in question is today 76.9 öre per kw/h (including energy tax and VAT). When the fan is running it has an effect of 1,5 kW/h, which means that the demand-control produces an energy saving of 970 kW/h, and a resulting reduction in running-costs of ca 750 SEK/month. If all residential garages were equipped in the same way the sum of energy saved would make for a considerable profit to society.

This study has shown that the measurement of several environmental parameters in several places simultanously makes complete analysis possible, both of sources of emission and of ventilation dynamics. If the gathering of data had also extended to a garage entrance detector and/or a vehicle counter, then further conclusions could have been drawn about, for example, the condition of the vehicles. At the present time we do not know how many entrances and exits form the basis of the values measured. In other words, we do not know the garage's load level (visit frequency). This would have been desirable in order to establish measurement norms, and thereby generalise the results to apply to all other garages.