XVII IMEKO World Congress
Metrology in the 3rd Millennium
June 22–27, 2003, Dubrovnik, Croatia

MEASURING OF CLIMATIC CONDITIONS IN A VEHICLE

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Abstract – In the paper results of measuring the climatic conditions (temperature and relative humidity) in vehicles, which are exposed to the sun, will be presented. The measurements will be analysed with respect to the type of a vehicle, colour, availability of air-condition, and weather conditions.

Keywords: temperature, relative humidity, air-condition

1. INTRODUCTION

Although the problem is well known and we all have experience with hot air and low relative humidity in a vehicle, which is exposed to the sun, to the best of our knowledge we couldn't find a single thorough analysis of the related problem. The problem seems trivial, but when we started to make a plan for measurements, we realised that it requires a suitable measurement system, which will be used in different type of vehicles and especially a lot of effort and time because the measurements are weather dependent.

The object of an interest is a vehicle. Since there are many different types, we decided to perform measurements in a limousine, station wagon, mini van and SUV (sports utility vehicle). Important vehicle features for analysis is also a colour and availability of an air-condition. During the measurements we wanted to check the efficiency of air-condition with respect to the set temperature and fan speed. Measurements are time consuming because they are weather dependent. The most important is the situation, when a vehicle is for longer time exposed directly to the sun, but it is also interesting to investigate the conditions, when the weather is mainly or completely cloudy. In both cases we are dealing with the condition of the "greenhouse effect". This effect refers to circumstances, where the short wavelengths of visible light from the sun pass through a transparent medium (window) and are absorbed by interior parts. By the absorption these parts get warm and radiate longer wavelengths (infrared), which do not pass readily through the glass. The trapping of the infrared radiation results in the temperature increase. It is wide known that even though we may be uncomfortably warm with bright sunlight streaming through the window, we can't get sunburns because the glass largely blocks shorter wavelengths (UV-ultraviolet).

2. MEASUREMENT SET-UP

The measurement system for measuring in one vehicle consists of two sub-systems and a portable computer with a PCMCIA-GPIB card, which enables parallel connection and communication with one of the sub-systems. The first sub-system consists of a precision micro-ohm meter and a multiplexer, to which ten fast-response platinum resistance thermometers are attached. The sub-system has a parallel GPIB connection with a portable computer. The second sub-system consists of a measurement device to which six sensors for combined measurement of temperature and relative humidity are attached. The sub-system has a serial RS-232 connection with a portable computer. A portable computer with a help of the special laboratory designed software acquires measurement data from 16 sensors in a two-minute interval and stores them in a text file, where they are available for later analysis.

3. MEASUREMENT PROCEDURE

The main purpose of measurements is to determine temperature and relative humidity in different types of vehicle, in various weather and other conditions, such as: use of shading, partly open windows, open sunroof, availability of air-condition etc. Besides the absolute values we are interested also in spatial gradients of temperature and relative humidity. In this respect we arranged in a vehicle 9 platinum resistance thermometers and 5 sensors for combined measurement of temperature and relative humidity, which are placed in the positions of passengers hearts (Fig. 1). With one resistance thermometer and one combined sensor the outside air temperature and relative humidity is measured.

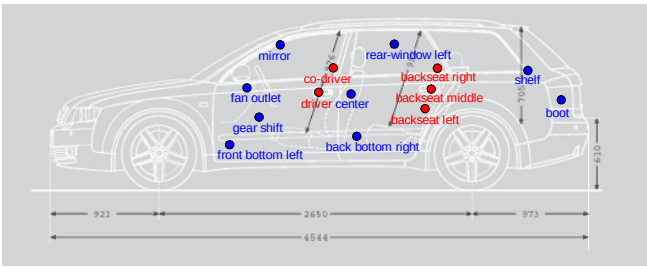

Fig. 1. Arrangement of sensors in a vehicle

4. MEASUREMENT RESULTS

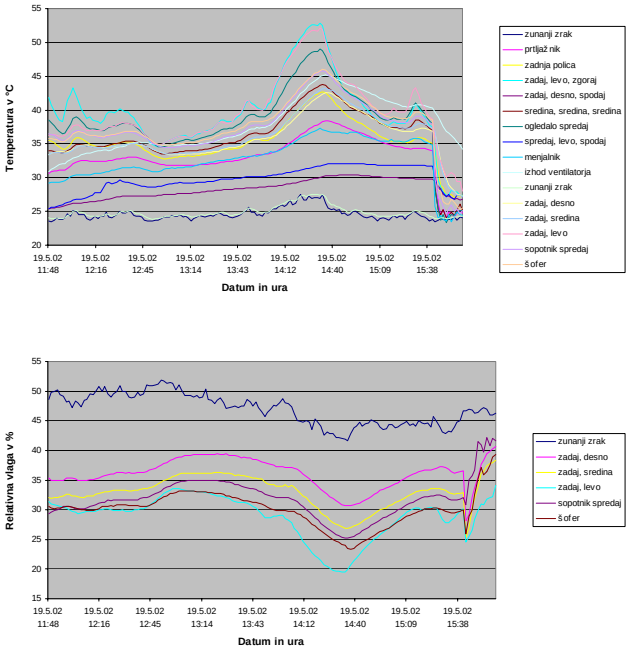

Fig. 2a and 2b: Temperature and relative humidity in Škoda Octavia combi, silver metallic, closed windows, 80 % clouds

4.1. Measurement in mainly cloudy weather

Measurement was performed in mainly cloudy weather, which means more that 80 % clouds (temperature 24 °C to 26 °C, relative humidity 50 % to 45 %). Temperature in the exposed parts of the vehicle (mirror, fan outlet, sunny side of a vehicle, upper level of interior) raised compared to the outer temperature for 35 % to 45 %. In the lower level of the vehicle temperature raised for 15 % do 20 %. Inner relative humidity was 15 % to 20 % lower than outer relative humidity, see Fig. 2a and 2b.

When it became sunny for 15 minutes during the measurement, temperature in the exposed parts of the vehicle raised steeply for more than 10 °C (25 %). Relative humidity dropped evenly all over the vehicle for approximately 10 %. Gradients of temperature were from 8 °C to 23 °C, while gradients of relative humidity were from 5 % to 10 %.

4.2. Measurement in clear weather, 2 cm opened windows

Measurement was performed in totally clear weather (temperature 27 °C to 28 °C, relative humidity 50 % to 35 %). The three-door vehicle had open windows for 2 cm at the front doors. Temperature in the exposed parts of the vehicle raised compared to th e outer temperature for 80 % to 120 %, while in the lower level only for 30 % to 50 %. Relative humidity dropped everywhere below 20 % later even below 15 %. The largest temperature gradient was 29 °C, and the largest relative humidity gradient was 11 %, see Fig. 3a and 3b.

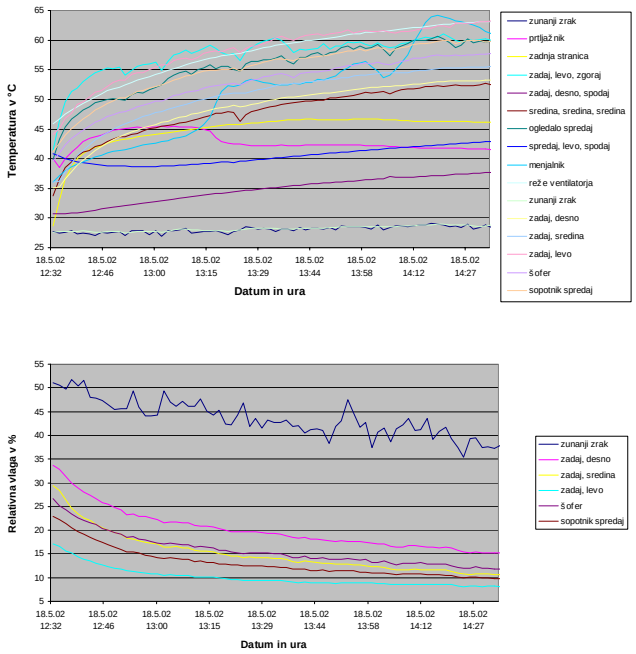

Fig. 3a and 3b: Temperature and relative humidity in VW Polo, turquoise green, 2 cm open windows, 100 % clear weather

4.3. Measurement in clear weather, closed windows

This measurement was continuation of the previous measurement. The difference was that the vehicle had closed windows. Temperature in the exposed parts of the vehicle raised compared to the previ ous temperature for up to 7 %. Temperature in the lower part of the vehicle even dropped for 6 %. Relative humidity practically didn' t change. Gradients of temperature cha nged for less than 5 %, while gradients of relative humidity changed for 2 %. (See Fig. 4a and 4b). The temperature drop was a consequence of the position of the sun. The sunbeams were not entering the vehicle through windows any more because the body of the vehicle hindered them. During the last stage of the measurement the door were opened and temperature dropped rapidly.

4.4. Measurement in clear weather, air-condition switched on after warming

Measurement was performed in totally clear weather (temperature 31 °C to 33 °C, relative humidity 50 % to 40 %). The vehicle windows were closed. Temperature in the exposed parts of the vehicle raised compared to the outer temperature for 70 % to 90 %, in the lower part of the vehicle for 30 % to 40 %. Relative humidity dropped to 23 % and 20 %. The largest temperature gradient was 21 °C, and the largest relative humidity gradient was 3 %.

After switching on the mechanical air-condition, and setting the highest cooling power and the first fan speed of four, temperature dropped in 25 minutes in the exposed parts of the vehicle for 17 °C and at the bottom of the vehicle for 3 °C only. In the first five minutes of air-condition operation temperature ev en raised for 1 °C at the bottom at the back seats and in the boot because the fan pushed hot air from the upper part of the vehicle to the back of the vehicle. Temperature at the mirror was not taken into

account for gradient calculation b ecause the stream of a cool air from the fan outlet was di rected to the respective thermometer. Temperature gradient was 10 °C. Temperature of the air from air-condition system was around 4 °C. Relative humidity dropped below 15 %, with the gradient of 4 %.

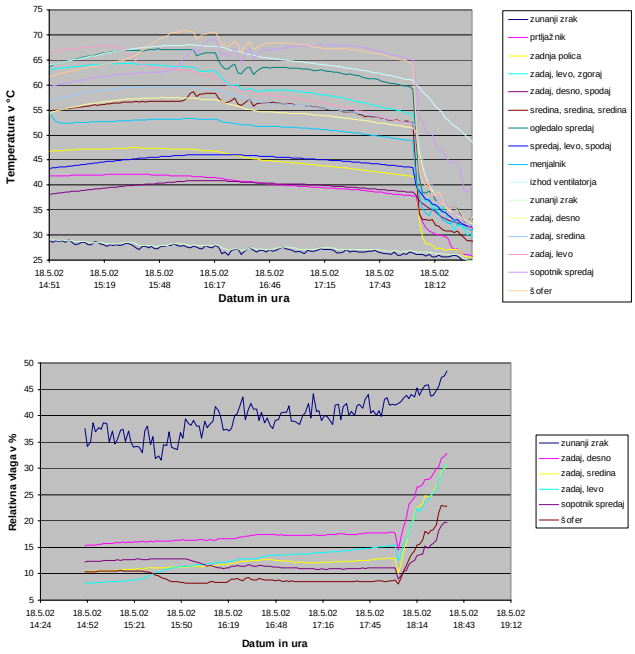

Fig. 4a and 4b: Temperature and relative humidity in VW Polo, turquoise green, closed windows, 100 % clear weather

After setting the fan speed to the second stage temperature dropped for 5 °C to 10 °C, and the gradient lowered to 8 °C. Relative humidity raised for 5 % with the unchanged gradient. Temperature of the air from the air-condition system was around 5 °C.

After setting the fan speed to the third stage temperature dropped for 3 °C with the unchanged gradient. Relative humidity raised for another 8 % with slightly higher gradient of 5 %. Temperature of the air from the air-condition system was around 9 °C.

After setting the fan speed to the fourth stage temperature dropped for only 1 °C with the unchanged gradient. Relative humidity raised for another 8 % with slightly higher gradient of 6 %. Temperature of the air from the air-condition system was around 12 °C.

After setting the fan speed to the second stage and closing the inlet of fresh air (circulation of inner air) temperature practically didn' t change, while the gradient raised to 12 °C. Relative humidity dropped for 10 % with the unchanged gradient. Temperature of the air from the air-condition system was less than 3 °C.

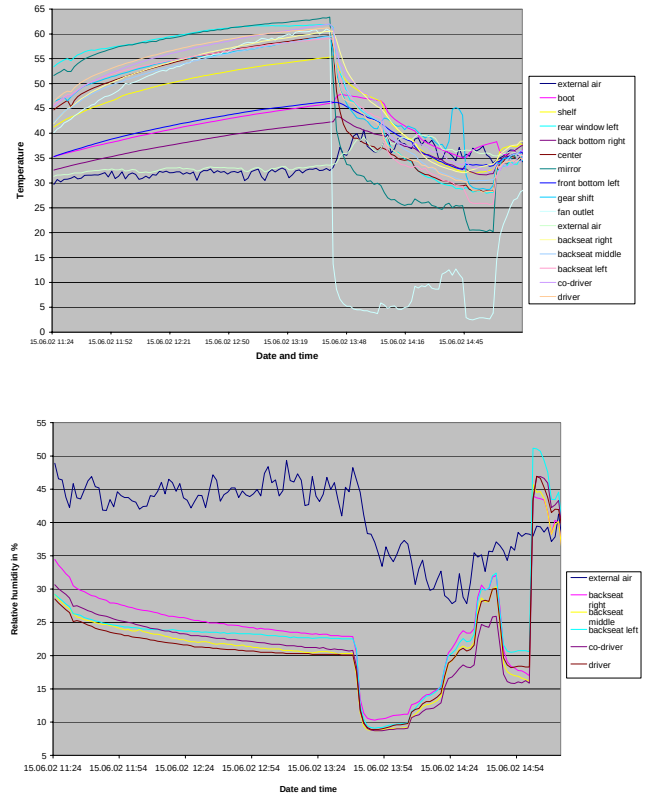

Fig. 5a (temperature), 5b (relative humidity), 5c (measurement set-up) in Škoda Octavia combi, metallic silver, closed windows, 100 % clear weather, with and without air-condition

5. CONCLUSION

Current measurements have revealed very interesting results. For example, in a cloudy weather the temperature rise is usually less than 15 °C, while the relative humidity drop is less than 20 %. If a vehicle is exposed to the sun for only a few minutes the temperat ure quickly rises for 10 °C, while the relative humidity falls for 10 %.

If a vehicle is exposed to the sun, a human being is practically unable to detect th e difference in temperature, when the rear windows are open for 2 cm or closed, because the difference is smaller than 10 %. More important is that a vehicle is ventilated by mean s of open doors for at least 10 minutes before a ride.

During the measurements it is important to track the position of the sun, because considerably higher

temperatures were measured w ith sensors placed close to the window or other exposed parts of the vehicle. In the following measurements we will determine also efficiency of special shades.

Air-condition is of course the most welcome device in a vehicle during the hot weather. While in operation, besides cooling of the internal air, also gradients are smaller. On the other hand a low relative humidity is even lower, which accelerates dehydration of pa ssengers. Measurements have shown that the optimal fan speed of air-conditioning is the medium. A slightly better cooling performance is achieved, if an inlet for external fresh air is closed.

It is very interesting that when a vehicle is parked in the sun the air-condition at its maximum power is not able to cool the internal air to the temperature, which is considerably lover than outside temperature. It would be very interesting to perform measurements in a moving vehicle but the problem is to ensure supply for measuring instruments and placement of th e measuring and especially the supply system.

The colour of a vehicle is al so an important factor. That means the colour of a car body as well as the interior parts, which absorb the short wavelengths of the visible light and radiate it back to the interior as long wavelength of infrared light, which is then trapped by the window. In this respect the measurements in three vehicles of the same type (Škoda Octavia combi) but different colours (metallic silver, metallic gold, metallic dark green) will be performed simultaneously under the same weather conditions. At the same time the temperature of the car body will be measured with a pyrometer.

By the time of the congress we hope that we will succeed to perform also some more measurements. Based on already obtained results we expect more interesting conclusions. After the results of particular measurements were obtained and analysed, we asked many people about their estimation of conditions in a vehicle but only a few of them were reasonably close to the exact measured values. The majority estimated completely different values.

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