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THERMAL COMFORT IN CONVENTIONAL VEHICLES (ICE) AND ELECTRIC (EV) - EVALUATION METHODS

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Abstract: Development and fine-tuning of a procedure for measuring the temperature in the car windshield area, with respect to the European demisting standard (CEE 78/317): by using a high-speed infrared thermography camera. Carry out a differential analysis of the experimentally obtained results both in terms of thermal comfort, between vehicles equipped with ICE technology (conventional) and vehicles equipped with EV technology.

INTRODUCTION

Electric mobility is expanding at a rapid rate.

Electric car deployment has been growing rapidly over the past ten years, with a global stock of electric passenger cars surpassing 5 million in 2018, a 63% increase over the previous year. About 45% of electric cars on the road in 2018 were in China, a total of 2.3 million, compared with 39% in 2017. By comparison, Europe accounted for 24% of the world's fleet, and the United States 22%.

Sales of electric vehicles in the world grew 64% in 2018.

Sales of electric vehicles in the world during 2018 reached 2.1 million. 69% of sales were all electric (EV) and 31% were plug-in hybrids (PHEV).

These figures include electric and plug-in hybrid passenger cars, light trucks in the US and Canada, and light commercials in Europe and China.

69% of sales were all electric (EV) and 31% were plug-in hybrids (PHEV). Fully electric vehicles have reached a 3% share since 2017. The causes, according to the Swedish consultancy EV-volumes, lie mainly in three factors. The first, growth in China. The second, the arrival of the Tesla Model-3. The third, the losses for PHEVs in Europe due to the entry into force of the WLTP protocol.

The largest contributor to growth, by far, was China. Its electricity sales increased by more than 500,000 units, to 1.2 million in 2018. It represented 56% of all electrified sales. (Figure 1)

Growth in Europe was moderate, at 34% (Figure 2). It was held back by limited ranges and long waiting lists for popular EVs. Also, due to the exhaustion of sales of PHEVs in stock.

In the US, sales were up 79% and the expected Tesla Model-3 contributed 138,000 units. It became the best-selling EV of all categories in 2018. It even dominated luxury car sales in North America. Sales outside of China, Europe and the US were 150,000 units (+ 39%), with Japan again the opposite. However, other markets such as Canada and South Korea grew much faster than average.

PURPOSE

Development and fine-tuning of a procedure for measuring the temperature in the car windshield area, with respect to the European Standard for demisting (CEE 78/317): by using a high-speed infrared thermography camera.

In this study, we aim to evaluate the effectiveness of windshield demisting systems in electric vehicles by using thermography (IR) techniques and infrared image analysis.

Thermography allows obtaining objective information (temperature values) in relation to the condition of the windshield, unlike other studies in which the evaluation of thermal comfort inside vehicle cabs is based on subjective evaluations.

Due to the use of other methods, such as digital thermometers and liquid crystals, there are few previous works where infrared thermography is used for the evaluation of temperature or thermal comfort inside vehicle cabs.

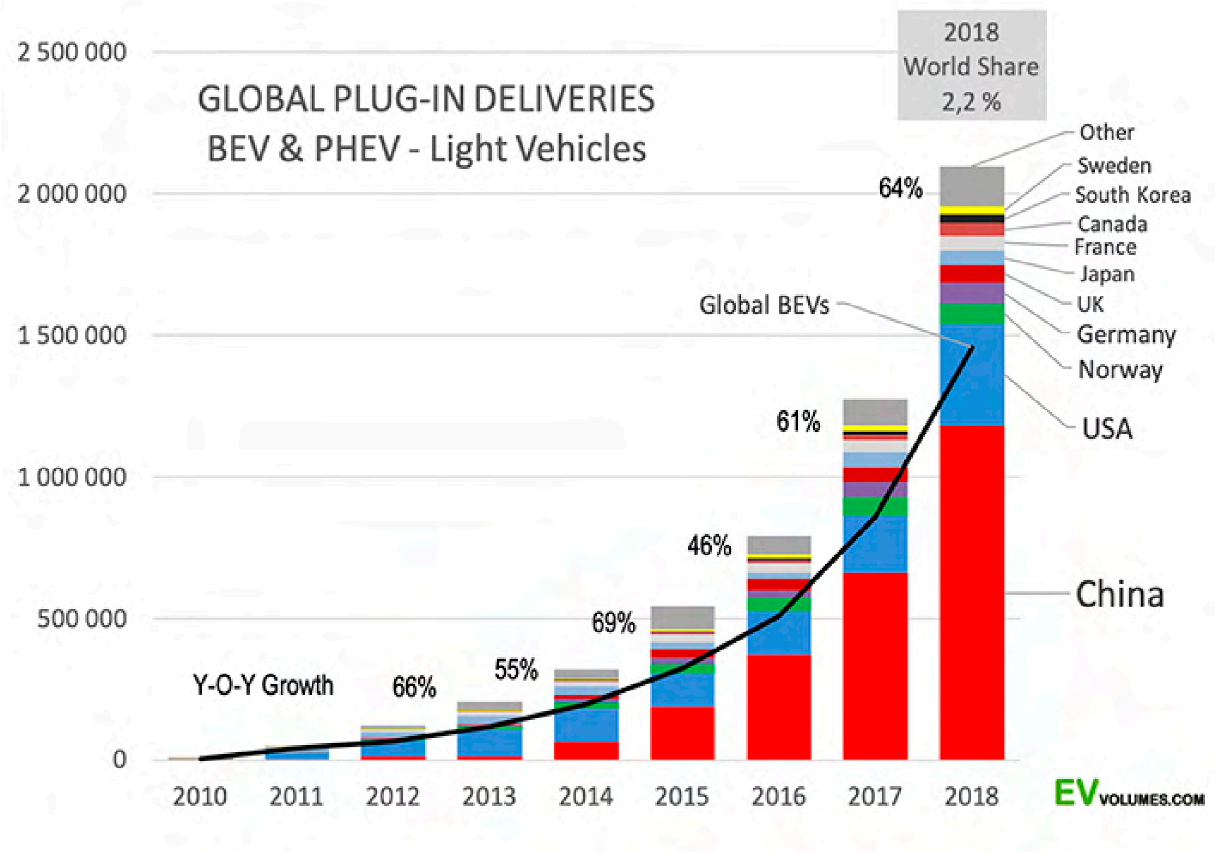


Fig. 1 – Global BEV & PHEV Light Vehicles Deliveries.

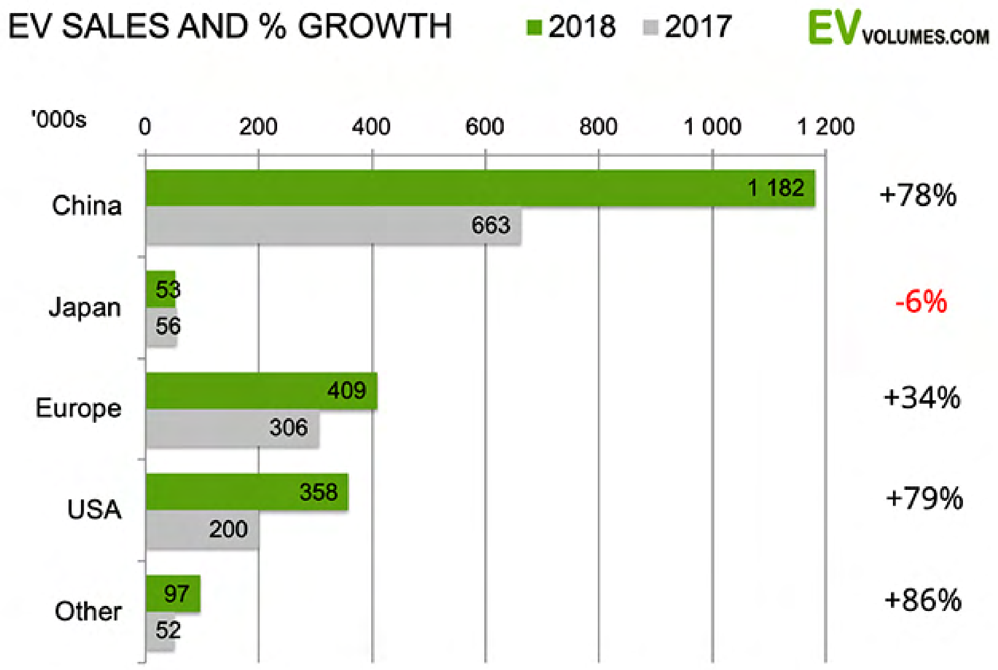


Fig. 2 – EV Sales and % Growth 2018 vs 2017.

MATERIALS AND METHODS

THERMAL CAMERA

- InfraTec ImageIR.
- Software: IRBIS 3 Professional.
- Lenses: 100mm + 500mm.
- Minimum spatial resolution of 30 μm.
- Image size: 320 x 256 pixels.
- Speed: 1000 fps.
- Resolution: 30 mK @ 30 °C
- Integration times from 1 μs to 10 ms.

We check that the entire windshield of the car is at -2°C of temperature, we start the engine, we close all the aerators except those for demisting the windscreen, we close all the doors and gate, we begin the test t = 0 at the right moment to start the engine. (Figure 3).

Test carried out on 3 vehicles: one equipped with a conventional heat engine (ICE), an EV equipped with resistance, and an EV equipped with a heat pump.

Average temperature on the windshield at the beginning of the Test, the average temperature is -2° C (We perfectly comply with the European Regulation CEE78 / 317, which requires between -1°C and -3°C), see Figure 4, average temperature throughout the windshield (for the 3 models tested, stabilized 24 hours).

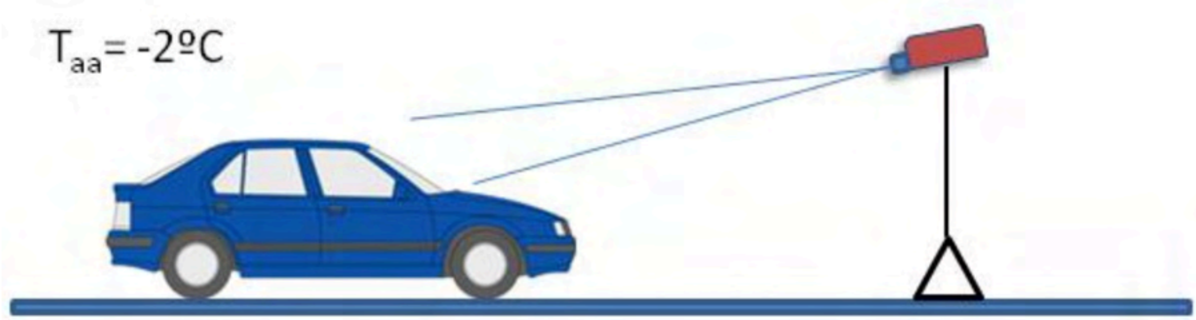


Fig. 3 – Scheme of the Measurement Method.

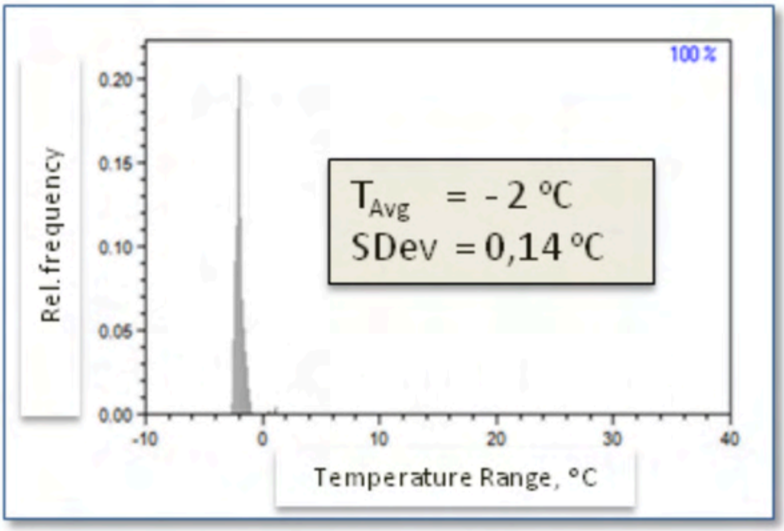


Fig. 4 – Average temperature on the windshield at the beginning of the Test.

RESULTS

Illustrative example: Minute 5, Thermal ICE (Figures 5 & 6).

Making a summary graph by average, maximum and minimum temperature in area R1, during the 20 minutes that the Test lasts, we obtain the following (ICE – Figure 7).

Making the same summary graph by average, maximum and minimum temperature in area R1, during the 20 minutes that the Test for the Electric Car with Resistance Heating lasts (Figure 8).

Making the same summary graph for average, maximum and minimum temperature in area R1, during the 20 minutes that the Test lasts, we obtain the following for the Electric Car with Heat Pump Heating (Figure 9).

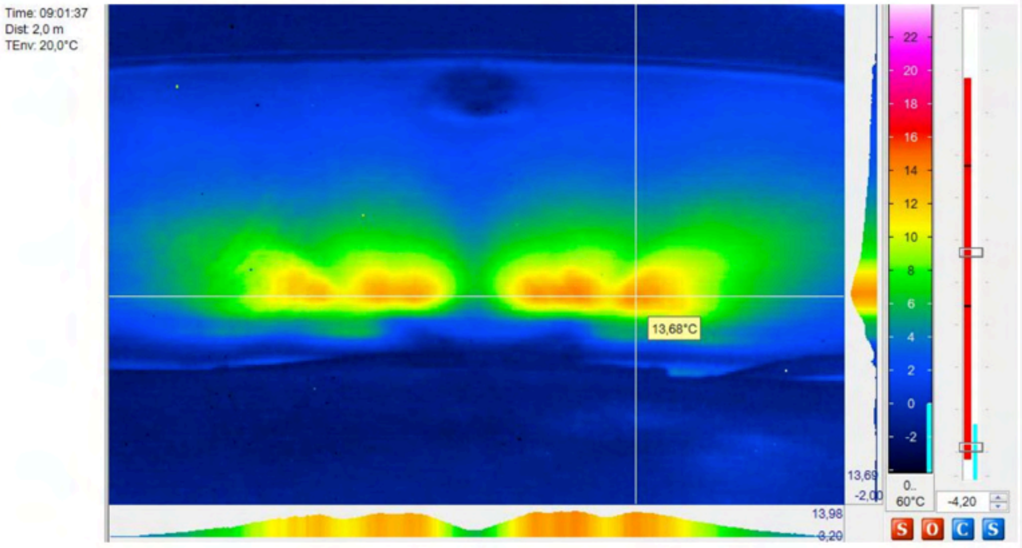


Fig. 5 – Example: Thermography map on the windshield (minute 5 – ICE Vehicle).

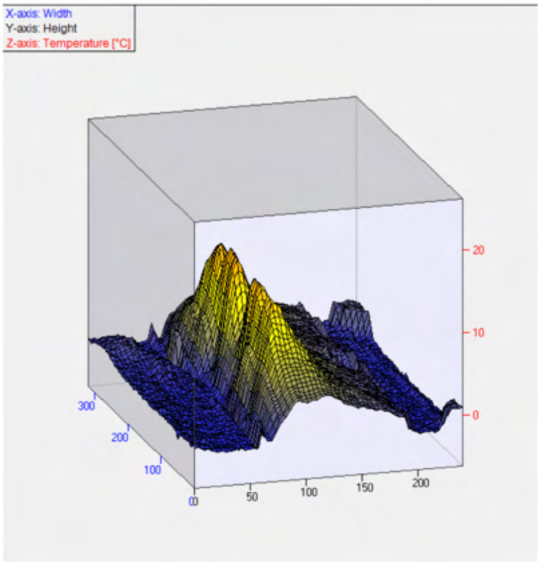


Fig. 6 – 3D graph of temperature on the windshield.

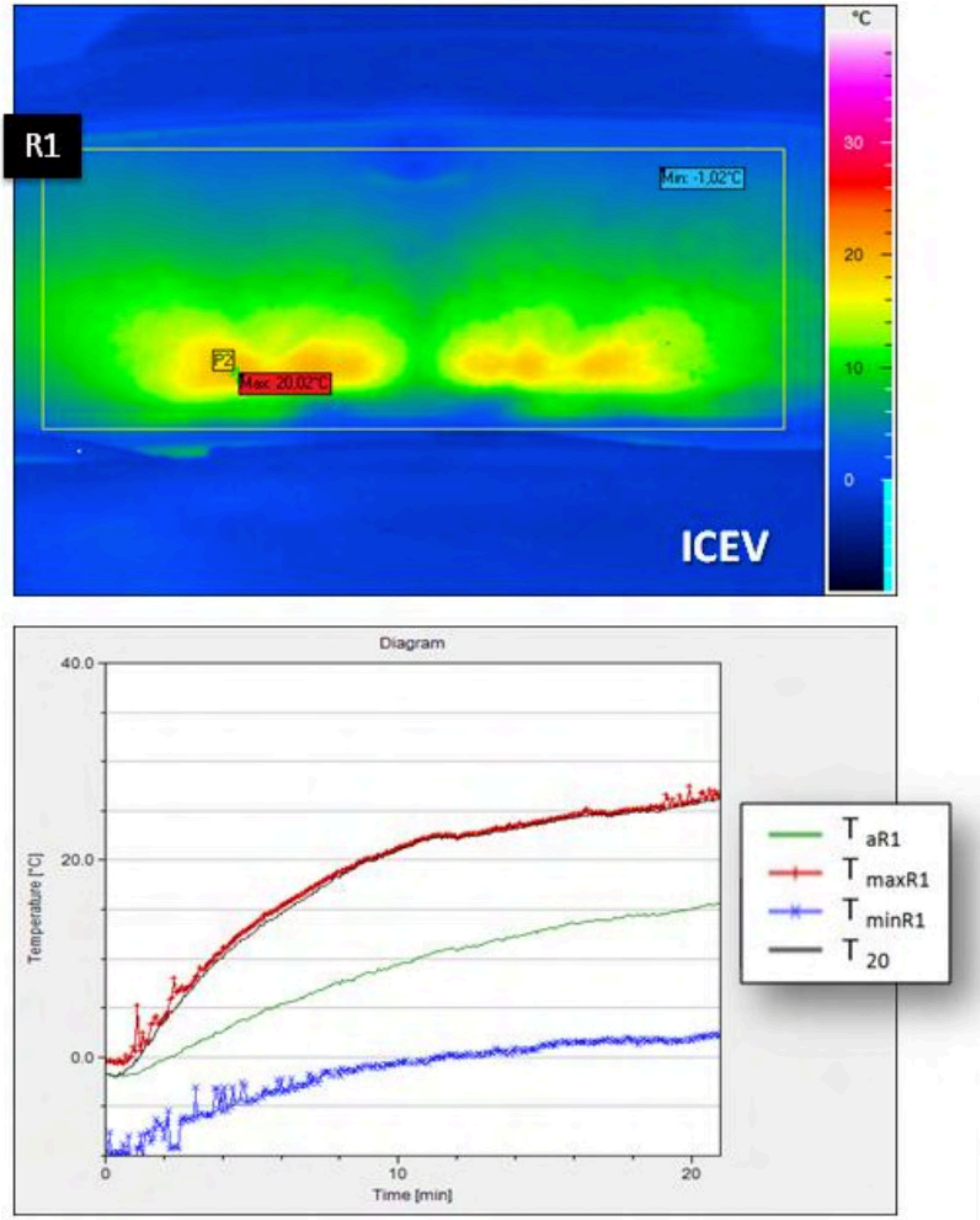


Fig. 7 – Average, maximum and minimum temperature in area R1 - ICEV.

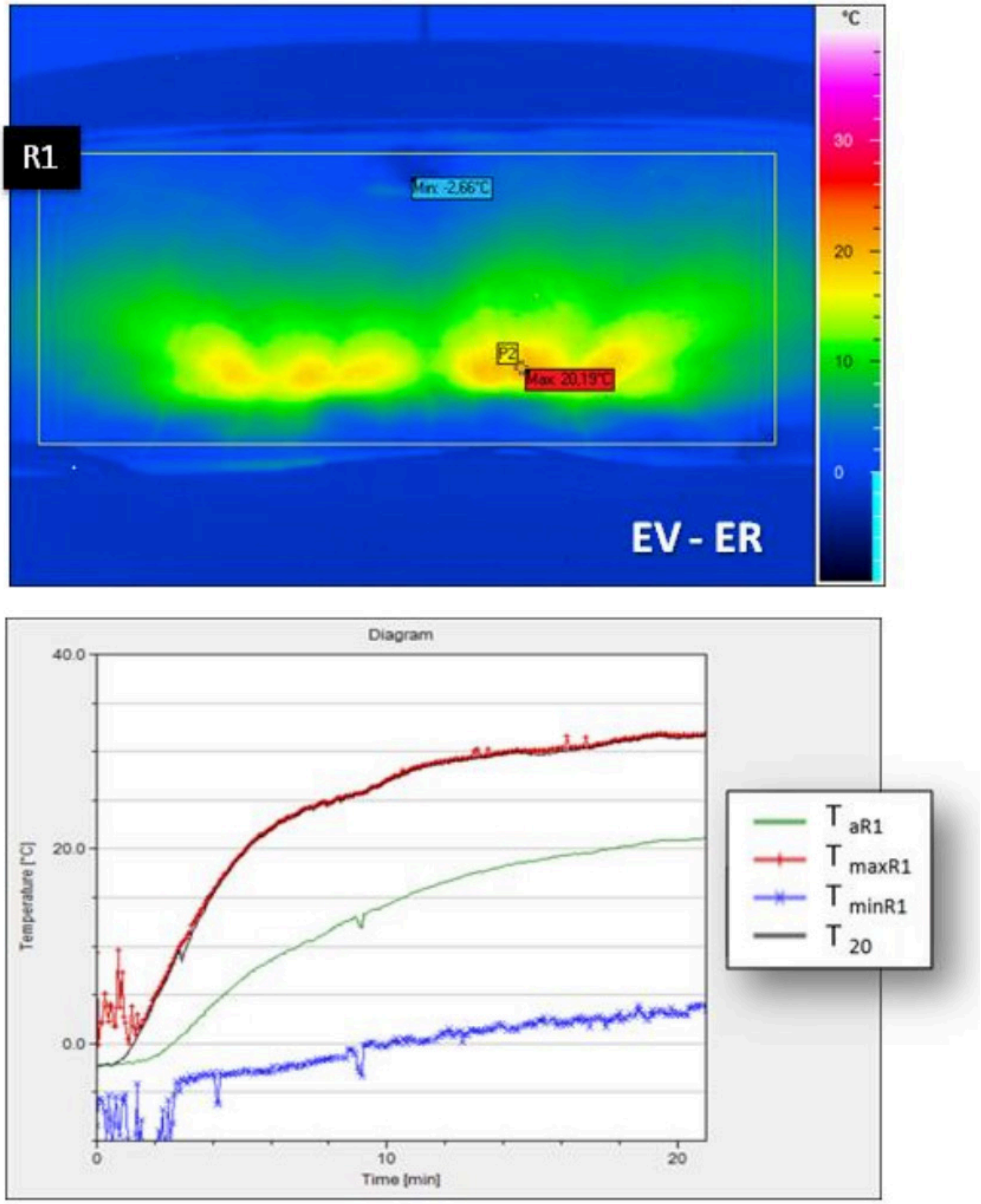


Fig. 8 – Average, maximum and minimum temperature in area R1 – EV-ER.

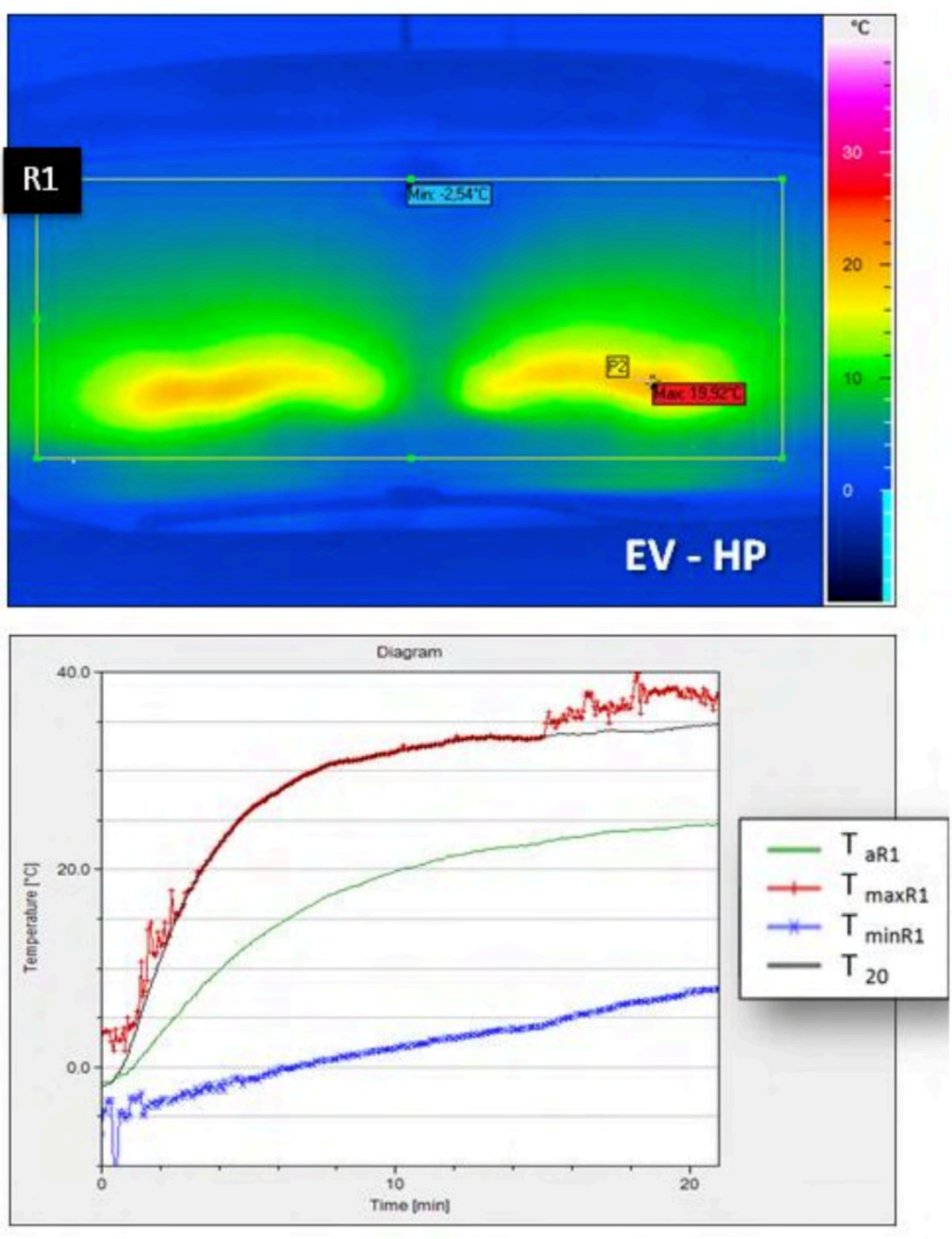


Fig. 9 - Average, maximum and minimum temperature in area R1 – EV- HP.

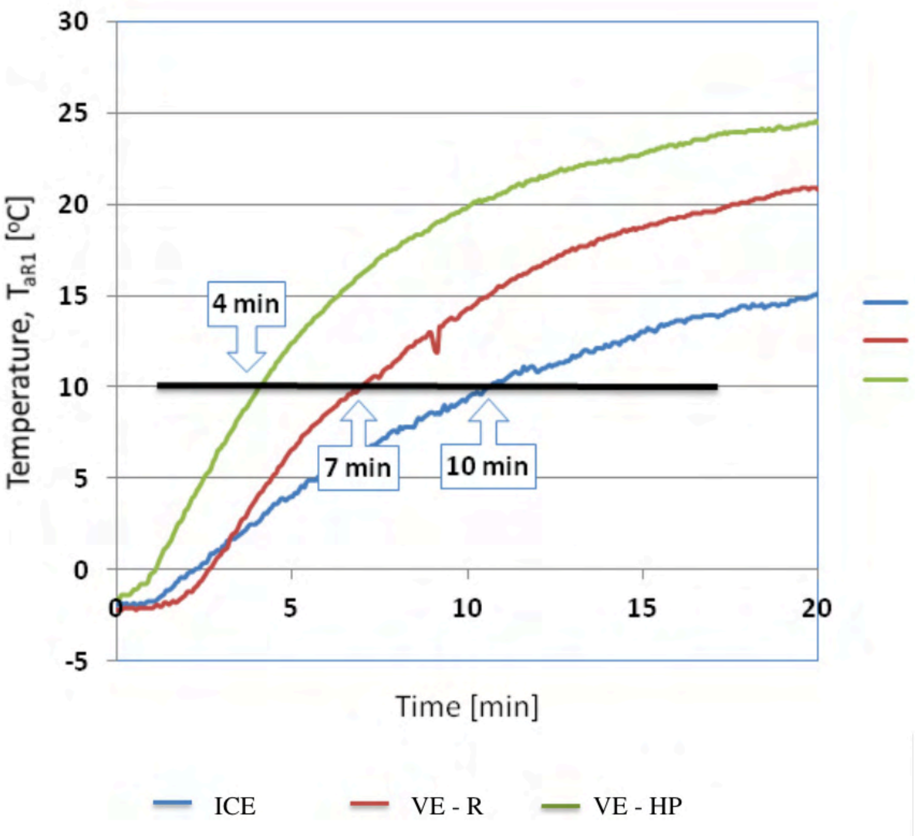
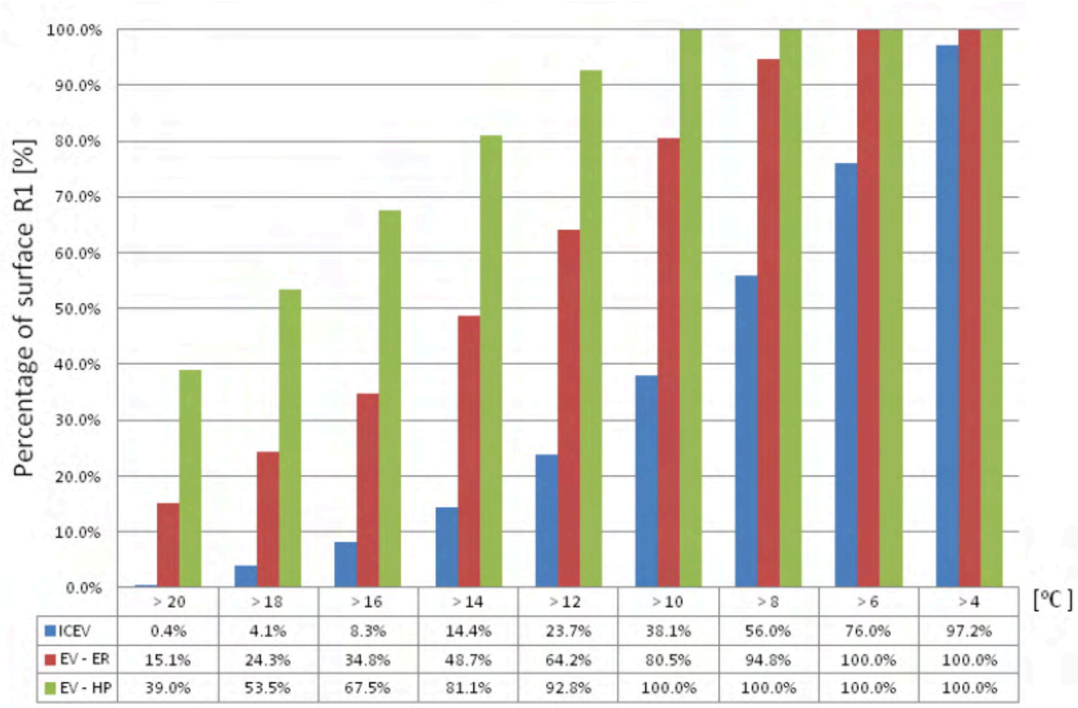


Fig. 10 - Graphical comparison Tª-time of the 3 models by average T.



	> 20	> 18	> 16	> 14	> 12	> 10	> 8	> 6	> 4
🟦 ICEV	0.4%	4.1%	8.3%	14.4%	23.7%	38.1%	56.0%	76.0%	97.2%
🟥 EV - ER	15.1%	24.3%	34.8%	48.7%	64.2%	80.5%	94.8%	100.0%	100.0%
🟩 EV - HP	39.0%	53.5%	67.5%	81.1%	92.8%	100.0%	100.0%	100.0%	100.0%

Fig. 11 - Percentage of the area R1 whose Tª is above a certain value at t = 10 minutes.

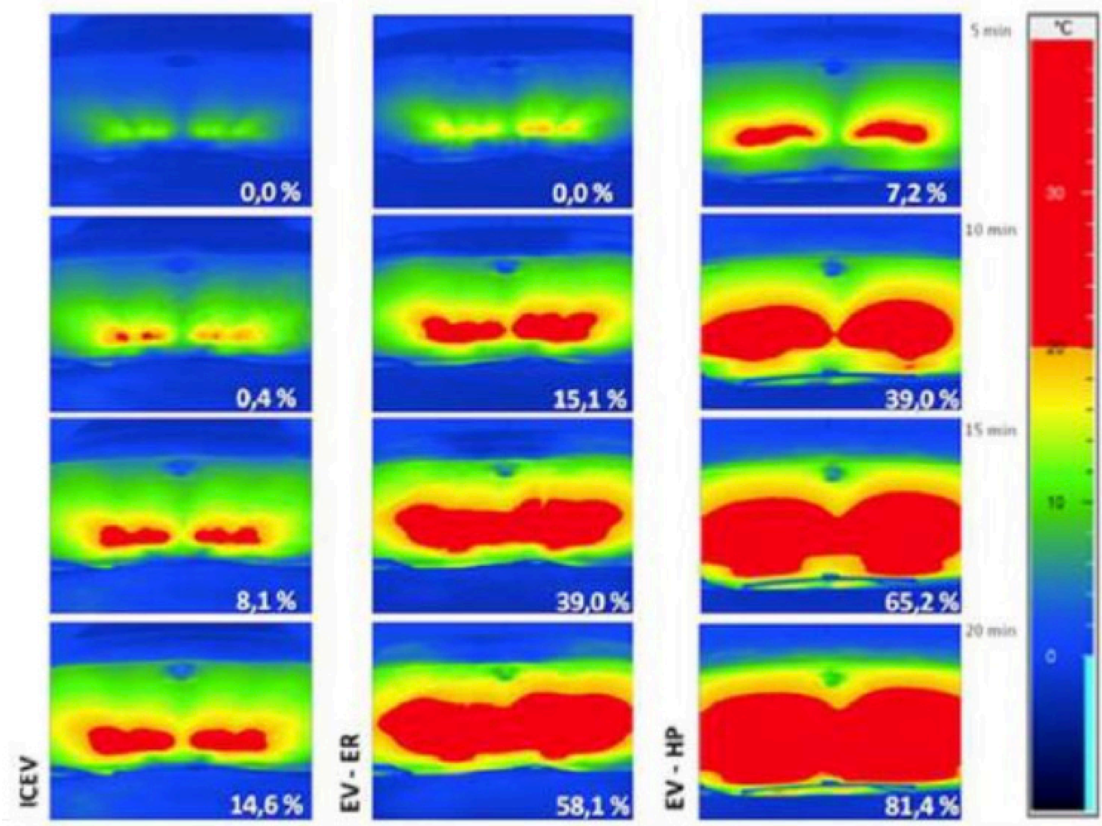


Fig. 12 - Thermography map on the windshield of the 3 models in time.

CONCLUSIONS

We can see in these Thermographic measurements that:

The most efficient vehicle in the demisting function is the EV (with heat pump), we rely on the following graphs and Tables to make it clear (Figure 10): We make a graphical comparison Tª-time of the 3 models by average T, highlighting the time to reach 10º C in area R1 (Windshield).

Lastly, these 2 graphs that show more clearly if possible that the demisting efficiency is VE-HP> VE - R> ICE, it shows the percentage of the area R1 whose Tª is above a certain value at t = 10 minutes; this % is cumulative, that is, it is the sum of the areas whose temperature is above a certain temperature (in percentage).

CONCLUSIONS

5.1. IR Thermography demonstrates the relevance of using this medium as an analysis and validation tool in the homologation of the defrosting / demisting performance of vehicles for the EU (according to current EEC 87/318 Regulation)

5.2. The electric vehicles tested are more efficient in the demisting task than the thermal vehicle.

5.3. Of the 2 electric vehicles tested, the EV equipped with a heat pump is more efficient than the EV equipped with a PTC resistor.

5.4. The range (or Battery autonomy) lost in this test is of the order of 25% for the VE with PTC resistance and 20% for the VE with heat pump, this, taking GENERAL MEASUREMENT of the STARTING TEMPERATURE of the TEST: the average temperature is -2ºC: according to the European Regulation CEE78 / 317, which requires between -1ºC and -3ºC, taking into account the little autonomy that these cars already enjoy, making this point a great burden on the customer satisfaction.

5.5. In conclusion, the electric vehicle enjoys greater thermal comfort compared to its equivalent of combustion, but at the same time it demands a more demanding job in the "non-loss" of range or autonomy that we "sacrifice" in this comfort, with ample possibilities of tuning one with respect to the other.

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