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# New heating system development working with waste heat for electric vehicles

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## Abstract

Researches carried about electric vehicles are focused on extending life of the battery today. Development of higher-range batteries is as essential as efficient use of current battery energy technology. EPT System, that has average efficiency of 85%, produces waste heat up to 15% of its nominal power. The current heat pump systems, which use the waste heat, are very expensive and have complicated structures. In addition, the energy is consumed about 50% of heat transfer with this way. With the newly developed and patent applied system, the average temperature of the waste heat of the engine is raised to the temperature of engine efficiently operating In addition, the energy could be used for heating purposes without additional energy consumption. Newly developed heating system can heat with high efficiency using heat pump and stored electrical energy from heat through braking energy without any extra energy consumption.


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## 1. Introduction

Electric vehicle HVAC systems are composed of air conditioning cycle, electric water heater (PTC) and a heat exchanger that generates cold water for battery cooling system. Currently used system is shown in Figure 1. HVAC system works in an integrated way with engine cooling system. Electric heater power used for one LCV is 5.5 kW. Air conditioning cooling power is 3.5 kW. Depending on the COP value, electric power varies between 1.5–2 kW. 2 kW of electric water heater power is used for heating the battery, while 3.5 kW for heating the cabin. Also, when the ambient temperature exceeds 35 ℃ (may vary depending on the battery type), an additional 2 kW cooling load is required for heat exchanger in order to generate cold water. As per legal demisting regulations (EU-672/2010), cabin heating and cooling systems are operated at maximum level for defrost mode. In this case, a vehicle working in defrost mode under zero degrees consumes 7–7.5 kW electric energy. If we assume that the vehicle's battery capacity is 28 kWh and the average power the vehicle consumes at 100 km/h steady velocity is 20 kW, the maximum distance it can cover is 140 km when HVAC system is off, while this distance drops to 100 km when HVAC system is turned on.

The most energy-consuming part of HVAC system is its heating function with 5.5 kW. Waste heat in ICE vehicles can be easily regained as they are high temperature and in large quantities. In electric vehicles however, an additional heating system is required due to low temperature heat excess in low quantities. Figure 2 shows the placement of currently used HVAC system on the vehicle.

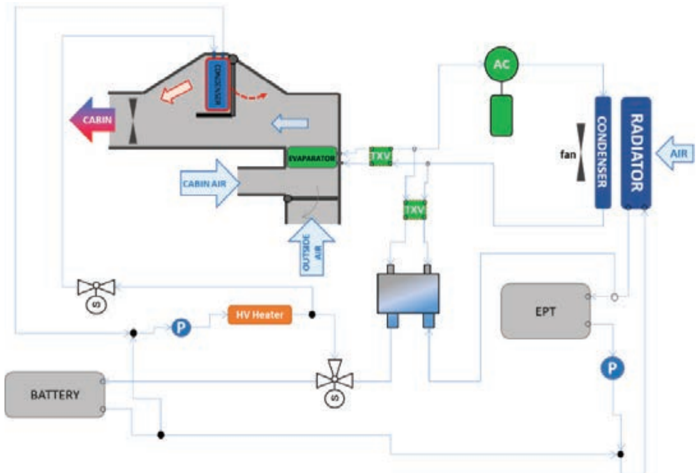


Fig. 1. Baseline EV's HVAC System.

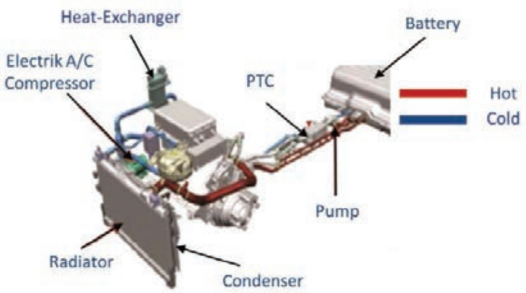


Fig. 2. Baseline EV's HVAC System on vehicle.

Figure 3 shows the cabin heating methods used in electric vehicles in the known state of the technique. About the cabin heating, conventional available technologies can be summarized as follows:

- Electric Heater: easy to be installed, purely dissipative. It is a common solution adopted also on conventional vehicles. Efficiency < 1
- Fuel Burner: needs a fuel tank and is not a ZEV solution.
- Hot Gas: purely dissipative, requires the A/C system adaptation. Mechanical work of the compressor is converted in heat, so the HVAC evaporator becomes a heater. Efficiency < 1
- Heat Pump: more efficient than PTC or hot gas and widely used for domestic application. It is a thermodynamic cycle that transfers heat from a cold source to a hot sink. Efficiency > 2

Electric vehicles requires very efficient systems to have the minimum impact on vehicle autonomy. Use the heat pump for heating the cabin is the right solution to reduce the energy demand and improve the thermal comfort because the efficiency of the heat pump is higher than the electrical heater or hot gas. The problem to use the heat pump in an electric vehicles is because it is difficult to find commercial one in the market. All the information that we can find it about the heater pump are prototypes or own systems designed for specials clients.

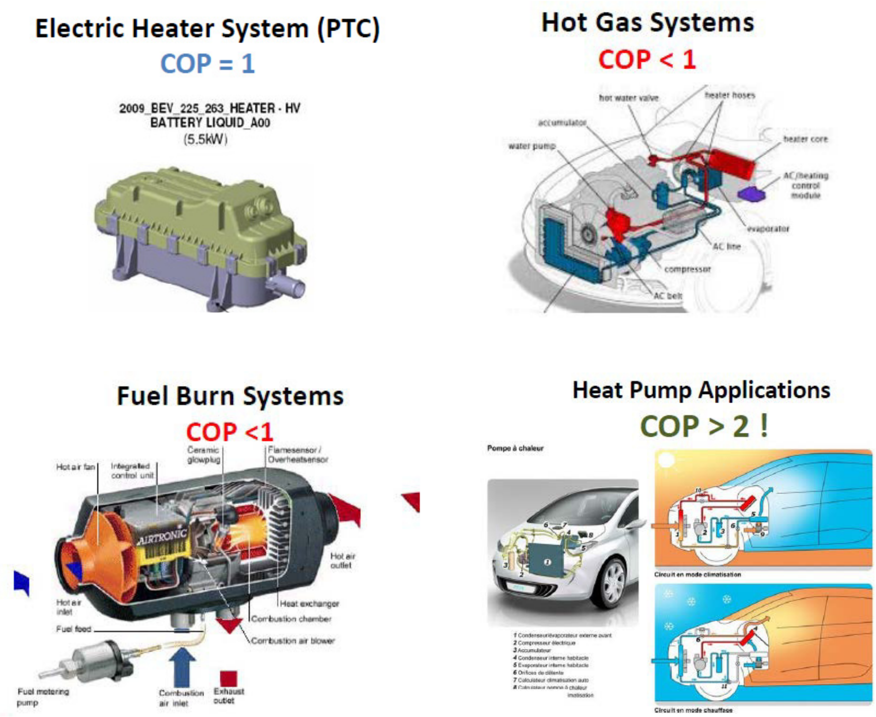


Fig. 3. EV cabin heating solutions.

## 2. New heating system development

In order to measure the total waste heat quantity of the present electric vehicle, physical tests were conducted according to ECE 98/69 NEDC standard shown in Figure 4. In the first group test, engine and battery cooling system's physical measurements were carried out in 0 ℃ conditions and average waste heat quantity was calculated. Upon examining the test results, battery heating/cooling water was 2 ℃ in the beginning of the test, while it reached 2.5 ℃ with only half a degree increase at the end of 18 minutes of testing. Engine cooling water was 2 ℃ again in the beginning of the test, and measured as 14 ℃ in the end (Figure 5).

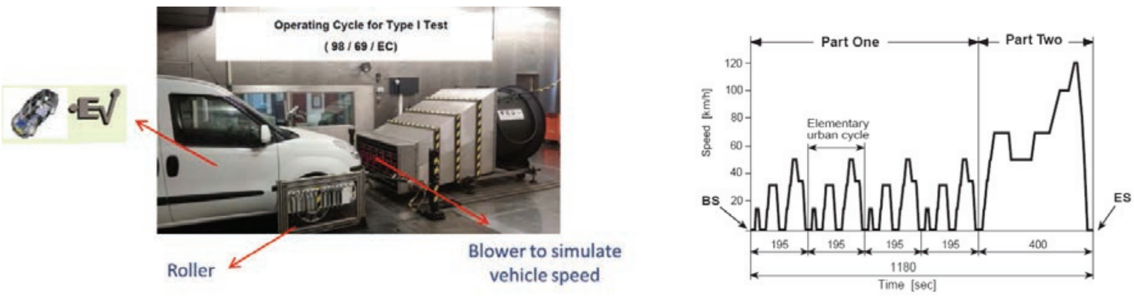


Fig. 4. ECE 98/69 NEDC.

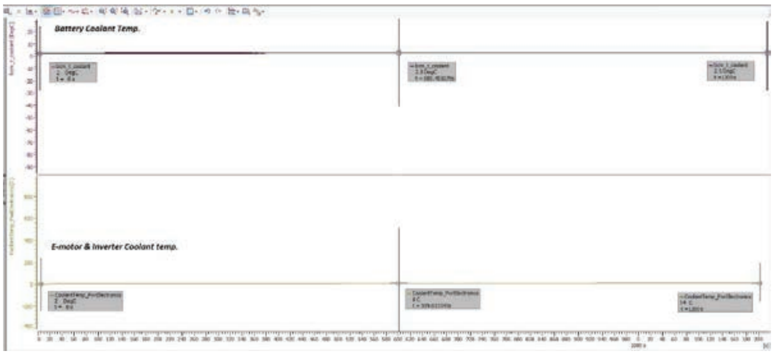


Fig. 5. Temperature measurements conditioned to zero degrees.

Second group test used the same physical conditions, but tests were conducted by covering the front end of the vehicle and removing radiator fan's socket. Covering the front end of the vehicle and removing the socket enabled simulating the procedure where engine cooling water is returned back to the engine with the 3-way valve without passing through radiator. Second group test assembly is displayed in Figure 6.


Fig. 6. Temperature measurements while front end covered and radiator fan socket removed.

As Figure 7 displays, battery water temperature rises from 2 ℃ in the beginning to 3 ℃ at the end of 18 minutes. Engine cooling water temperature rises from 4 ℃ to 21 ℃ after 18 minutes.

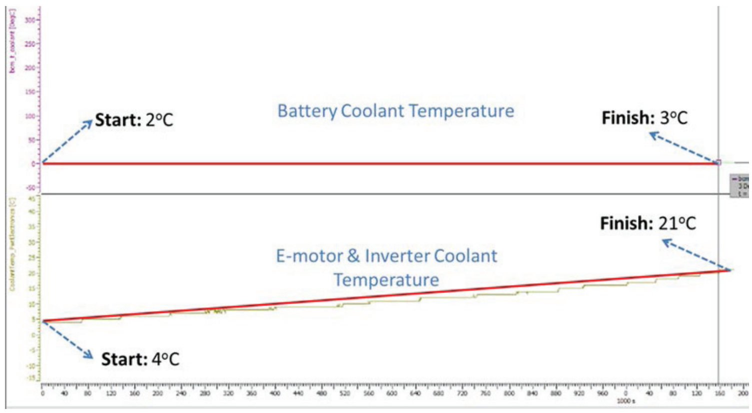


Fig. 7. Temperature measurement values while front end covered and radiator fan socket removed.

In this situation, if we consider the engine cooling water quantity is 8 l with all losses, waste heat quantity in one cycle is calculated as 161.8 Wh using Q=m*c*dT formula. Assuming that a cycle is 11.07 km and the vehicle can complete 13 cycles with a fully-charged 28 kWh battery when HVAC system is off, we determined that the system contained 2.10 kWh (7.5%) usable waste heat. However this waste heat cannot be used directly due to low temperature value. A new system is developed for this waste heat to be used. Within the scope of this study, the new heating system uses 3-way valve and phase shifting liquid (paraffin) for heat storage purposes. 3-way valve allows motor cooling water to be circulated without passing through the radiator. In this way, water's temperature value does not drop and when it reaches 50 °C, phase shifting material (paraffin) starts to melt. The heat is stored by utilizing the principal that temperature stays fixed during phase shift. Figure 8 shows this new heating system (Ayartürk et al., 2015).

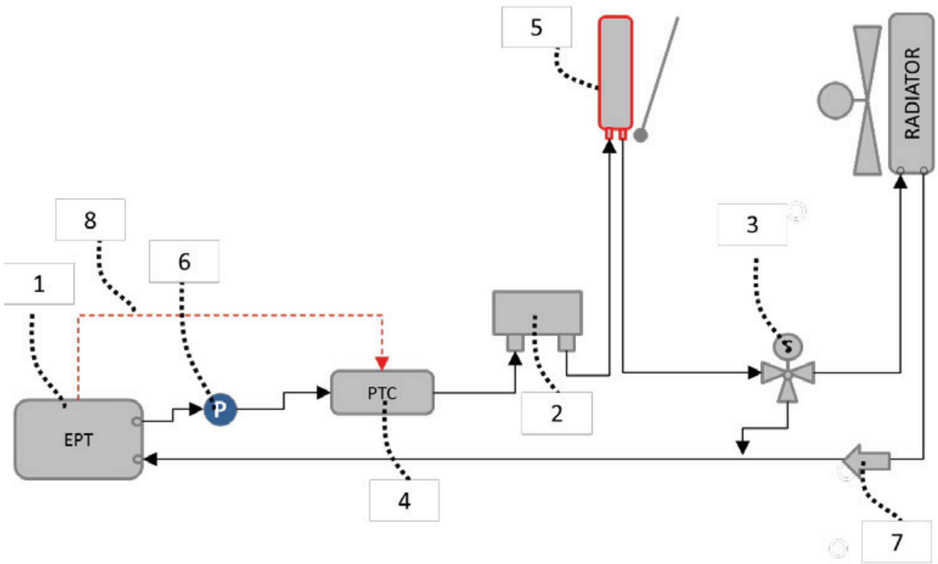


Fig. 8. New heating system (1) EPT-inverter-on board charger group (2) heat storage exchanger (3) tree-way valve (4) PTC (5) cabin heater (6) pump (7) one direction valve (8) regenaration.

When the vehicle is first started, comfort level should maintained until the water circulating in the system reaches 50 ℃. Cabin heating need is actually 3.5 kW, while nominal average use is 2.28 kW. The results of physical measurements show, as stated before, that 492.8 W of 2.1 kWh usable waste heat can be used in 4.26 hours at driving speeds regulated according to ECE 98/69 standard. Regained waste heat corresponds to 21.7 percent of total cabin heating requirement.

## 3. Results and discussion

Battery capacity of the present electric vehicle is 28 kWh. Within the scope of this study, heating energy saved using the waste heat thanks to the new developed system is determined as 2.1 kWh. Accordingly, vehicle's distance range is increased by 7.5%. Current vehicle range of 100 km is increased to 107.5 km. Thanks to the added heat storage system, power for water heater is supplied from the electric energy that cannot be utilized for charging the battery during braking, not from the battery. This allows using 7.5% of braking energy for heating according to ECE 98/69 standard. Figure 9 shows the patent pending fixed temperature system using waste heat for electric vehicles developed in this study.

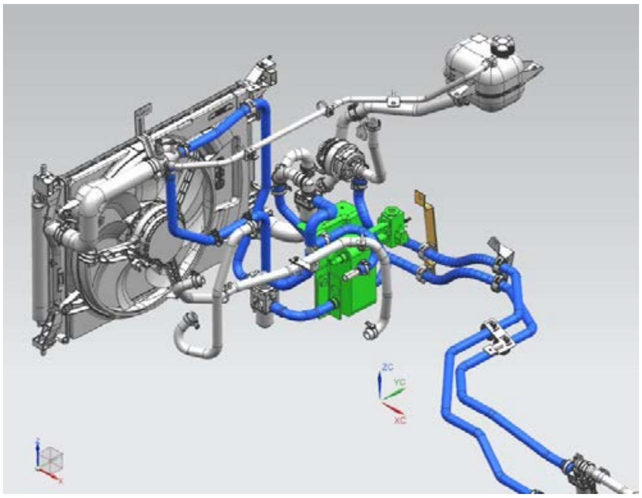

Fig. 9. Fixed temperature heating system using waste heat for electric vehicles.

## 4. Summary

Average waste heat of electric vehicles can be used for heating purposes. However, since waste heat amount is less than ICE vehicles, and does not allow a comfortable steady heating in varying speeds, it is not effective. In this study, we were able to store the excess heat electric engine generated during high speeds and provide heating temperature without using an additional heater. In order for heat to be stored and reused, a liquid that can melt and freeze at a fixed temperature, such as paraffin, is used. Regained waste heat can provide 21.7% of cabin heating requirement. Current vehicle range of 100 km is increased to 107.5 km.

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