



## ASPECTS OF CONSTRUCTION OF COMBINED THERMOSTATICS SYSTEM FOR ELECTRIC VEHICLE

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### ABSTRACT

Reasons for electric vehicles' low-appeal have been investigated within the present scientific article. Researches of electric vehicles within low-temperature duties' conditions have been analysed. Combined thermostatics system construction peculiarities are quoted by the example of VAZ-1817 (ELLADA), a series electric vehicle.

**Keywords:** vehicle, electric vehicle, hybrid vehicle, electric motor, energy efficiency, thermostatics, cooling system, heating up.

### INTRODUCTION

It is well known that today one of the ways to reduce hazardous substances emission from internal combustion engine (ICE) of motor vehicles (MV) into the atmosphere is a widespread implementation of electric vehicle in automobile industry [1; 2; 3; 4; 5; 6; 7; 8; 9; 10]. The fleet of electric vehicles constantly increases, but not rapidly enough, because there is a range of factors limiting their operation:

- the maximum electric vehicle mileage or number of kilometres travelled from a battery full charge to full discharge is less than that of a full-tanked ICE MV up to its full emptying;
- low energy density, heavy weight, limited service life and high cost of high voltage batteries;
- it is necessary to create an infrastructure for charging and maintenance of such vehicles;
- strict requirements or exactingness as to ambient temperatures.

One of the reasons preventing rapid expansion of electric vehicles is strict requirements for operating conditions under different climate and road conditions. At subzero temperatures and under severe climate conditions (snow-covered areas) the high voltage battery can partly discharge and fail to give sufficient amperage to ensure MV performance efficiency. Whereas at high environmental temperatures it is important to provide cooling of other electrical components (an electric motor, a converter, a vehicle-borne battery charger, a high voltage battery).

For instance, the German magazine named Auto Bild has run tests and discovered that cold weather reduces trip distance of an electric vehicle almost three times. Four out of five vehicles that participated in the test drive could run less than 70 kilometers after one recharge. These vehicles were BMW i3, Nissan Leaf, Renault Zoe and Mitsubishi i-MiEV. The only vehicle that could cover a

distance of 200 kilometers due to its capacious battery was the most expensive car participating in the test, Tesla Model S.

Test results:

- a) Tesla Model S, battery 85 kWh, declared trip distance 502 km, during winter test-drive 206 km
- b) Nissan Leaf, battery 24 kWh, declared trip distance 199 km, during winter test drive 69,1 km
- c) BMW i3, battery 21,6 kWh, declared trip distance 130-160 km, during winter test drive 61,4 km
- d) Mitsubishi i-MiEV, battery 16 kWh, declared trip distance 150 km, during winter test drive 61,3 km
- e) Renault Zoe, battery 22 kWh, declared trip distance 100-150 km, during winter test drive 58,9 km

It is obvious that electric vehicle design should provide for capability to maintain optimal operating conditions for each electric component.

For each of the components there are specific optimal temperature conditions:

- for most electric motors the limit temperature shouldn't exceed 100°C (the result of exceeding the acceptable temperature value is construction damage);
- for a converter and a vehicle-borne battery charger the limit temperature shouldn't exceed 60°C (the result of exceeding the acceptable temperature value is power loss and construction damage);
- optimal temperature for a high voltage battery ranges from 20°C to 40°C (if the battery is overheated there can be chemical damage and even inflammation, whereas at the environmental temperature below 0°C the battery cannot receive charge).



At the moment, in the Russian Federation and in other countries a lot of attention is paid to the issues of systems for cooling and heating up MV components [11; 12; 13; 14; 15], as this particular problem hinders active promotion of electric vehicles and MV with combined power installation (CPI).

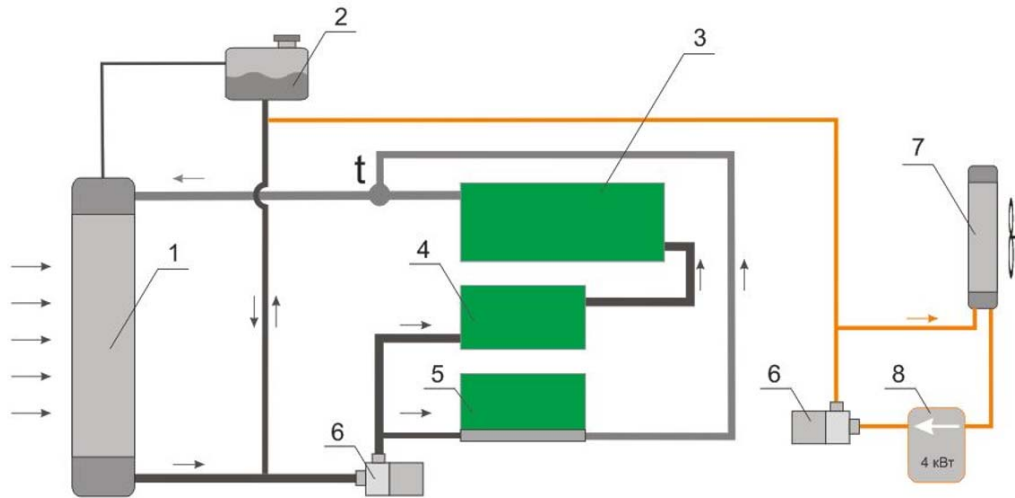
## RESEARCH METHODS

In the development of the combined circuit cooling systems use modern methods of calculation and

design of cooling systems using finite element. This method assessed the effectiveness of the cooling of electric components VAZ-1817 (ELLADA), which revealed weaknesses in the existing scheme.

## The main part

For example, Figure-1 shows principle diagram of a production electric vehicle VAZ-1817 (ELLADA) thermostatics [16].



**Figure-1.** Principle diagram of electric vehicle VAZ-1817 (ELLADA) thermostatics (1-main radiator, 2-expansion tank, 3- electric motor, 4-converter, 5-vehicle-borne battery charger, 6- pump, 7-heater radiator, 8-heater).

After analyzing the Figure it is apparent that supply of liquid to the converter (4) and the vehicle-borne battery charger (5) is performed in parallel, whereas supply of liquid to the electric motor (3) - consequently from the converter. Heat is rejected towards the radiator (1) which is blown over by the air flow during the electric vehicle run (fan is absent). Liquid circulation through the mentioned components is performed by the liquid electric pump (6) constantly at switch starting.

According to the results of analysis of the thermostatics principle diagram shown above it is possible to draw the following conclusions:

- it is impossible to control electric components temperature in this thermostatics system, neither jointly nor separately;
- it is impossible to maintain the electric components within the temperature range prescribed by the passport which can cause electric vehicle operation difficulties under different climate conditions;
- heating system is combined with electric components cooling system which can cause liquid circulation failure both in electric components heating as well as cooling circuit, while decreasing the sufficient volume

of cooling liquid can cause electric heater malfunction.

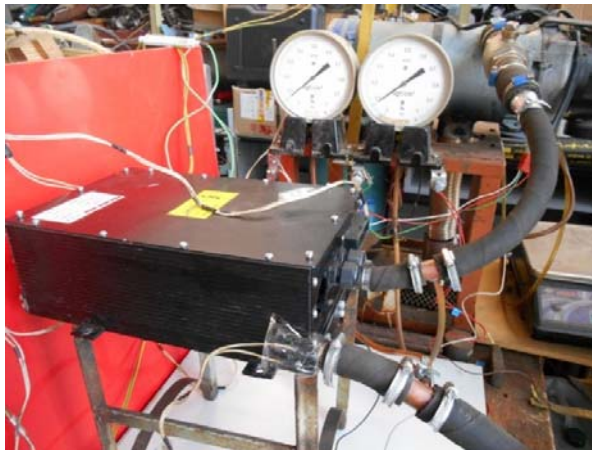
In order to perform a more thorough analysis of the cooling system, the vehicle was disassembled. The following electric power components were tested at the test bench: electric motor MES 200-250W3F (Figure-2), converter MES (Figure-3) and vehicle-borne battery charger EV POWERCHARGER (Figure-4). The interdependences were obtained between the heat medium flow and pressure difference in electric motor MES 200-250W3F (Figure-5), converter MES (Figure-6) and vehicle-borne battery charger (Figure-7).



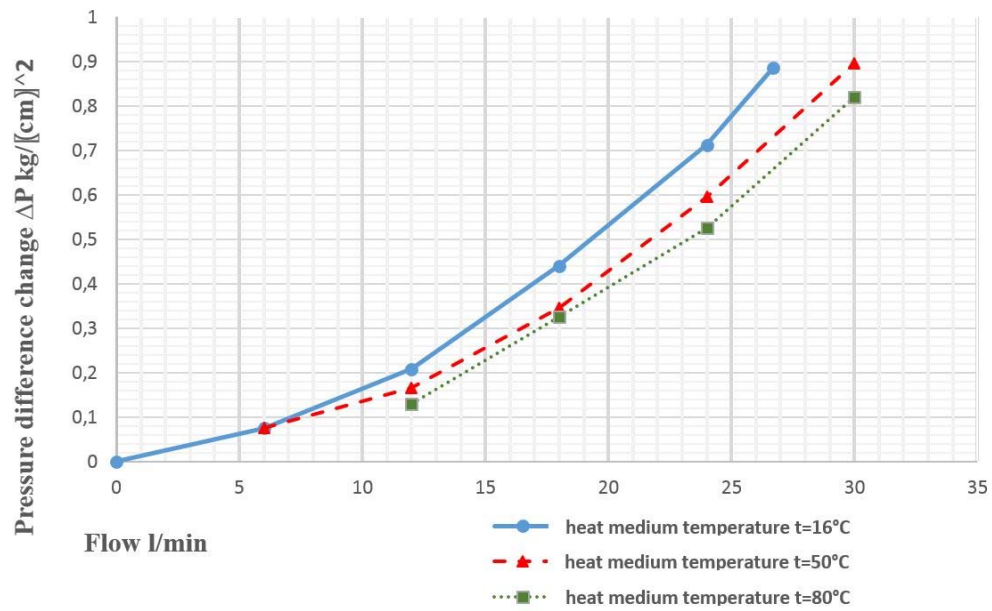
**Figure-2.** Electric motor MES 200-250W3F (30 kW).



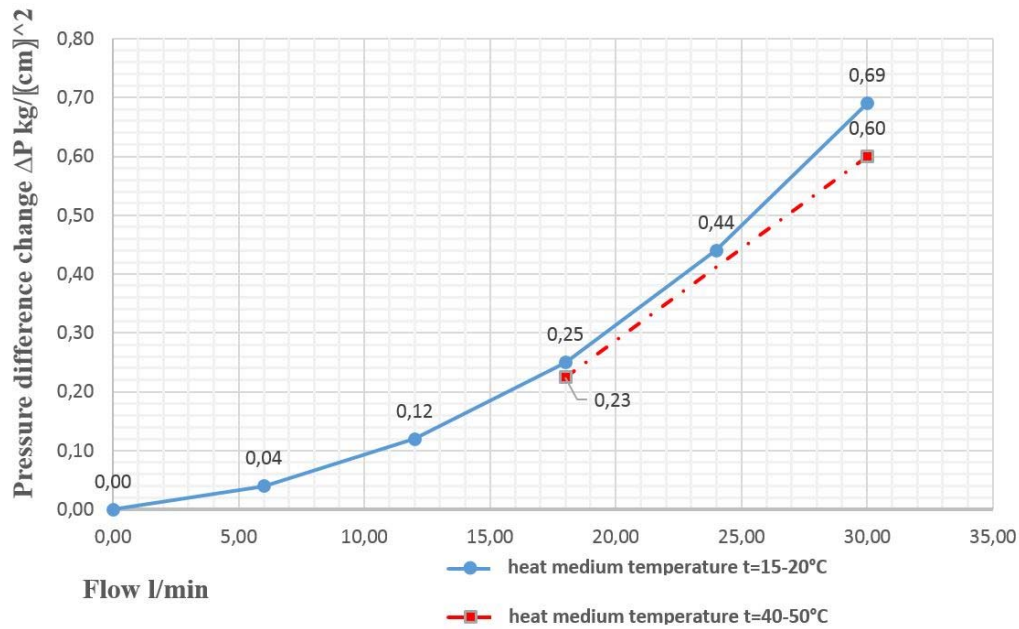
**Figure-4.** Vehicle-borne battery charger EV powercharger.



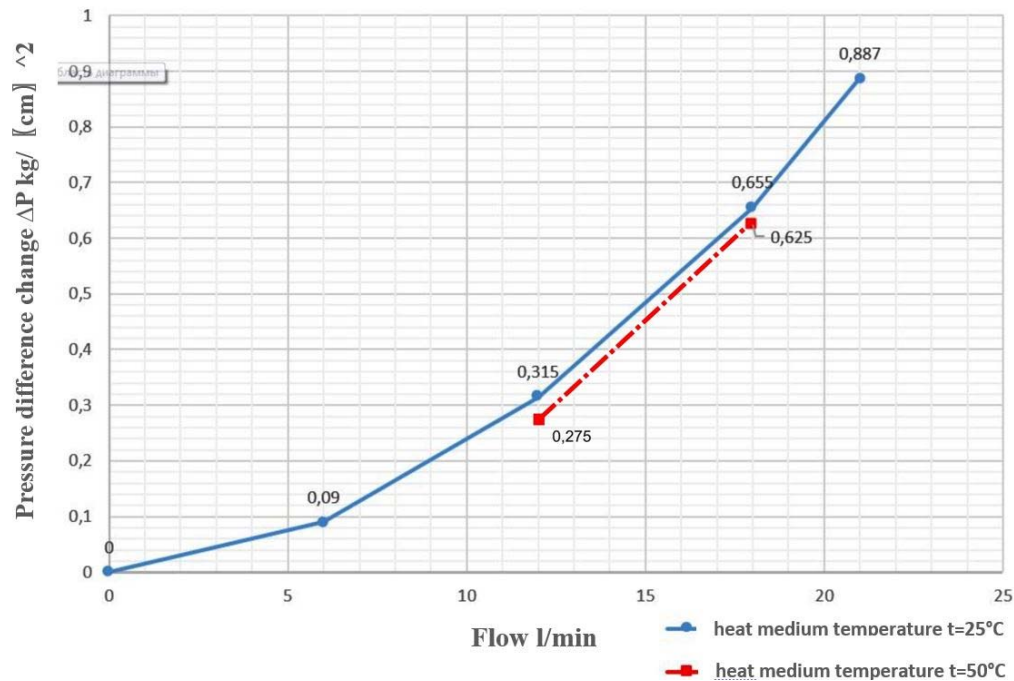
**Figure-3.** Converter MES.



**Figure-5.** Interdependencies of heat medium flow change on heat medium pressure and temperature difference in the cooling system for the electric motor MES 200-250W3F (30 kW)



**Figure-6.** Interdependencies of heat medium flow change on heat medium pressure and temperature difference in the cooling system for the converter MES



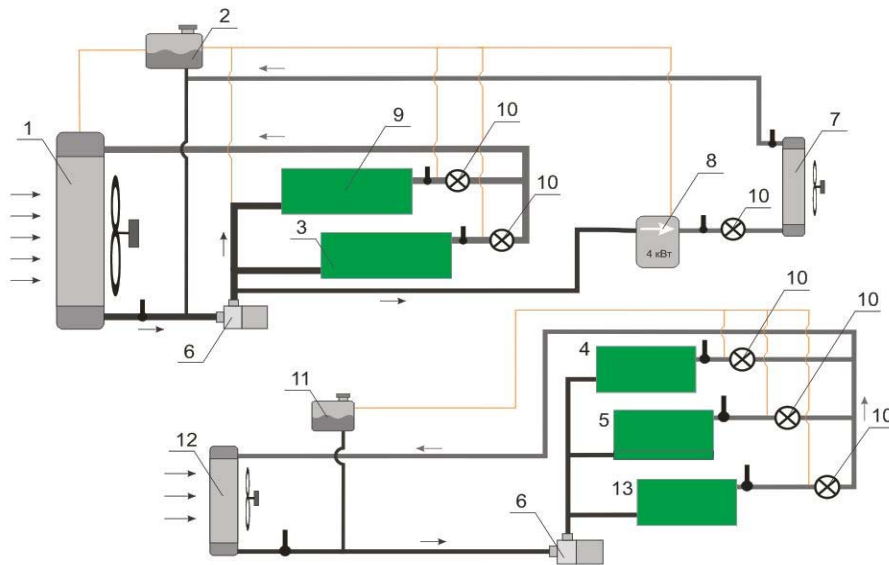
**Figure-7.** Interdependencies of heat medium flow change on heat medium pressure and temperature difference in the cooling system for the battery charger EV powercharger.

#### Possible solutions

Taking into account all the above mentioned disadvantages it is possible to suggest a new principle diagram of thermostatics for electric components of an electric vehicle. The main criterion is assurance of

performance efficiency and optimal output technical characteristics for electric components of electric vehicles. The specific feature of this diagram is that it has two independent cooling circuits.





**Figure-8.** Principle diagram of the combined thermostatics system for the electric vehicle VAZ-1817 (ELLADA) with Range Extender installation. (1-main radiator, 2-expansion tank, 3- electric motor, 4-converter, 5-vehicle-borne battery charger, 6- pump, 7-heater radiator, 8-heater, 9- Range Extender installation, 10-adjustable valve, 11- expansion vessel, 12-radiator, 13- high voltage battery).

In comparison to the previous diagram (Figure-1) the following components have been added: a liquid-air radiator, valves with remote adjustments, an expansion tank, a high voltage battery, a Range Extender installation. The first circuit includes an ICE cooling sub-circuit (in case of a MV with a Range Extender installation), an electric motor cooling sub-circuit and a starting preheater sub-circuit.

The first circuit consists of the following:

- a liquid-air radiator (1) with a fan providing heat rejection from the ICE (9) and the electric motor (3);
- a liquid electric pump (6) ensuring constant heat medium flow through the components;
- an electric liquid heater (8) at the heating system circuit
- three adjustable valves with electroproportional control (10) of heat medium flow efficiency;
- an expansion tank (2).

The second circuit consists of a converter cooling sub-circuit, a vehicle-borne battery charger cooling circuit and a sub-circuit of a high voltage battery block. Such diagram ensures maintaining the temperature conditions declared in the passport irrespectively of the power components and vehicle systems operation.

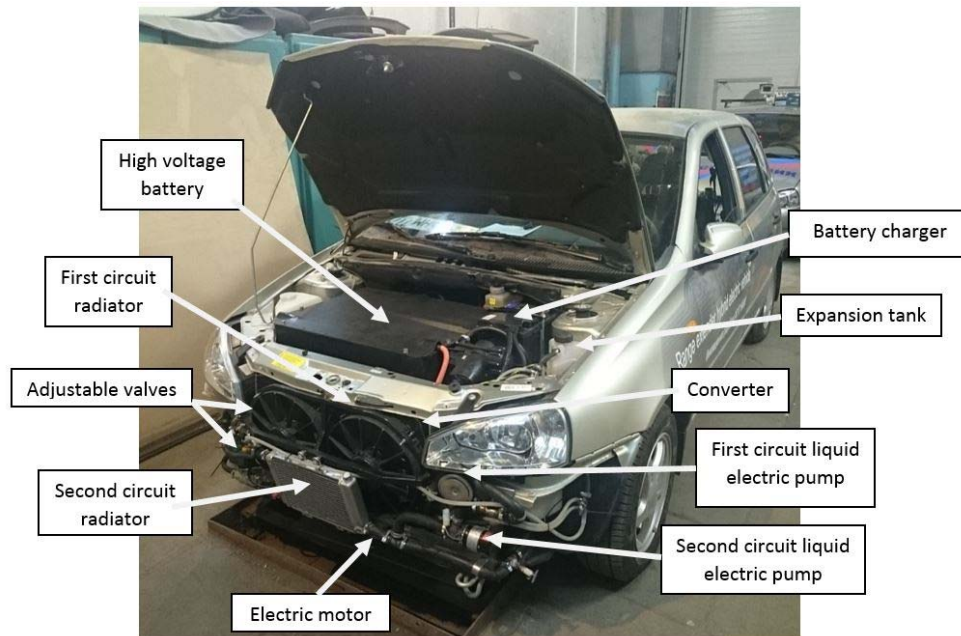
The second circuit consists of:

- a liquid-air radiator (12) with a fan providing heat rejection from converter (4), vehicle-borne battery charger (5) and high voltage battery (13);
- a liquid electric pump (6) ensuring constant heat medium flow through the electric components;
- three adjustable valves with electroproportional control (10) of heat medium flow efficiency;
- an expansion tank (11).

In both liquid circuits steam-water discharge points are located at the components output but before the adjustable valves with electroproportional control. Such connection scheme ensures constant minimum circulation of heat medium through the electric components. It is particularly important at the moment when the adjustable valve is fully closed, either by the control system or because of failure.

Adjustment of temperature conditions for the electric vehicle components is performed via changing liquid and air flows in each radiators circuit in automatic mode (within values declared by the passport).

The proposed diagram (Figure-6) was implemented in the electric vehicle VAZ-1817 (ELLADA). Layout for vehicle combined thermostatics system is shown in Figures 9 and 10.



**Figure-9.** Location of the components in the vehicle VAZ-1817 (ELLADA) (front view).



**Figure-10.** Location of the components in the vehicle VAZ-1817 (ELLADA) (rear view).

## RESULTS

On the example of vehicles developed by the new principles of the unified energy system on a single platform. Applied comprehensive technical and conceptual solutions to improve overall energy efficiency and to improve the performance of each component separately. The aim of this work is the rethinking of the established rules of design. The results obtained must be used on all types of vehicles, this will allow for technical and ideological level.

## CONCLUSIONS

The proposed diagram of the combined thermostatics system is applicable for any types of electric vehicles and ensures operation under any climate and road conditions. The introduced principles of temperature conditions control will allow optimizing temperature balance of all vehicle components and raise vehicle energy efficiency. Bench and road tests for determination and development of output thermotechnical characteristics for electric components and MV units should prove the efficiency of proposed combined thermostatics system diagram.



Within the framework of the study a Russian electric vehicle with Range Extender installation is being developed. Electric vehicle ELLADA manufactured by OJSC "AVTOVAZ" has been chosen as a basic vehicle. In further studies, it is planned to run tests in order to assess the efficiency of the proposed combined thermostatics system diagram.

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