

Reduction of Harmful Emissions During Start and Warming Up of the Engine

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Abstract: The question of decrease in harmful emissions when idling of a truck engine in the conditions of low temperatures is considered. The implementation of the thermogenerator for a power supply of electrical elements is offered in a design of the self-powered heater. The principle of the device operation is based on a thermoelectric effect at which there is heat absorption and thermo-EMF emergence. In a consequence of this process electricity is produced. The exhaust gases of the self-powered heater are the source of the absorbed heat and act as fuel for the thermogenerator. It allows developing energy for a power supply of electrical elements of the heater. It gives the chance not to start the engine for warming up during the long parking, thereby reducing harmful emissions.

1. Introduction

The number of the devices consuming the electric power in the vehicle rapidly grows. It concerns the increasing use in vehicles of navigation aids and video fixing, charging of portable mobile devices, complications of electronic systems of vehicles, etc. For trucks installation of the self-powered heater is very relevant for the heating of engine and salon during the parking. Installation of the heater also increases the number of the electric power consumers[1,2]. Additional consumers increase fuel usage during the trip and amount of the harmful substances (HS) emitted with exhaust gases (EG). Also the volume of harmful emissions in from trucks increases during the winter period because of long warming up before a trip to the working temperature of the engine and on the parking before loading/unloading, warm-up period depends on ambient temperature. Standard time of warming up is provided in the figure 1.

Structure of vehicle HS emitted with EG is multiunit. The greatest attention in the world [3] and in Russia in recent years is given to CO₂. So, according to the Transport strategy of the Russian Federation [4] the volume of CO₂ specific emissions on the motor transport has to be reduced on 22 percent.

For decrease in negative impact of vehicles on the environment it is offered to use thermoelectric modules (TEM), having implemented in a design of the self-powered heater (SPH). Their operation principle is based on a thermoelectric effect at which there is heat absorption and and thermo-EMF emergence. In a consequence of this process the electricity capable to supply the heater electrical elements is produced.



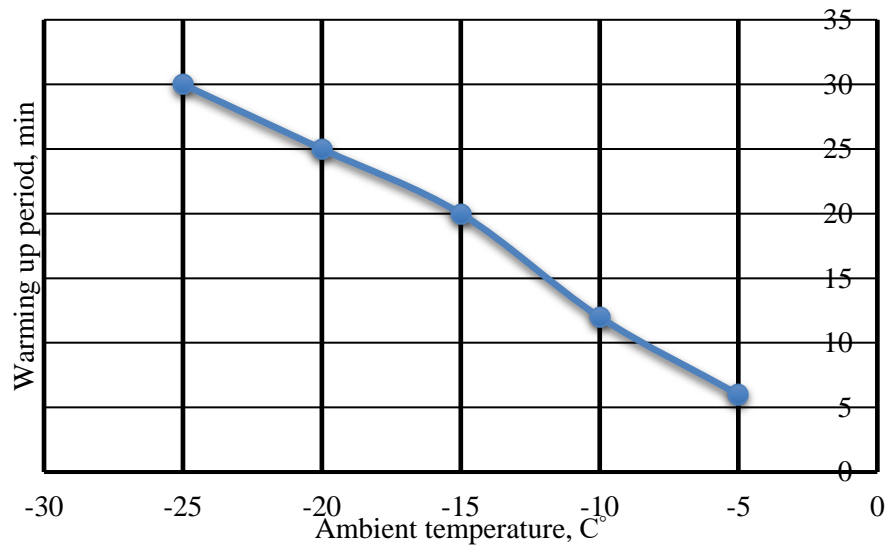


Figure 1. Warm-up period on not heated parking

TEM is a set of the thermocouples electrically connected, as a rule, in series (figure 2). In standard TEM thermocouples are located between two flat ceramic plates. Plates are made of oxide or nitride of aluminum. When a direct current passes through the TEM between its sides, a temperature difference forms. One side (cold) is cooled, and other (hot) heats up. If the efficient heat dissipation is provided from the hot side of TEM [5], for example, by means of a radiator, then on the cold side it is possible to receive temperature which will be lower than the ambient temperature by tens of degrees. The degree of cooling will be proportional to current level. In the presence of different temperatures on the different sides of TEM, it produces electricity.

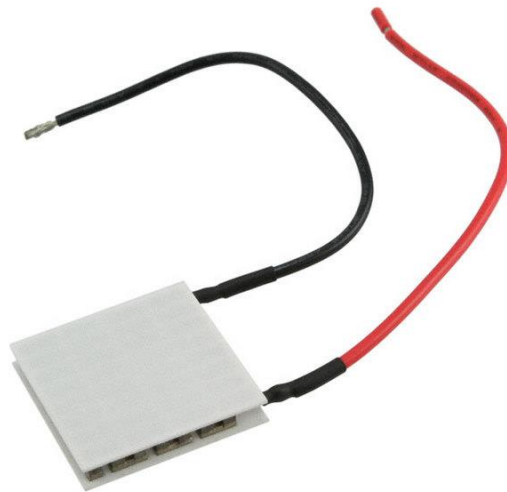


Figure 2. Thermoelectric module (TEM)

SPH is devices which serve for maintenance of optimum temperature condition in salon and preheat the engine before starting (figure 3). Their main feature is that they can function without the started engine. There are several modes of operation: standard ventilation and suction of air mix outside as well as heating the coolant. The external thermostat or the built-in timer is responsible for monitoring the operation. Heaters provide comfortable conditions for passengers, long-haul drivers, operators of the special equipment. Structurally the device is suitable for any vehicle and doesn't depend on dimensions

and assignment. The SPH is able to provide with warm air, as well as the small-capacity passenger car, and the huge truck and also is capable to warm the engine up to the working temperature by heating the coolant[5,6]. By means of the special control board it is possible to control the air temperature and a flow of its direction. In addition, the devices are divided according to the power supply principle. Electricity (12 and 24 volts), gas, diesel fuel or gasoline can be used as power supply [7]. Also there are models that heating cooling liquid of the vehicle which in turn heats the vehicle's interior. For a power supply of electrical elements of the heater it is offered to use TEM.



Figure 3. The principle of the self-powered heater operation

2. Methodology

It is offered to place TEM in the area with different temperatures (on one side of the module temperature higher, on the other is less) where it can produce the electric power. This feature allows to use TEM on surfaces with different temperatures for receiving the electric power [8,9]. Temperature of the EG in the heater is about 270 °C, this value is significantly higher than the ambient. Similar indicators allow to achieve a significant temperatures difference on the device. Implementation TEM in a design of the SPH, will allow using the heat of the EG and further to transform the existing temperatures difference to the electric power for the vehicle [10,11]. Thereby reducing harmful emissions, as there is no need to recharge the vehicle's standard battery (SB) without which the device can't function. Figure 4 shows the location of the TEM in the heater.

In an operating mode the TEM (Figure 4 № 17) will transform the heat of EG to the electric power for a power supply of the heater electrical elements. This makes the device autonomous and independent of the vehicle's on-board network. Table 1 describes the operating mode of the heater when it starts and the power sources are specified, depending on the cycle of operation. At the moment of start, the heater begins to consume current from the SB, this process takes 5 minutes, it is caused by the fact that at start of the heater, electricity consumption sharply increases (approximately three times), this energy is spent for heating of a heating plug [12,13]. Further the device passes into the warming up mode and switches to TEM from which the current to the heater is supplied. All remained operating time of the heater, consumption of current comes from TEM without the use of SB.

To determine the amount of CO₂ produced, an experiment was performed using the gas analyzer GARO AVG-4 (Figure 5). There are channels in the gas analyser for measuring the engine speed and the oil temperature [14,15]. The maximum measurement error for CO₂ is ±0.5%. The operating principle of the CO₂ volume fraction sensor is optical absorption.

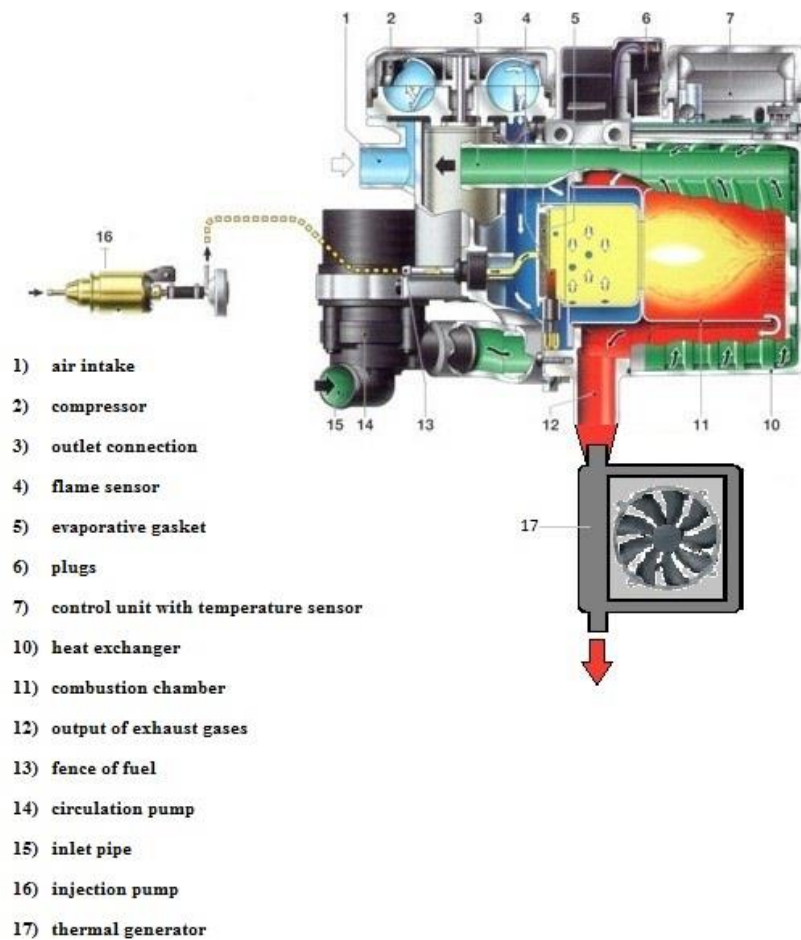


Figure 4. TEM location in the SPH

The instrument readings were recorded after steady-state values in the range of 15–30 seconds. The measurements were made on vehicles of brands: Freightliner, Volvo, MAZ. As SPH the Planar of 3 kW were used (Table 2).

Table 1. TEM operating mode

Power consumer			Power source	
Current intensity(A)	Electric potential (V)	Operation period(min)	Vehicle SB 55 Ah 12V	TEM 5A 12V
12	12	3	+	-
3.8	12	20	2 min SB+TEM	2 min SB+TEM
2.4	12	7	-	+
0.7	12	5	-	+

Table 2. Planar heater characteristics

Heat producing capability, kW	1 - 3
Fuel consumption, l/h	0.12 – 0.37
Heater input, W	10 – 42
Amount of heated air, m ³ /h	70 - 120
Fuel type	Diesel fuel
Operating supply voltage, V	12



Figure 5. Gas analyzer GARO AVG-4

3. Results and analysis

As a result of an experiment it was succeeded to find out that use of SPH during the long parking of the vehicle allows to reduce emissions of CO₂ on average by 10 times (Table 2). As the engine is in the muted state, and working temperature is maintained by the SPH.

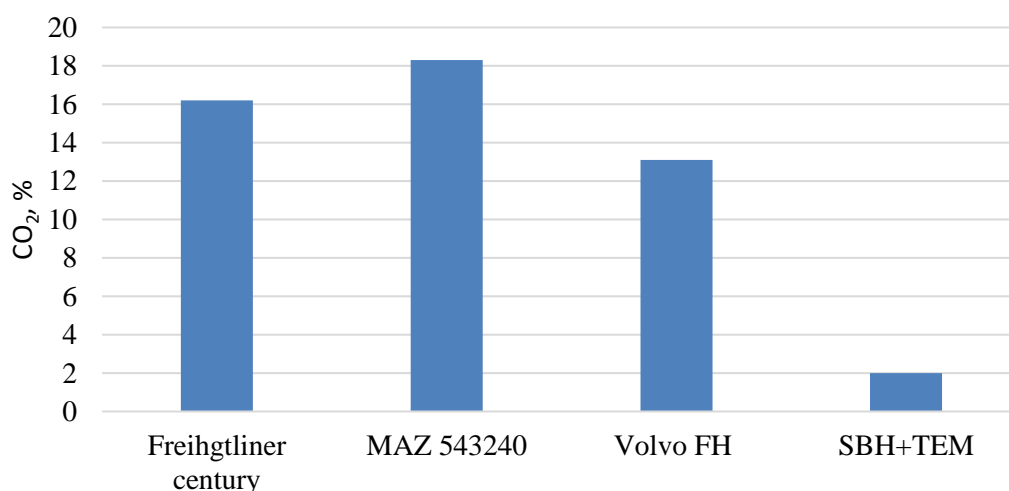


Figure 6. Amount of CO₂ in EG of trucks engines

Apparently from fig. 6 the greatest difference is reached on vehicles with a long service life. Considering that average age of the trucks park in Russia is 10.5 years [16], it is possible to draw a conclusion that in the conditions of the Russian Federation the TEM use will allow to give the maximum effect on decrease in CO₂ emissions. The last researches showed that in winter after start of the cold engine about 90% of all harmful emissions of CO₂ falls on time of the first kilometers of the movement. At start of previously warmed engine the content of harmful gases in an exhaust considerably decreases (by 5 times) therefore the use of the motor heater the in cold season has huge ecological effect. This indicator can still decrease by 1.5 times, at implementation in a design of TEM. The result is achieved because there is no need to start the engine during the long parking to recharge the batteries since their function was undertaken by the TEM.

4. Conclusions

As a result of the TEM installation it becomes possible to operate the SPH for a long time without starting the engine, at long parking under loading/unloading during the winter period. Engine start was necessary for recharge of SB, but with implementation of TEM in design this need disappears. Because of the closed system of power supply from TEM the period of operation is regulated only by a fuel quantity necessary for the heater. Thus, application of TEM in the independent heater will allow to receive the additional electric power and to use it for a power supply of electrical elements of the SPH, thereby reducing harmful emissions from the truck during the parking by 9 times.

References

- [1] Alim Nayum Christian A.Klöckner¹SunitaPrugsamatz², Influences of car type class and carbon dioxide emission levels on purchases of new cars: A retrospective analysis of car purchases in Norway // <https://doi.org/10.1016/j.tra.2012.10.009>
- [2] Anisimov, I., Ivanov, A., Chikishev, E., Chainikov, D., Reznik, L. Assessment of gas cylinder vehicles adaptability for operation at low ambient temperature conditions // *WIT Transactions on Ecology and the Environment*, 190 volume **1**, pp. 685-695, 2014, doi: 10.2495/EQ140651.
- [3] Bekir SamiYilbas^{ab}S.S.Akhtar^aA.Z.Sahin^{ab}, Thermal and stress analyses in thermoelectric generator with tapered and rectangular pin configurations // <https://doi.org/10.1016/j.energy.2016.07.168>
- [4] Bielaczyc, P., Szczotka, A., and Woodburn, J. Regulated and Unregulated Exhaust Emissions from CNG Fueled Vehicles in Light of Euro 6 Regulations and the New WLTP/GTR 15 Test Procedure // *SAE International Journal of Engines – Volume 8*, Issue 3, pp. 1300-1312, 2015, doi: 10.4271/2015-01-1061.
- [5] Bondarenko, E.V., Filippov, A.A. Evaluation of use of certain types of motor fuel for environmental safety criteria // *Autogas filling complex + alternative fuel – 4* (**52**), pp. 31-35, 2010.
- [6] Baranov E.F., Bugakova N.S., Gelvanovsky M.I., Gohberg L.M. Russian Statistical Yearbook 2016 729 pages // http://www.gks.ru/free_doc/doc_2016/year/year16.pdf (accessed September 4, 2017).
- [7] Chainikov D., Chikishev E., Anisimov I., Gavaev A. Influence of ambient temperature on the CO2 emitted with exhaust gases of gasoline vehicles Innovative Technologies in Engineering VII International Scientific Practical Conference. Conference Proceedings. National Research Tomsk Polytechnic University. 2016. C. 12109.
- [8] GOST R 41.24-2003 (Regulation № 24) Uniform provisions concerning: I. The approval of compression ignition (C.I.) engines with regard to the emission of visible pollutants; II. The approval of motor vehicles with regard to the installation of C.I. engines of an approved type; III. The approval of motor vehicles equipped with C.I. engines with regard to the emission of visible pollutants by the engine; IV. The measurement of power of engines – M.: Standartinform, 36 p., 2007.
- [9] HulinZhang^aYuhangXie^aXiaomeiLi^aZhenlongHuang^aShangjieZhang^aYuanjieSu^aBoWu^aLongHe^aWeiQingYang^bYuanLin^a, Flexible pyroelectric generators for scavenging ambient thermal energy and as self-powered thermosensors // <https://doi.org/10.1016/j.energy.2016.02.002>
- [10] Ling-YunHE^{abc}Lu-YiQIU^{d1}, Transport demand, harmful emissions, environment and health co-benefits in China // <https://doi.org/10.1016/j.enpol.2016.07.037>
- [11] Statistics of harmful emissions CO2 time series 1990-2014 per region/country// <http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2014&sort=des9> (accessed September 4, 2017).
- [12] Transport Strategy of the Russian Federation for the period up to 2030, https://www.mintrans.ru/documents/detail.php?ELEMENT_ID=22371&list=41307,39859,32563,22371,20611,19188,13008,13026,13016,13028 (accessed September 4, 2017).
- [13] Karnaukhov N.N., Reznik L.G., The differentiated correction of charge for air pollution // *Advances in transport*, Volume **16**, pp. 701-705, 2004, doi: 10.2495/UT040681.
- [14] Volkov N.A., Chaynikov D.A. Transformation of the engine's thermal losses into electric energy

- for the automobile // International Scientific and Practical Conference of Young Researchers named after Yu. DI. Mendeleev conference materials. Tyumen Industrial University, Institute of Industrial Technology and Engineering. 2016. P. 444-447.
- [15] Volkov N.A, Chainikov D.A. Conversion of heat loss engine electricity for car // In the collection: International Scientific and Practical Conference of Young Researchers. DI. Mendeleev conference materials. Tyumen Industrial University, Institute of Industrial Technology and Engineering. 2016. P. 444-447.
- [16] Volkov N.A. Improvement of the start process of the engine in the conditions of low temperatures and development of the technology of application of thermoelectric modules for increasing the autonomosity of the pre-heater worker // In the collection: Transport and transport-technological systems materials of the international scientific and technical conference. 2017. P. 102-106.