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RATIONAL POWERS OF THERMOGENERATORS FOR STARTING PRE-HEATERS OF VEHICLES

The main technical characteristics of starting pre-heaters for different kinds of vehicles are given. The electric parameters of thermogenerators necessary for the autonomous operation of such pre-heaters and the opportunities of power supply to other automobile equipment, including battery recharge, are defined.

Key words: starting pre-heater, thermoelectric generator.

Introduction

At the present time, the problem of startup of internal combustion engines of vehicles at low ambient temperatures is solved by using starting pre-heaters commercially produced by a number of companies, namely Eberspächer, Webasto, Truma (Germany), Ateso (Czech Republic), Teplostar (Russia), Mikuni (Japan). Such pre-heaters run on different kinds of fuel and are used in the cars, trucks, buses, yachts and boats [1 – 6].

Depending on application, there are air pre-heaters for heating of cabins and compartments of vehicles and liquid pre-heaters, which, in addition to heating, assure preliminary warm-up of internal combustion engine. Liquid pre-heaters are more efficient, as long as start heating of internal combustion engine assures its reliable startup and essential reduction of fuel consumption during the first kilometers of automobile trip. It is also important to reduce harmful emission to environment at automobile engine startup, since today the European Union standards, apart from total norm of emission for heated engine already regulate the amount of emission at its startup. It is established that the use of start heating can increase engine service life by 50-60 thousand km per year and reduce emission of toxic substances by a factor of 5, saving 90 – 150 l of fuel during one winter season. Moreover, comfortable conditions assured by start heating of automobile exclude completely the possibility of accidents because of the influence of cold on the driver [7].

Nevertheless, despite wide opportunities, starting pre-heaters have not found wide use yet, in particular, on the cars and minibuses. Even in the Nordic countries autonomous starting pre-heaters are installed only on one of thousand automobiles. One of the main reasons for this is a need in electric energy for power supply to heater components: fuel pump, fan for air delivery to combustion chamber, circulation pump for pumping of liquid heat carrier. Preliminary studies have shown that in operation of liquid heater with thermal power 4 kW and electric power consumption 60 W, a battery with capacity 60 A·hour within 4.5 hours will lose 50% of capacity. This leads to battery discharge and creates essential difficulties at engine startup [8].

The problem defined above can be solved through use of a thermoelectric generator which operates from the heater and supplies power to its components. Moreover, the excess electric energy of thermal generator can be used for battery recharge and power supply to other automobile equipment (standard

heating fan, warning systems, etc) [8 – 10]. Under these conditions, a relevant task is to create general-purpose thermoelectric converters that that would not only assure independent operation of each heater type, but would also find wide application as additional source of electric energy in different kinds of vehicles.

So, the purpose of this paper is to determine the electric characteristics of thermoelectric generators (TEG) for start heating of vehicular engines at low ambient temperatures.

TEG for liquid starting pre-heaters

In Table 1 are listed technical characteristics of liquid starting pre-heaters that are used for the preliminary warm-up of vehicular engines.

Table 1

Technical characteristics of liquid starting pre-heaters for vehicles

Manufacturer	Model	Fuel	Maximum thermal power, kW	Electric power requirement, W	Vehicle type
Webasto [1]	Thermo Top Evo 4	diesel	4	35	With engine displacement up to 2.5l. (compact and subcompact cars)
		petrol			
	Thermo Top E	diesel	4	36	
		petrol			
Eberspächer [2]	Hydronic 4W SFL	diesel	4.3	35	
		petrol			
	Hydronic 4W SC	diesel	4.3	48	
		petrol			
Webasto [1]	Thermo Top Evo 5	diesel	5	47	With engine displacement 2.5 – 4 l (medium and executive cars, off-road vehicles, microbuses)
		petrol			
	Thermo Top C/P/Z	diesel	5.2	40	
		petrol			
	Thermo Pro 50	diesel	5.2	46	
		petrol			
Eberspächer [2]	Hydronic 5W S	diesel	5	53	
		petrol			
	Hydronic 5W SC	diesel	5	50	
		petrol			
Teplostar [5]	Binar 5	diesel	5.5	70	
		petrol			
	Binar 5-SV	diesel	5	45	
		petrol			
Webasto [1]	Thermo Pro 90	diesel	9.1	90	With engine displacement 4 – 10 l (buses, freight transport, motor homes, custom vehicles)
		petrol			
	Thermo Pro 90 ST	diesel			
		petrol			

Table 1(continued)

Eberspächer [2]	Hydronic D 8 W	biodiesel	8	80	With engine displacement 4 – 10 l (buses, freight transport, motor homes, custom vehicles)
	Hydronic D 10 W	diesel	9.5	86	
			12	120	
Hydronic M		9.5	125		
Teplostar [5]	14TC-10-12	diesel	12	100	
	14TC-10		15	132	
	15TCГ	natural gas	12	128	
Webasto [1]	DBW 160	diesel	16	204	With engine displacement more than 10 l (freight transport with carrying capacity more than 10 t, trains, locomotives)
	DBW 230		23	214	
	DBW 300		30	204	
	DBW 350		35	195	
	NGW 300	natural gas	30	214	
	LGW 300	propane-butane		204	
	Thermo 230	diesel	23	169	
	Thermo 300		30	214	
Thermo 350	35		244		
Eberspächer [2]	Hydronic L 16	diesel	16	164	
	Hydronic L 24		24	184	
	Hydronic L 30		30	209	
	Hydronic L 35		35	224	
Teplostar [5]	20 TS	diesel	20	200	
	20 TS-D38		20	210	

From Table 1 it follows that autonomous operation of starting pre-heaters of thermal power 4 kW for vehicles with engine displacement up to 2.5 l requires on the average 40 W of electric energy (power supply to air fan, fuel and circulation pumps, electronics 13.0; 12 – 14; 16; 0.5 – 1.0 W, respectively); ~50 W of electric energy for heaters of vehicles with engine displacement 2.5 – 4 l. For liquid starting pre-heaters used in vehicles with engine displacement 4 – 10 and more than 10 l the electric power of thermogenerators should be about 100 W and 200 W, respectively.

Apart from power supply to starting pre-heater components, thermoelectric generator can be also used as additional electric energy source for vehicle itself, in the first place for power supply to a standard fan of heating system. For instance, to warm up passenger compartment of cars and trucks, jeeps and minibuses, one should connect a 15 – 30 W standard fan of heating system. If part of electric energy (15 – 20 W) is provided for battery recharge, then total electric power output of thermal generator for vehicles with engine displacement up to 4 l should be 70 – 90 W, and for vehicles with engine displacement 4 – 10 l and more than 10 l it should be 130 – 150 W and 230 – 250 W, respectively.

TEG for air starting pre-heaters

In some cases the use of liquid starting pre-heaters is impossible (automobiles with air cooling of engine) or unreasonable – for instance, for heating of bus passenger compartments, sailboat cabins,

truck cabins during parking and camping. For such cases, autonomous air heaters of passenger compartments are created, whose technical characteristics are given in Table 2.

Table 2

Technical characteristics of air starting pre-heaters for vehicles

Manufacturer	Model	Fuel	Maximum thermal power, kW	Electric power requirement, W	Vehicle type
Webasto [1]	Air Top 2000 ST	diesel	2	29	With passenger compartment (cabin) volume up to 5 m ³ (microbuses, custom vehicles, cars and freight transport, trailers, small boats).
		petrol			
Eberspächer [2]	AIRTRONIC	diesel	2.2	34	
			3	24	
Teplostar [5]	PLANAR-4DM	diesel	3	42	
Truma [4]	Trumatic E2400	propane-butane	2.4	20	
	Trumatic E4400	propane-butane	3.7	30	
Ateso [6]	Breeze III	diesel	2	35	
		biodiesel			
Webasto [1]	Air Top Evo 3900	diesel	3.9	40	
		petrol			
	Air Top Evo 40	diesel	4	40	
		petrol			
Eberspächer [2]	AIRTRONIC M	diesel	3.8	40	
		petrol	4	40	
Teplostar [5]	PLANAR-44D	diesel	4	62	
Pramotronic [11]	Pramotronic-4D	diesel	4	40	
Ateso [6]	Wind III	diesel	3.8	40	
Webasto [1]	Air Top Evo 5500	diesel	5.5	95	
	Air Top Evo 55	petrol			
	HL9	diesel	9	110	
Eberspächer [2]	AIRTRONIC L	diesel	5.5	80	
		petrol			
	AIRTRONIC D8LC	diesel	8	115	
Teplostar [5]	PLANAR-8DM	diesel	7.5	90	
Ateso [6]	X-7	diesel	8.2	100	

As is evident from Table 2, for vehicles with passenger compartment (cabin) volume up to 5 m³ air heaters of thermal power 2 – 3 kW are overwhelmingly used. In so doing, their autonomous operation

requires on the average 35 W of electricity. Air heaters used in the vehicles with passenger compartment (cabin) volume 5 – 8 m³ and more than 8 m³ consume ~ 40 W and 100 W of electric energy, respectively. If another 20 – 30 W is provided for battery recharge and other requirements (for instance, power supply to on-board control panel, warning systems), total electric power output of thermal generator for air starting heaters will be about 50 – 70 W for the volume up to 8 m³ and 130 – 150 W for vehicles with passenger compartment (cabin) volume more than 8 m³. It is noteworthy that in case of air starting pre-heaters there is no need in power supply to standard vehicle heating fan, as long as hot air is fed to compartment by heater fan of its own.

TEG for start heating of ambulance cars

Among special-purpose vehicles, ambulance cars are especially noteworthy. It is due to the fact that start heating in the first place provides for temperature conditions in vehicle passenger compartment necessary for patient transportation.

According to international EN1789 and the National Standard of Ukraine DSTU 7032: 2009, ambulance cars are divided into three main classes [12, 13]:

“A” class vehicles are intended exclusively for patients that do not call for urgent help during transportation. Therefore, in such vehicles a set of medical equipment is minimum, namely medicines, bandaging materials, oxygen inhaler and bronchial aspirating means.

“B” class vehicles are intended for short-distance transportation of patients with a simultaneous emergency medical treatment. Vehicles of this class are stocked with the necessary equipment for intensive therapy and reanimation, namely oxygen-breathing, defibrillator, with a mandatory availability of cardiograph.

“C” class vehicles – reanimation ambulance cars – are intended for rendering aid to very ill patients: intensive therapy and reanimation by the efforts of medical team. Medical equipment is similar to that in “B” class ambulance cars.

Table 3

Electric power of medical equipment of B and C class ambulance cars

Medical equipment	Model	Electric power, W
Defibrillator	PRIMEDIC DEFI-B [14]	20
	PRIMEDIC XD [14]	18
	MASTER IC-9000A [15]	24
	DKI-N-04 [16]	22
	Cardio-Aid 200 [17]	21
Cardiograph	Heart Screen 80 GL [18]	18
	ECG-101 G [19]	22
	Cardipia 800 [20]	15
	Ucard 100 [21]	15
	EK 12T-01 «P-Д» [22]	10
	Heaco 300 G [23]	27
Artificial respirator	A-IVL/VVL-TMT [24]	12
	DAR-200 [24]	10
	Sirio S2T [25]	5
	Fasa-5-01 [26]	9.5

Table 3 lists the electric powers of some medical equipment models stocked for “B”, “C” class ambulance cars according to requirements of DSTU 7032: 2009.

Thus, the electric power requirement of the necessary minimum of medical equipment stocked for ambulance cars is 45 – 55 W.

Moreover, the above standards establish the requirements to temperature conditions in passenger compartment and power supply to medical equipment for all classes of ambulance cars [3, 4]:

Temperature conditions:

- the temperature in compartment should be at least 20°C. The time of reaching the temperature in compartment should not exceed 30 minutes at the ambient temperature -25°C and 60 minutes at -40°C.

- medical compartments of “B” and “C” class ambulance cars should be equipped with air conditioning system that must provide for air temperature reduction by 10°C within at least 30 minutes at ambient temperature 40°C.

- thermostatic control of heating system must assure temperature variation not more than $\pm 5^\circ\text{C}$.

Power supply:

- “B” and “C” class ambulance cars should be equipped with a start battery (12V, 80A·h) and supplementary battery (12V, 63 A·h) for power supply to medical instruments;

- a system that allows power supply from external grid 220V for medical equipment of corresponding voltage and batteries discharge during parking is a mandatory requirement;

- “B” and “C” classes must be stocked with voltage converter 12/220V for power supply to medical equipment of voltage 220 V and power from 250 to 500 W;

- vehicle electric system must be adapted for storage of electric energy necessary for resumption of engine operation.

On the whole, total electric energy requirement of equipment used for ambulance car, with regard to lighting (20 – 30 W), ventilation (3 – 5 W) and vehicle heater (30 – 40 W) is 140 – 150 W.

With intensive operation of ambulance car for 4–5 hours, the capacity of start and supplementary batteries is reduced by about 40 – 50 %. This not only creates difficulties of engine starting, but also impairs efficient operation of ambulance cars in general.

So, the use of thermoelectric generator for autonomous start heating of ambulance cars and additional power supply to medical equipment is particularly promising and relevant.

Moreover, the use of such sources of heat and electricity will provide for heating of passenger compartment and battery recharge with an idle engine or at parking place, which is necessary to perform the functions of ambulance cars and their reliability enhancement.

Conclusions

1. It is shown that total electric power of thermal generator for starting pre-heaters of vehicles with engine displacement up to 4 l should be 70 – 90 W, for vehicles with engine displacement 4 – 10 l and more than 10 l – 130 – 150 W, 230 – 250 W, respectively. Such electric powers of thermal generator will provide for not only autonomous operation of starting pre-heaters, but also allow power supply to standard vehicle heating fan and battery recharge.
2. It is established that total electric power output of thermal generator for air starting heaters used in the vehicles with passenger compartment (cabin) volume up to 8 m³ should be within 50 – 70 W and 130 – 150 W for vehicles with the volume more than 8 m³. Apart from autonomous operation of air heater components, the excess electric energy of thermal generator can be used for battery recharge and power supply to other automobile equipment (on-board control panel, warning systems).
3. For ambulance cars the use of starting pre-heater allows creating the necessary temperature

conditions in the passenger compartment. The use of a 60 – 90 W thermoelectric generator will assure autonomous operation of such heaters and additional power supply to the necessary minimum of medical equipment in the cars (cardiograph, defibrillator, artificial respirator). Moreover, the use of such combined heat and electricity sources will assure heating of passenger compartment in a car and allow recharging of supplementary and starter batteries with an idle engine or at parking places.

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