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Thermoelectric Generator and Cooler Operated Fog Removal System For Automobile: A Review

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Abstract

The problem of vehicle window dewing not only affects the occupants' comfort in the vehicle, but also interferes with the driver's sight and potentially threatens the safety of driving as well as electronic equipment in the vehicle. Fog is a natural weather condition that can cause visibility to become zero. Now a day the air conditioners are very efficient and reliable but it has some demerits. According to International Institute of Refrigeration, air conditioning and refrigeration consumes around 15% of the total worldwide electricity and also contributes to the emission of CFCs, HCFCs, CO_2 etc. Due to the use of such refrigerants it leads to much harmful effect to our environment i.e. the global warming. For air conditioning use of fuel also increases and all these are affects on the car efficiency. To overcome the problem of emission and fulfill the mismatch between the demand and supply of energy consumption the thermoelectric Air conditioning can be used. This system is not going to be noisy, a there will be no hazardous emission to the environment so the system is totally eco friendly. As the Peltier module is quite compact in size the design can be easily acquired according to space and need.

Keywords−− Vehicle window dewing, Fog, Thermoelectric air conditioning, Eco friendly system, Peltier module

I. INTRODUCTION

A thermoelectric module is an electrical module, which produces a temperature difference with current flow. The emergence of the temperature difference is depending on the peltier effect designated after Jean Peltier. The thermoelectric module is a heat pump and has similar function as a refrigerator. It gets along however without mechanically small construction units (pump, compressor) and without cooling fluids. The heat flow can be turned by reversal of the direction of current. Thermoelectric cooling provides an alternative solution to the common compressor and absorber cooler. Thermoelectric coolers are used especially if small cooling power is required up to 500 W. The thermoelectric technology can be divided into two categories according to the seebeck effect and peltier effect respectively I. Thermoelectric

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generator for power generation when the two materials are exposed in different temperature, ii. Thermoelectric cooler for cooler for cooling when the voltage is added onto two materials.

Our goal is to define the new Heating Ventilation and Air Conditioning (HVAC) system using thermoelectric couple which shall overcome all the drawback of current HVAC system. If this system comes in present HVAC system, then revolution will occur in the automobile. With rising population and pollution at an alarming rate this system has come to rescue as these are environment friendly and compact. Conventional compressor run cooling equipment has more limitations related to energy efficiency and Chloro-Fluro Carbon (CFC) refrigerants use. Both these factors indirectly point to the impending scenario of global warming. As most of the electricity generation relies on the coal power plants, which add greenhouse gases to the atmosphere is the more cause of global warming. Although researches are going on, best alternatives for the CFC refrigerants is still on the hunt. So instead of using conventional air conditioning systems, other products which can efficiently cool a person are to be planned. By using other efficient cooling device, we can save the electricity bills as well as control the greenhouse gases that are currently released into the surrounding atmosphere. Although thermoelectric property was discovered about two centuries ago thermoelectric device save only been commercialized during current years. The applications of thermoelectric vary from small refrigerator.

II. LITERATURE SURVEY

Yue Yang et.al [1] studied Optimization of the automotive air conditioning strategy based on the study of dewing phenomenon and defogging progress. The problem of vehicle window dewing not only affects the occupants' comfort in the vehicle, but also interferes with the driver's sight and potentially threatens the safety of driving as well as electronic equipment in the vehicle. This study focuses on the process of condensation and defogging in the cabin of a truck model, where the outside heat dissipation and internal air conditioning system are considered together. By examining various conditions of the air inlet mode, temperature, humidity and speeds of the ventilation system, it was found that the mass flow rate, inlet temperature and humidity could influence the dewing film thickness directly. Dewing is a very common phenomenon, as it refers to vapor condensing on the surface of an object when the temperature is lower than a critical (dewing) point. In engineering applications, it can potentially cause severe hazards. Similar to human beings, vehicles are also severely affected by dewing problem in the cabin. Dews on the vehicle windows would not only influence the sight of the driver, potentially leading to a traffic accident, but also increase the humidity inside the vehicle, affecting the comfort of occupants. With the increasing number and complexity of electronic devices in vehicles, which are sensitive to the humidity and temperature, the vehicular control system can also be affected by dewing problem. To deal with the dewing problem, three primary methods have often been discussed: changing the ventilation condition, raising the window surface temperature and using anti-fogging materials. Controlling the air conditioning system appears to be the most widely used method of defogging, despite energy consumption. This paper has numerically studied the dewing phenomenon and defogging progress of a truck cabin model. The study was focused on the dewing phenomenon of a truck cabin, where the heat dissipation of window glasses was considered by simulating the

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external flow field. A total of 33 different working conditions with different temperature and relative humidity of air-condition system flow velocities were simulated to better understand the development of dewing film. The defogging airflow was also discussed with different flow velocities to evaluate the defogging performance. It was found through the external flow velocity field, the convective heat transfer coefficient of the front window was higher than that of the side and back windows. Low cabin temperature affects the occupants' thermal comfort, whereas high temperature will increase the content of water vapor in the cabin, thereby worsening the problem of condensation.

Mingjian Liao et.al [2] studied A three dimensional model for thermoelectric generator and the influence of Peltier effect on the performance and heat transfer. This study explains a new complete thermoelectric generator model consist of 127 thermocouple has been developed and laboratory TEG system has been built to verify the accuracy of the model. The open circuit model, internal resistance maximum output power has been studied by numerical simulation and experiment. It has ability to generate electricity from waste heat therefore it more attracting and more attention. It has more advantages such as no moving parts, no chemical reaction, no pollution, no noise and a longer lifespan. TEG generates a voltage when there is a temperature gradient. It used to recover the energy in many processes in which heat is directly released to atmosphere. It recognized one of the most potential technologies in the 21^{st} century. In early attempt using single thermocouple the numerical and experimental results are compared .it indicated that temperature dependence property of material have significant impact on calculation results. The power output and the efficiency are related leg size and spacing of the thermocouples. The output power increases parabolic ally with increases of the temperature gradient between the two sides of generator. The influence of the peltier effect on the effective temperature difference is limited when the temperature at the boundary is constant. The load resistance and the internal resistances are inconsistence when the output power of TEG reaches the maximum. This paper gives us the idea about that, how to improve the performance of peltier plate by providing different dimensional fins on the TEG.

Wei He, Gan Zhang et.al [3] studied Recent development and application of thermoelectric generator and cooler. This paper explains the basic concepts of the thermoelectric module and discusses its recent material researches about the figure of merit. It also reports the recent applications of the thermoelectric generator, including the structure optimization which affects the TEG, the low temperature recovery, heat resource and its heat resource and its application area. Then it reports the recent application of the thermoelectric cooler including the thermoelectric model and its application area. The thermoelectric technology can be divided into two categories according to the seebeck effect and peltier effect respectively I. Thermoelectric generator for power generation when the two materials are exposed in different temperature, ii. Thermoelectric cooler for cooler for cooling when the voltage is added onto two materials. This review provides discussion of recent researches of the Thermo electric materials and their practical applications. This research work would help to illustrate the foundation and new directions in thermo electric technology. Experiment results shows that with varying thermal conditions, power output behaves exponentially relative to temperature. The BiTe (Bismuth Tellurium) based materials which one has the best prospective of ZT in room temperature is widely used in TE devices. It is observed that

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higher ZT is, the better the material is. For TEG, the temperature plays a significant role for TEG applications. For TEC, the COP is a significant parameter to evaluate the performance of cooler.

Lin Lin, Zhang et.al [4] studied A new configuration design of thermoelectric cooler driven by thermoelectric generator. This paper explains the new design configuration of thermoelectric cooler and thermoelectric generator. This paper related to the design configuration of TEG-TEC. The series electric current configuration between TEG-TEC leads to low cooling capacity and small temperature drop across thermoelectric cooler. To overcome this problem, a two stage configuration is developed. The new design is combining of TEG-TEC. The three dimensional thermoelectric model is developed to compare the performance of new design and original design. The comparison shows that, new design not only enhances the cooling capacity but also increase maximum temperature drop across thermoelectric cooler. It has been recognized that single stage thermoelectric cooler can reach only a maximum temperature drop about 70k across thermoelectric cooler, when it's hot end maintained at room temperature. However, single stage thermoelectric cooler is replacing by two-stage one, the maximum temperature drop increase to about 120k. Comparing the performance between original and new design for fixed parameters, it is observed that, the maximum cooling capacity enhanced by 75% as compare with original design also temperature drop across thermoelectric cooler enhanced by 76.8%.In new design configuration, two single stage thermoelectric generator replace by the two stage thermoelectric generator employed in original design. Because two single stage thermoelectric generator separately powers the hot stage and cold stage of two stage thermoelectric cooler. The result of this design always yields a stronger cooling capacity of system and larger maximum temperature drop. So by putting a new design, it helps to improve cooling effect required to remove fog in winter and rainy season also it helps to provide cooling in case of summer season.

Z.B. Tang et.al [5] studied A Research on Thermoelectric Generator's Electrical Performance under Temperature Mismatch Conditions for Automotive Waste Heat Recovery System. This study explains the thermoelectric generators recover useful energy with the help of thermoelectric modules which can converts waste heat energy into electricity from exhaust of automobile and it operates under temperature mismatch conditions. In this case study, an individual module test system and analyze the impact of thermal imbalance on output electrical power. Variability of temperature difference and clamping pressure are also being tested, from this it can be noticed that due to mismatch temperature, power of TEG decreased. To overcome this situation they improve thermal insulation on the modules and proved it. TEG is a device which converts thermal energy into the electrical energy based on Seebeck Effect with the use of exhaust waste heat recovery. The thermal variability and poorly controlled thermal conductivity are affects the individual module's poor working performance under mismatch temperature. By applying proper pressure on the TEM to improve performance. TEM in series connection are performing better than parallel connection. In series to increase operating voltage. TEG system connected to middle part of the exhaust pipe of the engine. As the temperature distribution decreases along the exhaust direction and the mech. pressure applied on module up to 180 kg. Hot gas taken from exhaust system and cold side taken from coolant of engine. After temp. Difference occurred voltage generates if temperature varies the electrical characteristics changes by regulating thermal conductivity. It is convinced that the thermal insulated TEG system performs better under temperature mismatch conditions at higher speed of engine

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and also in series form. It concludes that a proper mechanical pressure applied on the module improves the electrical performance. This situation is improved with thermal insulation on the modules power loss also reduced.

Y. Y. Hsiao et al. [6] studied A mathematic model of thermoelectric module with applications on waste heat recovery from automobile engine. In this paper, chosen two potential position on an automobile to apply thermoelectric module. For e.g. exhaust pipe and radiator and also cylinder head to examine the feasibility. A one dimensional thermal resistance model is also build to predict the behaviors of this module and the results are verified. Consequently, only about 30 percentage energy released from consumed fuel is converted as propelling force, the other 70 percentage is either discharged by exhaust gas, or expelled by the cooling system. This waste heat can be converted to electricity from the exhaust pipe and radiator on an automobile. In 1988, Birholz et al. presented the first TEG's application on the automobile. In this, a single TEG unit using FeSi2 as material was adopted to produce 1 W electric power. Many experiments have been done to apply TEGs on an automobile, however, only a few works. This will helps to understand the characteristics of TEG. If we consider waste heat recovery from exhaust pipe, when the heat spread from the hot junction to the cold junction, the cold side temperature is affected by the effect of heat conduction from the hot side. Therefore, the temperature increment in the hot junction will be higher than in the cold junction, the temperature difference of TEG still increases with the engine speed. Because the temperature difference increases with the engine speed, both output voltage and current become higher. Therefore, the output power and thermal efficiency of TEG are improved too. The temperature difference between the hot and cold junctions of TEG increased as the engine speed or the coolant temperature increase. The output voltage, according to the Seebeck effect, also increased as the temperature difference increased therefore output power and thermal efficiency increased.

Dongliang Zhao et al. [7] studied A Review of Thermoelectric Cooling: Materials, Modeling and Application. This study reviews the recent advances of thermoelectric materials, modeling approaches, and applications. Thermoelectric cooling systems have advantages over conventional cooling devices, including compact in size, light in weight, high reliability, no mechanical moving parts, no working fluid, being powered by direct current, and easily switching between cooling and heating modes. In addition, it possesses advantage that it can be powered by direct current (DC) electric sources. In this study, historical development of thermoelectric cooling has been briefly introduced first. Next, the development of thermoelectric materials has been given and the achievements in past decade have been summarized. To improve thermoelectric cooling system's performance, the modeling techniques have been described for both the thermo element modeling and thermoelectric cooler (TEC) modeling including standard simplified energy equilibrium model, one-dimensional and three-dimensional models, and numerical compact model. Finally, the thermoelectric cooling applications have been reviewed in aspects of domestic refrigeration, electronic cooling, scientific application, and automobile air conditioning and seat temperature control, with summaries for the commercially available thermoelectric modules and thermoelectric refrigerators. It is expected that this study will be beneficial to thermoelectric cooling system, simulation, and analysis. Thermoelectric module is a solid-state energy converter that consists of a bunch of thermocouples wired electrically in series and thermally in parallel. A thermocouple is made of two different semiconducting thermo elements, which generate thermoelectric cooling effect (Peltier-

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Seebeck effect) when a voltage in appropriate direction applied through the connected junction. Thermoelectric module generally works with two heat sinks attached to its hot and cold sides in order to enhance heat transfer and system performance. For a specific module and fixed hot/cold side temperatures, there exists an optimum current for maximum coefficient of performance (COP). Typical applications of thermoelectric cooling have been summarized in five categories, including domestic refrigeration, electronic cooling, automobile and chemical applications.

Yulong Zhaoa et al. [8] studied Performance Investigation of an Intermediate Fluid Thermoelectric Generator for Automobile Exhaust Waste Heat Recovery .This study reviews the efficiency of the internal combustion engine, is only 25–30 percentage, and approximately 40 percentage of this energy is discharged. This not only wastes energy but also accelerates environmental pollution. The installation and maintenance of a TEG is more convenient because of merits such as simple structure and no mechanical moving parts. Consequently, many researchers have stated that the efficiency can be improved by strengthening the heat transfer between the hot and cold fluids and the thermoelectric modules. A direct contact TEG system was designed by Kim et al. to realize a scheme with no interface between the modules and the heat source/coolant. In view of the above problems, an intermediate fluid thermoelectric generator system is proposed in this work. In the proposed system, the exhaust heat is transferred, by boiling and condensation of the intermediate fluid, without additional power consumption.

Bradley Orr, et.al [9] studied Prospects of waste heat recovery and power generation using thermoelectric generators. In this paper they studied that by using waste heat recovery from exhaust gases of car engine or engine head heat generates the electricity with TEG. TEG system is used to generate the electricity by using heat. These devices make use of the seebeck effect. They are made up of many N and P type elements which are electrically connected in series but thermally in parallel. When there is temperature difference over the plate, the small voltage would be generated. As all elements are connected in series forms these small voltage add up to generate usable voltage. Voltage generated by TEG is directly proportional to temperature and electrical power produced is directly proportional to square of temperature difference. For TEG system commonly material used is Bismuth Telluride (BiTe) but according to requirement other materials are also used. Possibilities of using TEG as primary source - TEGs are not typically used as power source due to their lower thermal efficiency compared to other heat engines such as IC engines, but TEGs have advantages over this heat engines. A TEG system would have no moving parts, no complexity no noise, no vibration, no maintenance and no direction dependence. TEGs have been shown to the potential to be applied to car exhaust waste heat recovery system or engine head waste heat recovery system

Song lan et.al [10] studied Feasibility study on vehicle or Thermoelectric generator for both waste heat recovery and engine oil warm up. This paper explains the bidirectional characteristics of thermoelectric module in which TEG module work either for generation of power or for heating - cooling mode. The module also can be used for cooling the engine. In this paper a dual mode TEG module is developed to predict the bidirectional behavior of thermoelectric generator. A dual mode thermo electric module consists of semiconductors and ceramic plates. A P-type and N-type thermoelectric module makes a thermocouple. The ceramic plates are electrically insulating but thermally conductive. The thermoelectric module used as a dual mode model is GM917210-127-28-10. When bifunctional thermoelectric module

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works in engine warm up mode with electric current applied, a 3s time faster warm up effect of engine oil obtained compared with thermoelectric generator only operating in waste heat recovery mode. By operating TEG in engine warm up mode of vehicle starting, faster warm up effect is obtained. The faster warm up effect is obtained by operating TEG in engine warm up mode and it is also found that the performance of waste heat recovery mode of TEG is not effective at starting of vehicle and at low speed.

III.RESEARCH ELABORATIONS

A. *Working of Car Air Conditioning System*

The working of automotive air condition system is similar to all other air conditioning systems. The refrigerant vapour from the evaporator is compressed to high pressure by the compressor. The compressor is driven by the engine through a belt drive. It is connected by an electromagnetic clutch which serve engage and disengage the compressor required. A variable displacement AC compressor is sometime used to match compressor capacity to varying cooling requirement. Refrigerant pressure and temperature increases in the compressor and convert it into vapour form. This high pressure and temperature refrigerant vapour from the compressor then discharge to the condenser, which is a heat exchanger situated in front of vehicle. In the condenser the refrigerant liberate heat and convert into liquid form. Sometime the ram air is not sufficient so an extra engine or electric driven fan is used to cool down the refrigerant. This cooled but high pressure refrigerant allow passing form dehydrator to extract any moisture. Dry refrigerant liquid is then made to pass through expansion valve mounted at the inlet side of the evaporator. The expansion valve allows the refrigerant liquid to expand to low pressure in the evaporator. The process of expansion to low pressure makes the refrigerant to evaporate and thereby cool the evaporator. A sensing device, called temperature tube signals the diaphragm in the expansion valve to vary orifice size depending upon the refrigerant temperature at the evaporator outlet, thus achieving automatic temperature control. The evaporator is similar in construction to the condenser.

B. *Need of Thermoelectric Air Conditioning*

Now a day, an automobile is a necessity for everybody. For a far or near travelling people need car regard to the safety, environment and most important comfort. Due to these reasons, many vehicles are equipped with heating, ventilating and air conditioning system. In vehicle without HVAC system no one feel comfortable so, HVAC together with part of people life. This HVAC system is more efficient and reliable but it has some limitations. It has been seen during the previous two decades that the ozone (O3) layer is slowly destroyed because of the refrigerant like CFC and HFC used for the refrigeration and air conditioning. The refrigerant used is HFC's which are leaked into the atmosphere. When they reach to ozone (O3) layer they act on O3 –molecules and the layer of O3 is destroyed. It includes demerits like; the compressor is driven by the crankshaft of the engine. So, it consumes about 5 to10% power of the engine. This consequently reduces mileage of the vehicle. An Air-conditioning system consumes as much as 8h.p. with a unit capacity of 3 tons or 9072 kcal/hr. approximately. So, due to these the pickup of vehicle decreases. The cost of present HVAC system is more; it may vary depending upon price and model of vehicle. Maintenance and repairing cost of this system is more. Each component of HVAC is very costly. This system occupies very large space in engine compartment and dashboard. In this system, if any component fails to perform well then, the whole system either will not function properly or will not function at all. Instead of this, today's electronically and computer controlled HVAC system has sensors.

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If somebody wants to start an AC system, but due to high power requirement of an engine, the AC system will not start and person will need to wait for the starting of the HVAC system.
To overcome these demerits the existing HVAC system could be replaced by newly emerging thermoelectric couple or cooler which works on Peltier and seebeck effect. Thermoelectric cooling can be considered as one of the major applications of thermoelectric modules (TEM) or thermoelectric coolers (TEC). The idea of cooling is based on Peltier effect, as when a dc current flows through TE modules it generates a heat transfer and temperature difference across the ceramics substrates causing one side of the module to be cold and the other side to be hot. The purpose of the project is to make use of the cold side to cool the ambient air to a lower temperature, so that it can be used as a personal cooler.

C. *Types of Thermoelectric modules*

Thermoelectric Generator (Seebeck Generator): A thermoelectric generator (TEG), also called a Seebeck generator, is a solid state device that converts heat flux (temperature differences) directly into electrical energy through a phenomenon called the Seebeck effect (a form of thermoelectric effect). Thermoelectric generators function like heat engines, but are less bulky and have no moving parts. However, TEGs are typically more expensive and less efficient Thermoelectric generators could be used in power plants in order to convert waste heat into additional electrical power and in automobiles as automotive thermoelectric generators (ATGs) to increase fuel efficiency. Another application is radioisotope thermoelectric generators which are used in space probes, which has the same mechanism but use radioisotopes to generate the required heat difference.

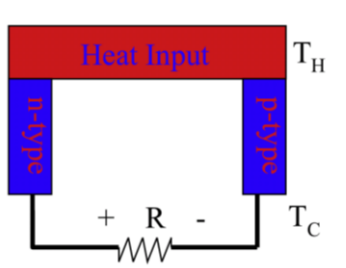

Fig. 1. The schematic diagram of thermoelectric generator [3]

Thermoelectric Cooler (Peltire Plate): Thermoelectric cooling has quickly become a practical proposition for many types of electronic equipment. Devices on the market today are compact, efficient and – with the benefit of advanced internal construction – overcome the traditional reliability challenges that have restricted opportunities for this type of device in the past. As alternative to commonly used passive cooling techniques, thermoelectric cooling can offer numerous advantages. These include accurate temperature control and faster response, the opportunity for fanless operation (subject to heat sink performance), reduced noise, space savings, reduced power consumption and the ability to cool components to sub-ambient temperatures.

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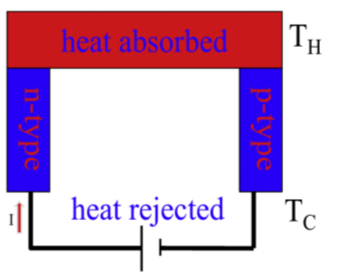

Fig. 2. The schematic diagram of thermoelectric cooler [3]

D. *Peltier elements*

The internal structure of the Peltier element comprises semiconductor pellets fabricated from N-type and P-type Bismuth Telluride materials. The array of pellets is electrically connected in series, but thermally arranged in parallel to maximize thermal transfer between the hot and cold ceramic surfaces of the module (Fig.3).

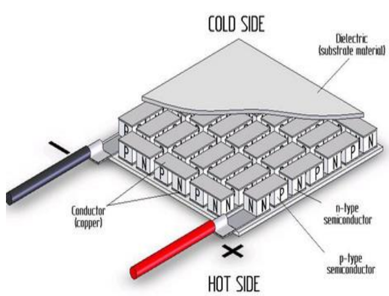

Fig.3. Peltier element schematic [12]

Thermoelectric cooling takes advantage of the Peltier effect, which is observed as heat being either absorbed or emitted between the junctions of two dissimilar conductors when a current is passed. A thermoelectric module comprising a Peltier element sandwiched between two ceramic plates of high thermal conductivity, with a power source, is effectively able to pump heat across the device from one ceramic plate to the other. Moreover, the direction of heat flow can be changed simply by reversing the direction of current flow. Applying a DC voltage causes the positive and negative charge carriers to absorb heat from one substrate surface and transfer and release it to the substrate on the opposite side. Therefore, the surface where energy is absorbed becomes cold and the opposite surface, where the energy is released, becomes hot.

IV. CONCLUSION

After the study of thermoelectric refrigeration system, we could demonstrate the cooling ability of the Peltier module and its use as an alternative to refrigerant based cooling systems. The study concludes that there are a no. of places where TEC can play a more promising role than the conventional Air

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conditioners with the added advantage of not using the refrigerants and hence protecting the ozone layer. With its reliable cooling and precise temperature control, this solid-state cooling technology can replace conventional cooling in a multitude of applications. Also with the advancements in material technology, there shall be a drastic rise in the cooling performance. This experiment is just an effort to demonstrate the need and means of replacing the conventional systems due to their adverse environmental effects and to highlight the future scope of the Thermoelectric Cooling Devices.

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