Mitsubishi Heavy Industries, Ltd. (MHI) has begun commercial production of a water-based PTC (Positive Temperature Coefficient) semiconductor heater for the occupant’s compartment of an electric vehicle (EV) or a plug-in hybrid vehicle (PHEV). A PTC heater provides a heat source in an EV or a PHEV, where no engine exhaust heat is available, and is applicable to each vehicle’s safety and packaging requirements.

1. In-vehicle heating

Figure 1 shows the configurations of the vehicle-heating systems. EV and PHEV both use hot water heated with a PTC heater instead of high-temperature coolant heated with engine waste heat. The hot water is circulated with an electric water pump.

Compared with an air heater, the hot water heater offers the following advantages:

(1) For safety’s sake, the high-voltage heating unit is located outside the occupant’s compartment.

(2) The heating, ventilation, and air conditioning (HVAC) module of the base vehicle can be used to reduce the development cost.

2. Primary features

(1) Safety assured by the self-regulating function of the heating element

This heater uses a PTC semiconductor as the heating element. A PTC semiconductor increases drastically its electrical resistance at temperatures above a certain level and is able to maintain a constant heating element temperature during load and supply voltage changes.

For this reason, the risk of the heating element’s overheating or catching fire is minimal, even under unexpected boil-dry conditions due to the loss of hot water. Moreover, the heat generation capacity is nearly constant over a wide range of battery voltage fluctuations.
(2) Easy packaging with small size

The plate-heating elements are placed between insulators with high heat conductivity, and the heat is released to the upper and lower water passages (Figure 2). Thanks to its compactness and high heat-release capability, the heater can be mounted in a limited space. In addition, the integrated control board reduces the amount of wiring in the vehicle.

![Figure 2](image)

**Figure 2** Construction of water-based PTC heater

(3) Multi-stage on/off control with heating-element modules

Four heating-element modules are provided to achieve up to eight-step capacity control utilizing various combinations of modules with differing capacities and on/off switching.

(4) Control board module

The control board is divided into three functions: (a) heat generator on/off, (b) capacity calculation/control, and (c) communication. By combining these functions, the heater is applicable to varying customer requirements, such as those listed in the following section.

# 3. Future development

Anticipating the electrification of future vehicles, we are proceeding with the development of products to satisfy each automobile manufacturer’s requirements.

(1) Small size and light weight

The development will proceed in two stages (Figure 3).

(First stage) Miniaturization and weight trimming based on current design

(Second stage) Further miniaturization and weigh trimming based on a new heat-exchanger concept and adaptation of resin parts

(2) High functionality

(a) Autonomous temperature control

The present heater controls the heat-generator modules by turning the power on/off via the external calculation unit (ECU) and its commands. Autonomous temperature control will be achieved by integrating the ECU and sensor.

(b) CAN/LIN interface

With the integration of the calculation unit in the heater, communication of command and self-diagnosis information as well as CAN/LIN communication to and from the vehicle will be available.
Figure 3  Future development of water-based PTC heater