Air-Conditioning system
For Electric Vehicles
(i-MiEV)

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1. Introducing “i-MiEV” (1)

Mitsubishi Motors Corporation (MMC) recently developed “i-MiEV” as an electric vehicle utilizing the ultimate eco-friendly zero-emission driving based on the “i” mini car.

“i-MiEV” is the reconstructed electric vehicle adopting revolutionary technology such as high-performance lithium-ion batteries and compact high performance motors.

“i-MiEV” vehicles are currently in service throughout Japan via joint MMC - Power Company cooperative fleet testing.

Fig. 1.1 Mitsubishi “i-MiEV”
1. Introducing “i-MiEV” (2)

Basic configuration and major specifications of the vehicle are shown as follows.

<table>
<thead>
<tr>
<th>Table 1.1 Major specifications of i-MiEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>L * W * H</td>
</tr>
<tr>
<td>Wheelbase</td>
</tr>
<tr>
<td>Mass</td>
</tr>
<tr>
<td>N of Passengers</td>
</tr>
<tr>
<td>Max Speed</td>
</tr>
<tr>
<td>Range/charge</td>
</tr>
<tr>
<td>Motor</td>
</tr>
<tr>
<td>Drive</td>
</tr>
<tr>
<td>Battery</td>
</tr>
</tbody>
</table>

The vehicle has sufficient driving performance and cruising range for normal customer usage (160km/100mile).

<table>
<thead>
<tr>
<th>Table 1.2 Charging performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power source</td>
</tr>
<tr>
<td>Quick charge</td>
</tr>
<tr>
<td>Regular charge</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
1. Introducing “i-MiEV” (3)

Fig. 1.3 Vehicle system configuration
2. Outline of the AC system (1)

2.1 Concept of the system

Basic concept of the AC system for “i-MiEV” is to appropriate original vehicle’s system to the vehicle due to cost reduction in both development and parts.

Features:
The system has a refrigerant cycle with a Electric driven compressor for cooling and a coolant cycle with a PTC Heater for heating.
2. Outline of the AC system (2)

2.2 Actual Configuration of the system

Fig. 2.2 Actual AC system configuration

HVAC module
Coolant condensing tank
Electric driven Coolant pump
Condenser
Coolant PTC Heater

: Appropriated parts
2. Outline of the AC system (3)

2.3 Specification of key components

(1) Electric driven compressor

Table 2.1 Electric driven compressor spec.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>L * W * H</td>
<td>291 * 162 * 157 (mm)</td>
</tr>
<tr>
<td>Mass</td>
<td>10.2kg (with Bracket)</td>
</tr>
<tr>
<td>Compressor type</td>
<td>Scroll with rare earth metal motor</td>
</tr>
<tr>
<td>Displacement</td>
<td>30 cc/rev.</td>
</tr>
<tr>
<td>Inverter</td>
<td>Integrated, suction ref. cooling</td>
</tr>
<tr>
<td>Max. rev.</td>
<td>6000 rpm</td>
</tr>
<tr>
<td>High Voltage range</td>
<td>DC 220 ~ 400 V</td>
</tr>
<tr>
<td>Low Voltage range</td>
<td>DC 8 ~ 16 V</td>
</tr>
<tr>
<td>Max. power</td>
<td>4.5 kW</td>
</tr>
<tr>
<td>Max. input current</td>
<td>20.5 A (@DC 220V)</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>HFC-134a</td>
</tr>
<tr>
<td>Ref. Lubricant</td>
<td>POE oil</td>
</tr>
</tbody>
</table>

Oil separator is integrated due to improvement of both ref cycle capacity and efficiency.
2. Outline of the AC system (4)

(2)-1 Coolant PTC Heater

Table 2.2 Coolant PTC Heater spec.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>L * W * H</strong></td>
<td>290 * 160 * 100 (mm)</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>7.4 kg (dry)</td>
</tr>
<tr>
<td><strong>Heating devices</strong></td>
<td>PTC heating elements</td>
</tr>
<tr>
<td><strong>Heating Capacity</strong></td>
<td>5.0 kW (@ 6L/min., 25 deg C)</td>
</tr>
<tr>
<td><strong>Coolant press. Drop</strong></td>
<td>2 kPa (@ 6L/min., 80 deg C)</td>
</tr>
<tr>
<td><strong>Capacity control</strong></td>
<td>On/Off cycling (8 steps)</td>
</tr>
<tr>
<td><strong>High Voltage range</strong></td>
<td>DC 220 ~ 400 V</td>
</tr>
<tr>
<td><strong>Low Voltage range</strong></td>
<td>DC 8 ~ 16 V</td>
</tr>
</tbody>
</table>

PTC: Positive Temperature Coefficient

The heater is installed in vehicle under hood area. Therefore the high voltage cable doesn’t need to be leaded into the cabin.
2. Outline of the AC system (5)

(2)-2 Coolant PTC Heater

This heater is basically 4 layer structure; control board part, upper coolant passage part, PTC elements part, and lower coolant passage part.

The heater has 3-dimensional coolant flow passages for efficient thermal conduction from PTC elements to coolant.

Fig. 2.5 Coolant PTC Heater (cross section)

Fig. 2.6 Coolant PTC Heater (coolant passages)
2. Outline of the AC system (6)

2.4 Control specification

(1) Temperature control

There are 6 positions of “Cool”, 6 positions of “Hot”, and “Ventilation” position. This control decrease the situation in which both the compressor and the PTC heater are operated simultaneously.

(2) MAX switch (SW)

MAX SW ON:
The system is operated under maximum capacity.

MAX SW OFF:
Fan speed and coolant temp are limited.
⇒ Usually “OFF”

Fig. 2.7 Control Panel (1)
2. Outline of the AC system (7)

(3) **Fan auto control**
Fan speed is controlled automatically to keep comfort temp in the cabin.

(4) **Ventilation position**
Both the compressor and the PTC heater are off. Only fan is operated for ventilation.

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**Fig. 2.7 Control Panel (2)**
3. Performance (1)

3.1 Vehicle test results (Cooling performance)

The cooling performance of “i-MiEV” is slightly better than that of the baseline vehicle “i”.

Fig. 3.1 Cooling Performance
3. Performance (2)

3.2 Vehicle test results (Heating performance)

The heating performance is better than that of the baseline vehicle, especially under warming up and idling conditions.

Fig. 3.2  Heating Performance
3. Performance (3)

3.3 Electric Power consumption

(1) Power consumption

Large electric power is necessary when heater is operated.

Driving pattern: 10-15 mode

AC
MAX_SW ON

MAX_SW OFF

Heater
MAX_SW ON

MAX_SW OFF

Motor Power

AC&Heater Power

Power consumption [kWh]

Fig. 3.3 Power consumption
3. Performance (4)

(2) **Cruising range**

The cruising range decreases when AC and Heater are operated.

**Driving pattern**: 10-15 mode

- **AC & Heater OFF**
  - MAX_SW OFF
  - MAX_SW ON

- **AC & Heater ON**
  - MAX

**AC & Heater OFF**

- (AC & Heater OFF)
- (AC ON (@35degC))
- (Heater ON (@0degC))

**Cruising range [km]**

- 160

**Fig. 3.4 Cruising range**
4. Summary

• Mitsubishi Motors have developed the Air-Conditioning system for Electric Vehicle “i-MiEV” with an electric-driven compressor and coolant PTC heater as key components.

• The cooling/heating performance of the vehicle is almost equal to the baseline “i”, which is a conventional engine vehicle, under normal usage conditions.

• Operating the AC system have influence on the cruising range of the vehicle, especially under heating mode.
5. Next Step – future development (1)

- Improve cruising range by decreasing AC system power consumption during vehicle driving.
  - Decreasing vehicle thermal load (including “Pre AC” during charging)
  - Improving the efficiency of the AC system
    etc.

- Improve power consumption of coolant PTC heater, especially.
  - Reducing size and mass
  - Improving control and efficiency
5. Next Step – future development (2)

**Improvement of coolant PTC Heater**

We should pursue downsizing (small & light weight), and controllability (smooth capacity control & communication to the vehicle).

- **Power circuit board**
  - **Gen1** Current Product
    - On-Off step control by a external controller
    - On-Off signal line
    - Volume: 100% (Baseline)
    - Mass: 100% (Baseline)

- **Gen2** Development
  - Integrated control circuit
  - PWM control (or On-Off step)
  - CAN or Local communication
  - Volume: 70% (compared with Gen1)
  - Mass: 70% (compared with Gen1)

- **Gen3** Future Target
  - Integrated control circuit
  - PWM control (or On-Off step)
  - CAN or Local communication
  - Volume: 50% (compared with Gen1)
  - Mass: 50% (compared with Gen1)

- **Brand-new structure**
  - Same structure as Gen 1

**Timeline**

- **2009~**
  - Power circuit board

- **Around 2011**
  - Gen2

- **Around 2013**
  - Gen3
END

Thank you for your attention.