

Ejector-Type Cool Box

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ABSTRACT

Ejector Cycle[®] development has been under way to improve refrigeration cycle performance and increase its efficiency in light of global environmental conservation. Ejector Cycle[®] can be applied to cool boxes that cool drinks using the refrigeration cycle of the vehicle air-conditioning system. We commenced deliberating Ejector Cycle[®] application to improve cool box system performance. Difficulties associated with the cool box include the decline in cabin air-conditioning performance due to simultaneous operation of the cabin air conditioning and cool box. We have solved this problem by using an ejector to achieve continuous operation with two evaporator temperatures in the same system. Furthermore, we have configured the cycle to be suitable for vehicle air-conditioning systems, designed a high-efficiency two-stage variable ejector, and addressed various system problems. The result is successful commercialization of the Ejector system (hereafter, it is shown EJECS[®] (EJEctor Cycle System) cool box, which provides substantial performance improvements at a level unachievable using a conventional system (Cabin air conditioning: +15% in performance; Refrigeration: 20% reduction in cooling time). The development is outlined below.

INTRODUCTION

In recent years, global warming and increased vehicle heat loads have led to the demand for improvements in vehicle air-conditioning system performance. In intensely hot areas, specifically in the Middle East, the deficiency in air-conditioning capacity has become obvious. However, it is difficult for some vehicle classes to achieve performance improvements, due to the need to use an upsized system or increased power. We have addressed the challenge of improving the performance of cool box systems in SUVs and high-end vehicles principally used in intensely hot areas. To achieve substantial performance improvements while meeting both air-conditioning and cooling requirements, it was necessary to design a new system that is not merely a simple improvement on conventional part functions. Ejector Cycle[®] makes effective use of energy that would otherwise be lost due to the expansion valve. We commenced deliberation on Ejector Cycle[®] application to the cool box.

1. MEETING BOTH AIR-CONDITIONING AND COOLING REQUIREMENTS

The cool box uses the refrigeration cycle of the vehicle air-conditioning system to cool drinks. The Ejector Cycle[®] system chills two different spaces simultaneously, using one compressor and two evaporators; one for the cabin air conditioning and the other for the cool box. Accordingly, the system must achieve different cooling temperatures for air conditioning and cool box refrigeration. The evaporating pressure of the cool-box evaporator must be lower than that of the air-conditioning evaporator.

Temperature required for air conditioning: 10 to 20°C

Temperature required for refrigeration: 5°C or below

In the past, a solution that meets the above requirements called Freezing by Intermittent Running (FIR) has been used successfully. In this system, a solenoid valve is inserted upstream of the air-conditioning evaporator. The solenoid valve is repeatedly turned on and off to feed refrigerant at different temperatures alternately to each evaporator (Fig. 1).

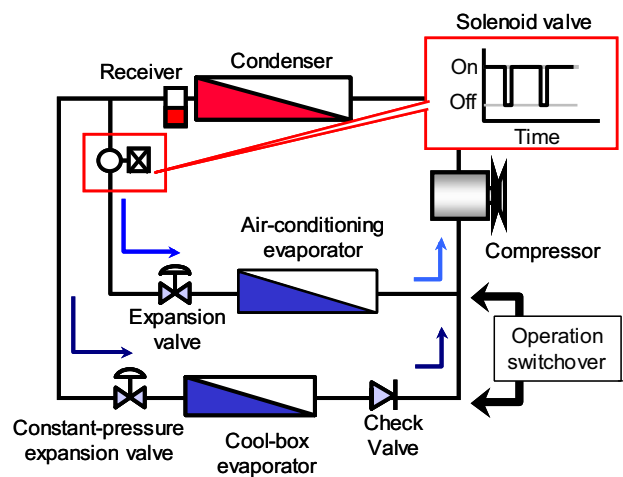


Fig.1 FIR system

One drawback of the FIR system in relation to air-conditioning-only operation is reduced cabin air-conditioning performance due to the interruption in refrigerant feed to the air-conditioning section during the switchover. This causes variation in the HVAC air outlet temperature, which reduces comfort. These adverse effects resulting from the switchover should be eliminated. For this purpose, we considered a system that generates two temperatures through continuous running. More specifically, a pump is provided to produce different evaporating pressures between the cabin air-conditioning evaporator and the cool-box evaporator. Thus the cool box section is operated at a lower pressure than the cabin air-conditioning section, thereby maintaining the cool box at a lower temperature. The ejector was selected as a pump for this purpose, since it is a fluid pump capable of energy regeneration.

2. ENERGY CONVERSION BY EJECTOR

The ejector comprises of a nozzle, mixing section and diffuser, as shown in Fig. 2. High-pressure refrigerant flowing into the nozzle (drive flow) undergoes decompression and expansion by the nozzle. The pressure after decompression is lower than the inflow pressure of the intake section, allowing the refrigerant to be drawn in. Pressure energy generated through the decompression and expansion process at the nozzle is converted to kinetic energy and increases the refrigerant flow velocity. The ejector is designed so that the drive flow is mixed with the intake gas at the mixing section to produce a homogenous mixture. In the diffuser section, the mixed refrigerant decelerates and increases in pressure due to gradual enlargement of the cross-sectional area.

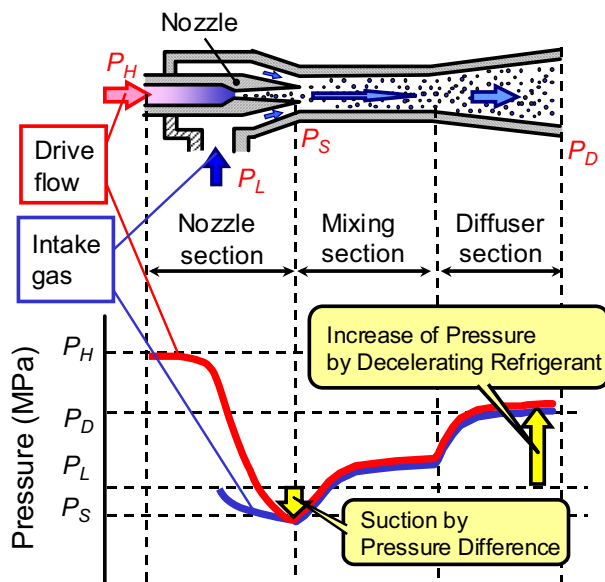


Fig.2 Structure and inside pressure of ejector

As described previously, the ejector is a device intended to pressurize the intake gas by using the kinetic energy of the drive flow. In other words, it is an energy converter that converts the kinetic energy of the drive flow to compression work on the intake gas.

3. EJECS® COOL BOX

Figure 3 shows the refrigerant circuit configuration of the newly developed EJECS® cool box. After division at the condenser outlet and decompression, the high-pressure refrigerant is fed to the air-conditioning evaporator and cool-box evaporator. The ejector is installed upstream of the air-conditioning evaporator to draw in refrigerant exiting the cool box. This circuit features a solenoid valve placed upstream of the cool box that allows the cool box to be turned on and off.

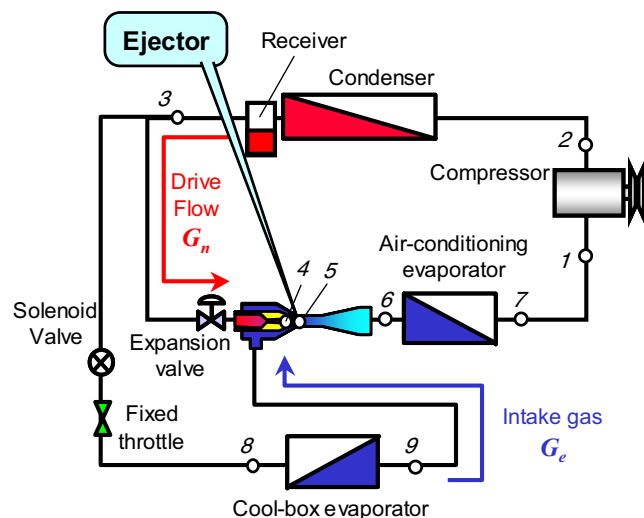


Fig.3 Structure of EJECS® cool box

Figure 4 shows a P-h diagram representing the refrigeration cycle operation. Numbers 1 through 9 in Fig. 4 correspond to the numbers on the refrigerant circuit in Fig. 3. At the condenser outlet, the high-pressure refrigerant undergoes decompression and expansion (3 → 4) through the ejector (nozzle). This process generates expansion loss energy Δh_{max} , which is used to draw refrigerant from the cool box outlet (9 → 5) and is at the same time converted to compression work Δp (5 → 6).

Thus, two temperatures are achieved by setting the evaporating pressure of the cool-box evaporator lower than that of the cabin air-conditioning evaporator. A similar mechanism enables reduction of the compression work performed by the compressor.