# DUAL THERMOACOUSTIC CORE COMPACT HEAT-PUMP FOR AUTOMOTIVE APPLICATION

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In order to reduce environmental impact, the automotive industry investigates alternative "green" technologies. In this context, the use of chemical refrigerants (such as CFCs and HFCs) for vapor-compression refrigeration in air conditioning systems, which are known as potent global-warming gases, has been identified as one of the sources of pollution in a vehicle. Moreover, cooling systems draw significant power from the engine and reduces the overall efficiency of the vehicle. Thermoacoustic cooling devices, which use an inert gas as working fluid, could be a good alternative, especially with the rapid development of hybrid and electric vehicles, although very few thermoacoustic solutions have been adapted to automotive applications because of weight and space restrictions. This paper outlines the design and performance predictions for a compact coaxial thermoacoustic heat-pump with two coupled acoustic sources.

The concept of such device has been developed by Poignand & al. [1]. In this system (Figure 1-a), one end of the thermoacoustic core, comprising the stack - or regenerator - and the heat exchangers, is set on an acoustic source, which creates the displacement field needed in the thermoacoustic process. The second acoustic source is set on the opening of the cavity and creates a quasi-uniform pressure field inside the cavity. The sources are working at the same frequency and their amplitudes and phases can be independently tuned for optimizing the performances of the device, i.e. acoustic pressure and the particle velocity are no longer linked by standing wave or travelling wave conditions. As a direct consequence, the working frequency can be such that the wavelength is much greater than the dimensions of the resonator, so that the compactness of the device is significantly improved.

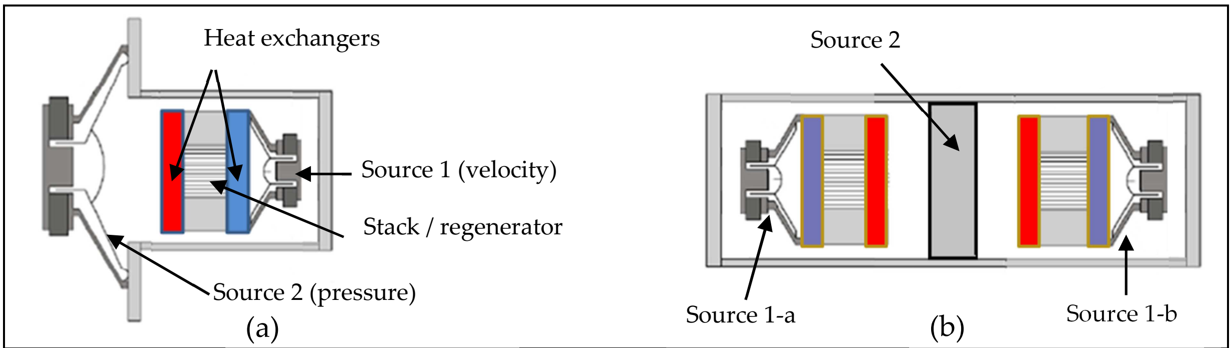


**Figure 1:** **(a)** *the compact thermoacoustic device developed by Poignand & al. [1];* **(b)** *the compact thermoacoustic device with two thermoacoustic cores.*

The device described in [1,2] was designed for low power applications, moving about 1 W of heat, the acoustic field being generated by two "commercial" electrodynamic loudspeakers and the device using air at atmospheric pressure. In order to match automotive performances in air refrigeration, it was necessary to increase the amount of heat extracted by the device and its efficiency to reduce the indirect energy-related contributions. For this purpose, we have designed the dual thermoacoustic core compact heat-pump whose sketch is presented in Figure 1-b. In this device, filled with gas Argon under P=40 bars, two thermoacoustic cavities are placed on both sides of the Source "2", which allows doubling the heat pumping of the refrigerator. This configuration permits to use the acoustic energy dissipated at the back of the pressure source to power the additional thermoacoustic cavity.

The device has been designed using DeltaEC [3] in order to fit performances of an air refrigeration system for standard automobile. For this application, it should move 5 kW of heat from the cold heat exchanger at 5°C and rejects heat to the ambient heat exchanger at 55°C. Low-power electrodynamic loudspeakers create the velocity fields in the thermoacoustic cores. The design of heat exchangers is based on elements used in the automotive industry, adapted so that the thickness is about the order of the particle displacement into the regenerator, which consists of metallic meshes stacked together. Numerical simulations permitted to set the characteristics of the thermoacoustic cores as well as the working frequency that satisfies the performances goal. The dimensions of the cavities were optimized, and we ended up with a machine of about the size of a cylinder measuring 33 cm in diameter and 32 cm in height (not including the pressure source), working at f=40 Hz. In the present model, the main acoustic source is not included but simulations allow getting the characteristics for this key element. We plan to design an adapted source based on technologies used in automotive industry. Good candidates for such a high power pressure source are indeed linear motors, as they can create high acoustic pressure fields with an efficiency that usually exceeds 80%, which should permit to achieve the maximum power consumption of about 2.3 kW necessary for this device. With such a source the theoretical overall coefficient-of-performance for the designed device should be equal to 2.2, which is competitive with most efficient thermoacoustic cooling machines to date, as well as with today's automotive air conditioning systems.

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