PROJECT PROPOSAL

Thermoacoustic Refrigeration

SUBMITTED BY

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STATEMENT OF IDEA

Due to current age of impending energies and environmental crisis, current cooling technologies continue to generate greenhouse gases with high energy costs. Through the construction of a functional model of thermoacoustic refrigerator, we will demonstrate the effectiveness of thermoacoustics for modern cooling, high efficiency with wide range of temperature differences of more than 22 degrees Centigrade.

OBJECTIVE

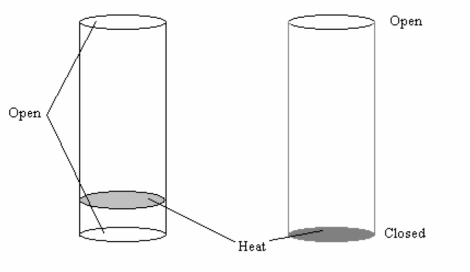
- To design and build a descriptive working thermoacoustic refrigerator following a plan similar to the one designed by $Russel^1$ and to demonstrate that this device have the ability to create & maintain a large temperature gradient, more than 22 degrees Centigrade, which would be useful as a heat pump.
- To increase the efficiency of the device through achieving the specified optimal $thermal\ penetration\ depth^2$ of 4 which is ideal according to G.W. Swift.

METHODOLOGY

Basic principle behind the working of a thermoacoustic refrigerator is the ability to generate temperature differences using acoustic oscillations. The equation for the frequency of a wave travelling through a closed tube is given by

$$f_n = \frac{v}{4L} \qquad \text{For n= 1, 3, 5 …}$$

Where *f* is frequency, *v* is velocity, and *L* is length of the tube.



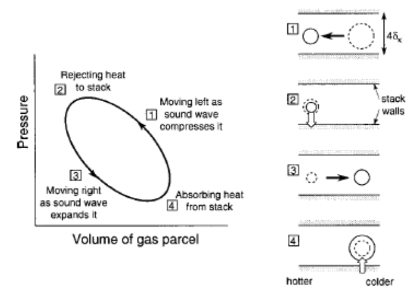


Figure 1: The Rijke Tube on the left has two open ends, and heating element near the base. The Sondhuass Tube has one closed end, which is heated to produce odd-numbered harmonic standing waves.

PHASES: Heat is applied to the closed end of the tube. As the temperature increases, heat is converted to kinetic energy in the gas molecules at the closed end of the tube. The gas molecules accelerate towards the cooler end of the tube, thereby creating an area of relative low pressure in the heated end. As these molecules cool off, other gas molecules accelerate towards the hot end to fill in the area of low pressure. These molecules are then heated, and the process begins again. This completes one cycle of a thermal oscillation, and is analogous to the $Stirling^3$ Cycle. $Figure\ 2^1$ traces the basic thermoacoustic cycle for a packet of gas, a collection of gas molecules that act and move together.

TECHNIQUES: The stack consists of a large number of closely spaced surfaces that are aligned parallel to the to the resonator tube. The purpose of the stack is to provide a medium for heat transfer as the sound wave oscillates through the resonator tube.

The primary constraint in designing the stack is the fact that stack layers need to be a few thermal penetration depths apart, with four thermal penetration depths being the optimum layer separation. The thermal penetration depth, $\boldsymbol{\delta}_k$ is defined as the distance that heat can diffuse through a gas during the time t=1/π f, where *f is* the frequency of the standing wave. It depends on the thermal conductivity, k, and density, ρ, of the gas and the isobaric specific heat per unit mass, C_p according to $\boldsymbol{\delta_k} = \sqrt{\frac{\boldsymbol{k}}{\pi f \rho C_p}}$

PROCEDURE

The stack is to be constructed with film and fishing wire. The design called for the fishing line to be placed in 5 mm separations, so we have to create looms as templates for stack. The looms is to be created from 5 cm wide cardboard roughly 33 cm in length with slits placed every 5 mm on each side. This allowed for a straight application of the fishing line to the film. For tube, 2 cm diameter and 25 cm long Plexiglas tube and squares of 8 × 8 in. sq. with a 2.8 cm hole in the center is to be machined and inserted into the hole in the center of the Plexiglas squares. A speaker is to be attached to the Plexiglas square and sealed.
After sealing, the stack is to be inserted into the tube down to 4 cm from the top of tube using a machined 2.5 cm tool designed not to destroy the stack. Two thermocouples are to be created for determining temperature gradient by using 0.015 cm chromel and 0.015 cm alumel welded together.

RESOURCES REQUIRED

INFRASTRUCTURAL: Machine Shop, Measurement & Thermal Laboratory, Welding Shop, and Sheet Metal Shop.

FINANCIAL: Approximately Rs. 1000.

MATERIALS:

Quantity	Materials	Specifications
1	Nylon fishing wire	15 lb/6.803 Kg, diameter 0.34 mm
1	Wide Cardboard	35 cm
1	Plexiglas tube	150 × 150 cm
1	Boxed loudspeaker	6 inch, low-range
1	Amplifier	40 W
1	BNC to RNA Connector	N/A
1	Aluminum Stopper	N/A
2	Thermometer	N/A
2	Thermocouple	TYPE K

EXPECTED OUTCOME

High temperature gradient above room temperature is expected. We would be able to cool the air significantly creating a 22 degree centigrade heat pump. Efficiency is expected to be increased by coupling the stack to a heat source or a heat sink, the transfer of heat would be more efficient.

SCOPE FOR COMMERCIALIZATION

Most noise is generated by waster heat, *computer components* [4] and other semiconductor devices operate faster and more efficiently at lower temperatures. If thermoacoustic cooling devices could be scaled for computer applications, the electronic industry would realize longer lifetimes for microchips, increased speed and capacity for telecommunications, as well as reduced *energy costs*[5]. It can also be used in submarines and *space shuttles*[6] as reliable air conditioning devices.

Future applications of thermoacoustic air conditioners would not be restricted to industrial uses but could offer inexpensive heating and cooling for homes. Additionally, since current air conditioners use HFCs and other potentially harmful chemicals, thermoacoustic cooling systems that employ inert gases would have long-term benefits on the *environment*[6].

REFERENCES

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