Project OSCAR
Open Source Courseware Animations Repository

Template for the Storyboard stage

General Instructions:

- The template shown is an example. You can add more slides if required.
- Include images for explaining the concepts.
- Label the images.
- Clearly list out the user interactions planned.

- Prepare a questionnaire with answers on the concept for self-assessment of the user.

- If reviewer suggests modifications, you have to re-upload your storyboard with the modifications shown in **bold letters**.

- The blue band at the bottom will have suggestions about the slide contents.

Mention what will be your animation medium: 2D or 3D
Mention the software to be used for animation development: JAVA, Flash, Blender, Shikay, Maya..etc

THERMOACOUSTIC REFRIGERATION
SUBJECT : MECHANICAL ENGINEERING
NAME: RAM C. DHULEY

1.THERMOACOUSTIC

2. LOUDSPEAKER

3. REFRIGERATION

'Thermoacoustic' or ***thermoacoustics*** explains the relation between heat and sound. It is a science that explains how sound energy can be converted to heat or vice versa, and teaches how to realize the conversion practically by means of special kind of engines and refrigerators

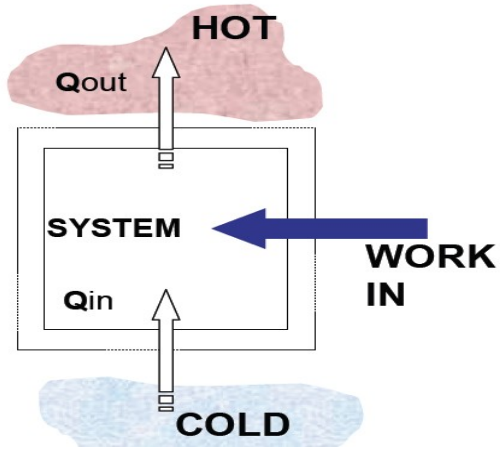
'Loudspeaker' is one of the device used to drive thermoacoustic refrigerator

'Refrigeration' means to remove heat from cold place and to dump it to relatively hot place (thereby further cooling the cold place) by means of some kind of 'mechanical work'

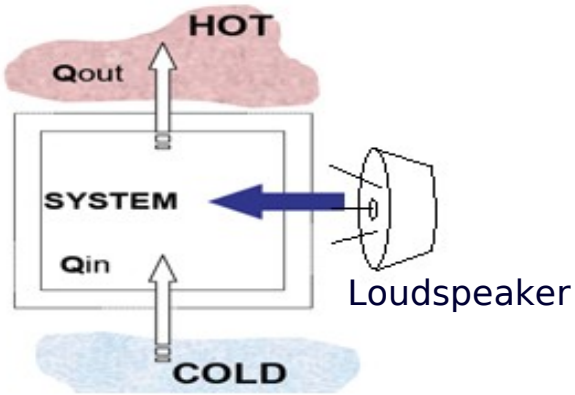
Definitions of the keywords used in the animation

Thermoacoustic Refrigerator

- ***The Principle of REFRIGERATION***:To pump heat from lower temperature to higher using work input.

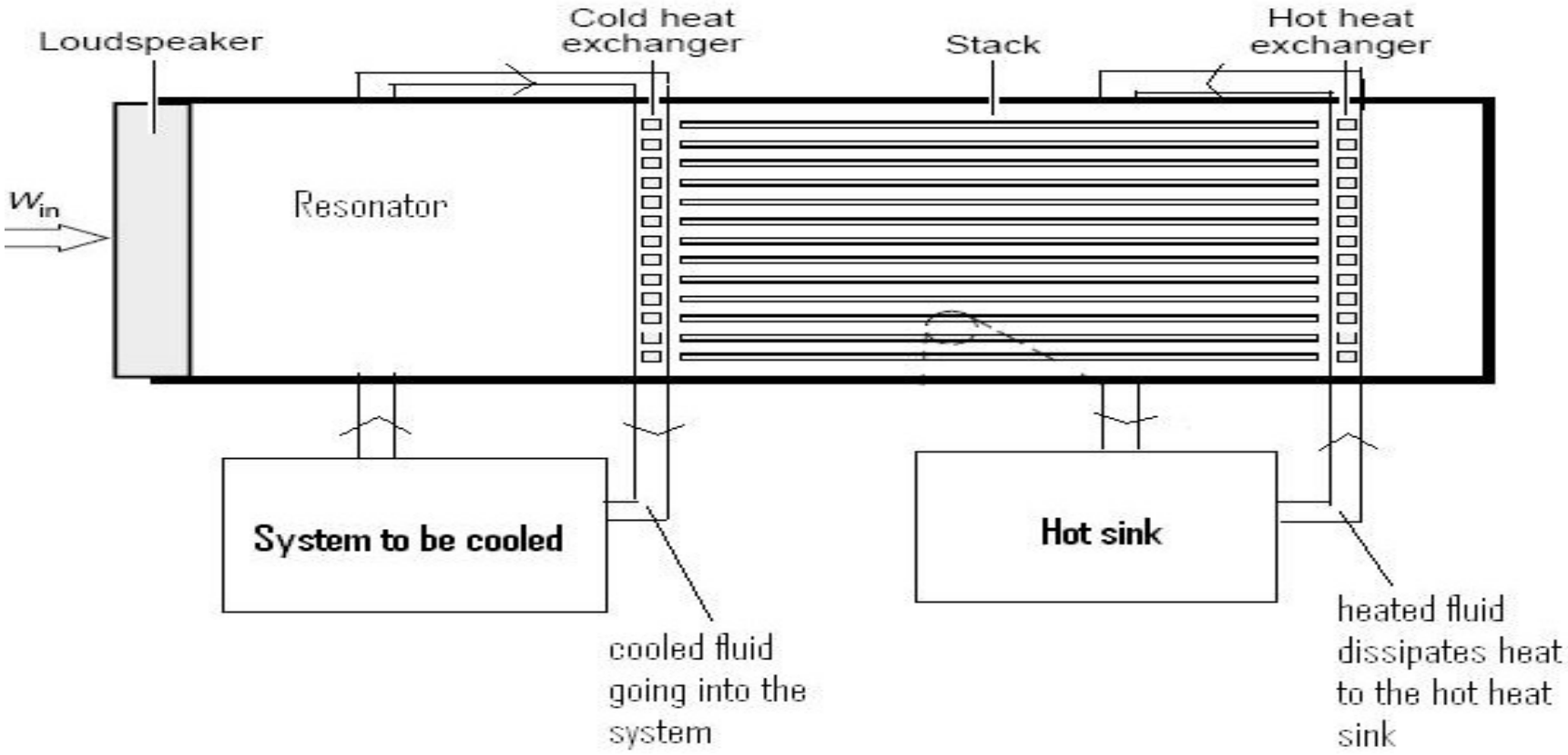


Moran and Shapiro, 2000, p.70



- The **Thermoacoustic refrigerator** employs high pressure waves for the required heat transfer

Thermoacoustic Refrigerator



www.lanl.gov/malonerefrigeration

The basic scheme of a thermoacoustic refrigerator

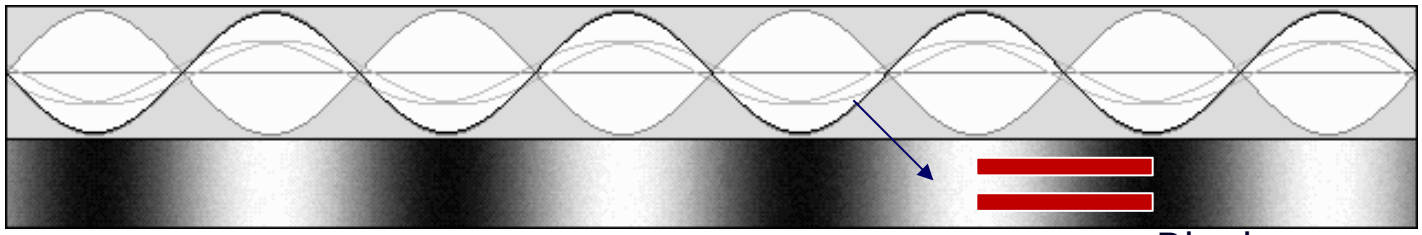
To explain how refrigeration can be realized using simple things like a loudspeaker

- Formation of standing pressure waves --- Refer to slide no.4
- Introduction of porous medium / blockage/plates in this standing wave ---- Again refer to slide no. 4
- Creation of temperature difference across the 2 ends of blockage … Refer to slides 5-8
- Trace of a point on the pressure-temperature diagram… Refer to slide 9

Describe the concept chosen and clearly illustrate how you want to explain the concept in the animation.

The Thermoacoustic Effect

- **Thermal + Acoustic**
  - generating sound using temperature gradient and vice-versa...



http://www.glafreniere.com/sa_plane.htm

Blockage eg. solid plates

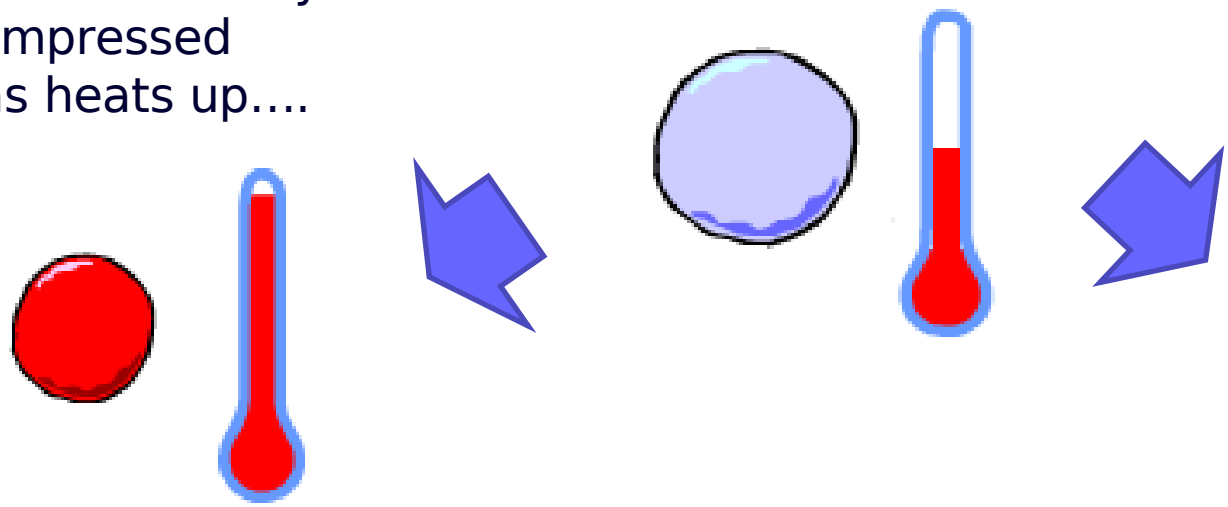
Thermal gradient across a blockage in an acoustic field
- refrigeration or a heat pump...

The Thermoacoustic Effect

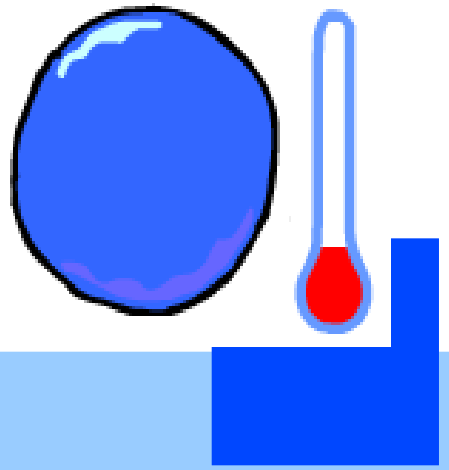
Gay Lussac's Law

$$T \propto P$$

An adiabatically compressed gas heats up….

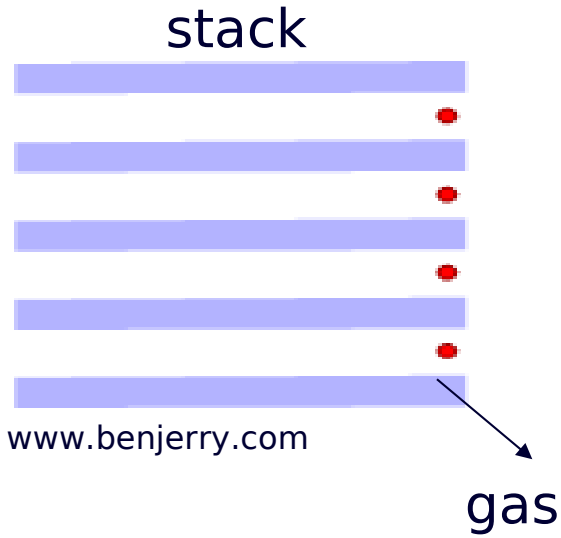


An adiabatically expanded gas cools down…

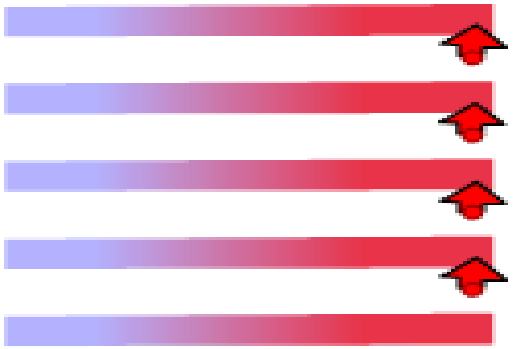


Standing wave Thermoacoustic Refrigerator

Working



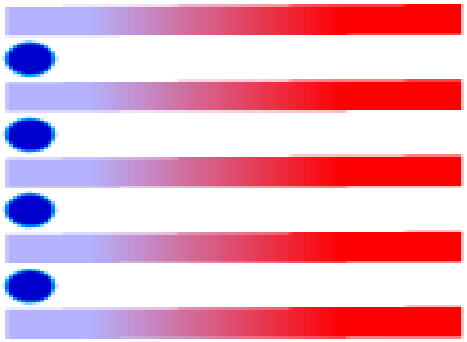
- Hot compressed gas at the right end of stack.



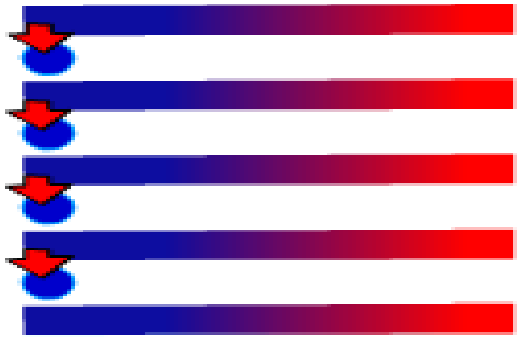
- Heat loss to stack. Stack temperature rises

Standing wave Thermoacoustic Refrigerator

Working (contd..)



- Gas expands while moving to left and cools.

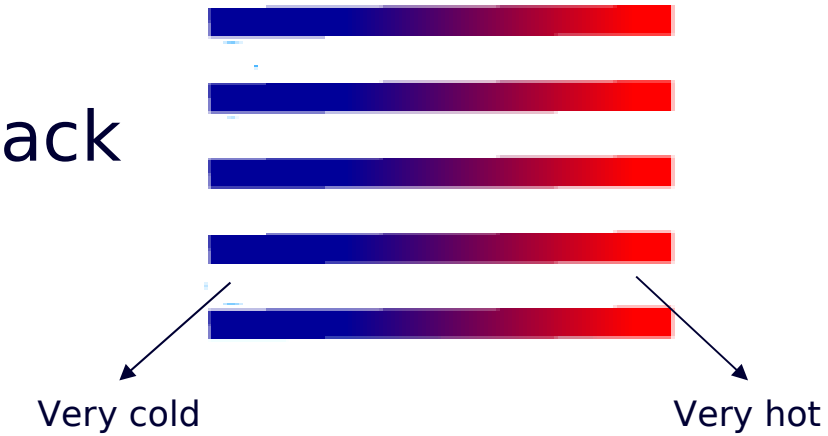


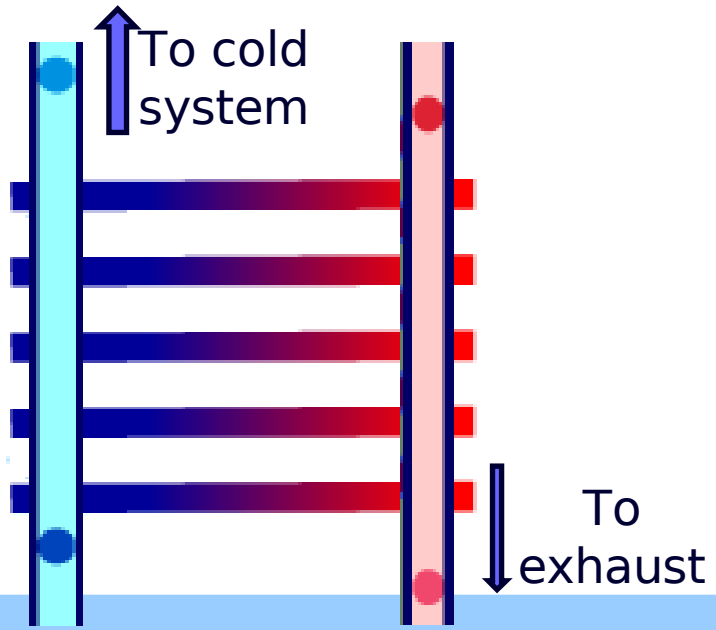
- Cold gas takes heat from stack. Stack becomes colder.

Standing wave Thermoacoustic Refrigerator

Working (contd..)

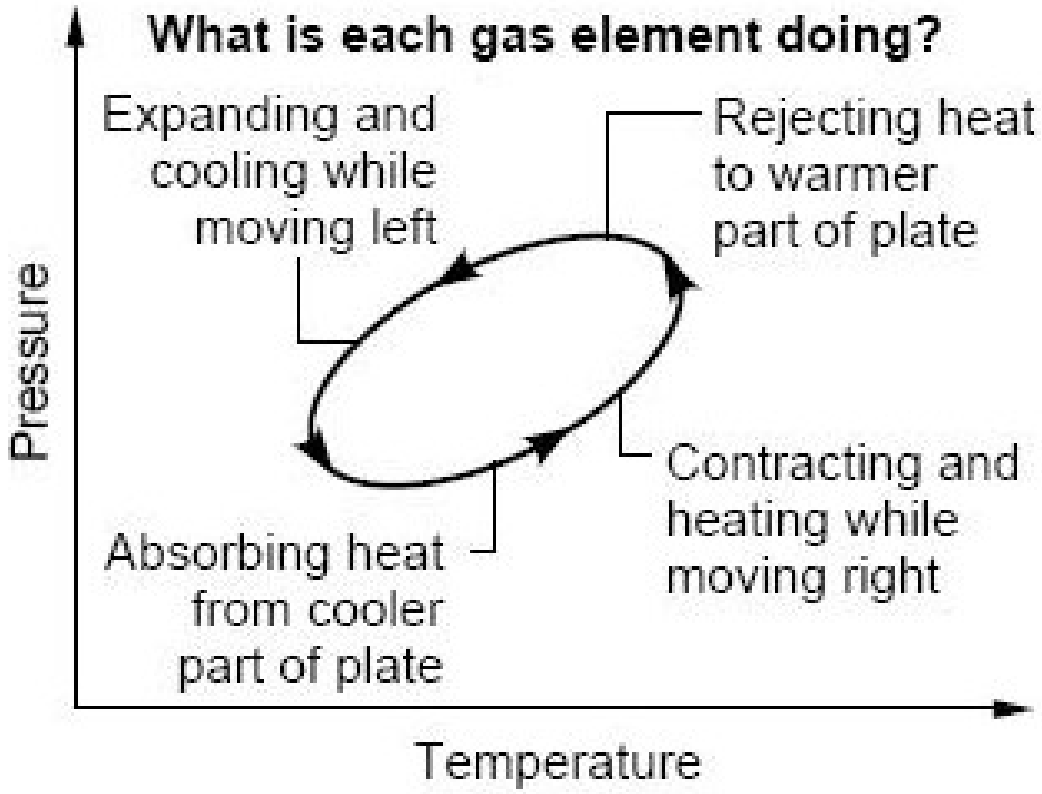
- Temp gradient across the stack is established.





- Circulating fluid picks up/loses heat at the heat exchangers.

Standing wave Thermoacoustic Refrigerator



www.lanl.gov/malonerefrigeration

- The P vs T plot of gas inside the resonator

· The user can move the ‘balloon’ of gas in the resonator. When the balloon is placed in high pressure region, it would shrink and its temperature will rise (it will become red). When moved to low pressure region, it expands becoming cold (blue)
·<Please refer to slide no. 5 which shows Gay- Lusaac’s Law

· The user may be given an option to simply assemble he setup, press the start button and see how things get cold inside the refrigerator

List out user interactions that will be there to enhance the understanding of the concept in the animation.

After going thru this animation, the viewer should be able to answer simple questions like:

1) Which component inputs power into the system?
a) Loudspeaker

2) What phasing does the sound wave posses?
A) Standing or stationary phasing

3) Can a ‘musical track’ make the system work?
A) No, the system works with a specific type of input signal (constant frequency) for which the system is designed

4) Will the loudspeaker make unnecessary noise in its vicinity?
A) No, the sound wave is confined to the resonator (Little buzz would be obviously heard outside, but not ‘noise’)

5) How can the system be used for creating ‘hot’ instead of cold?
(A question meant for ppl with basic refrigeration knowledge)
A) By controlling the cold heat exchanger temperature

A small questionnaire with answers based on the concept.

http://www.lanl.gov/thermoacoustics/

http://www.acs.psu.edu/users/sinclair/thermal/tafaq.html

http://www.acs.psu.edu/thermoacoustics/refrigeration/

http://www.youtube.com/watch?v=__UhEF8hghk

Links for further reading/references

1. Audio support required.
2. Color changes to be shown.
3. Gas bubble expansion-compression to be shown.
4. Standing wave generation to be shown.
5. Gas bubble moving through the temperature gradient to be shown for approx. 3 mins.
6. Theory will come in the left panel of the animation or in response to pressing a 'Theory' button.
7. Keywords should come in 'Glossary' section.
8. 'Help' button should give stepwise instruction of how to operate the animation.

Further User Specification

Theoretical Basics

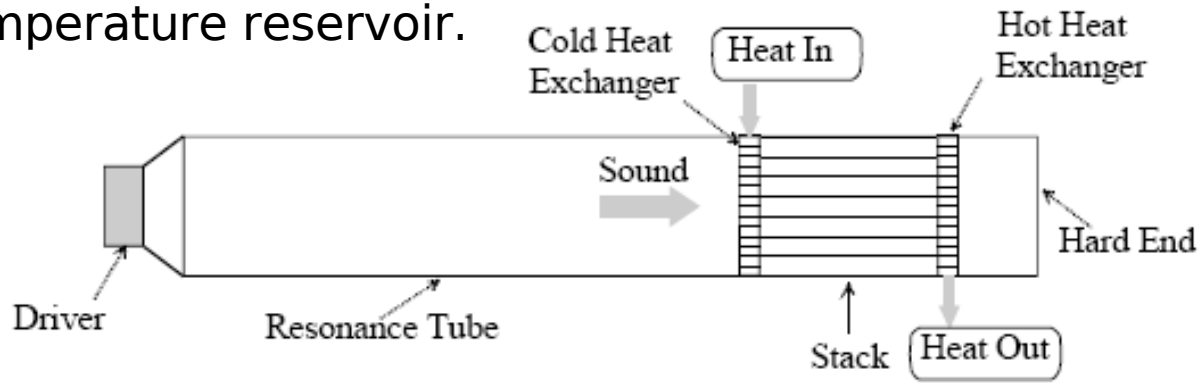
Pressure and displacement oscillations in a sound wave are accompanied by temperature oscillations. For an adiabatic sound wave propagating through an ideal gas, the temperature oscillations are related to pressure oscillations as :

$$\frac{T_1}{T_m} = \frac{\gamma - 1}{\gamma} \frac{p_1}{p_m}$$

In medium like air at STP and pressure amplitude of ordinary conversation (60 dB), the magnitude of temperature oscillations is about 10^{-4} ^{o}C and go undetected by human senses. Working at high pressure amplitudes, the thermal interaction of sound waves (fluid) with a different medium (a solid for instance) can result into sufficiently large amount of heat exchange between the fluid and the solid.
Thermoacoustic refrigerator is a special kind of device that uses energy of sound waves or acoustic energy to pump heat from low temperature reservoir to a high temperature reservoir.

Theoretical Basics

Thermoacoustic refrigerator is a special kind of device that uses energy of sound waves or acoustic energy to pump heat from low temperature reservoir to a high temperature reservoir.



The source of acoustic energy is called the ‘driver’ which can be a loudspeaker. The driver emits sound waves in a long hollow tube filled with gas at high pressure. This long hollow tube is called as ‘resonance tube’ or simply ‘resonator’. The frequency of the driver and the length of the resonator are chosen so as to get a standing sound wave in the resonator. A solid porous material like a stack of parallel plates is kept in the path of sound waves in the resonator. Due to thermoacoustic effect (which will be explained in detail in the animation), heat starts to flow from one end of stack to the other. One end starts to heat up while other starts to cool down. By controlling temperature of hot side of stack (by removing heat by means of a heat exchanger), the cold end of stack can be made to cool down to lower and lower temperatures. A refrigeration load can then be applied at the cold end by means of a heat exchanger.