DESIGN AND FABRICATION OF THERMOACOUSTIC REFRIGERATION SYSTEM

Under

ISHRAE Student Research Project Grant (SRPG)

by

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ABSTRACT

Thermoacoustic Refrigerators use acoustic power for generating cold temperatures. Development of refrigerators based on Thermoacoustic technology is a novel solution to the present day need of cooling, without causing environmental hazards. With added advantages like minimal moving parts and absence of CFC refrigerants, these devices can attain very low temperatures maintaining a compact size. The present work describes an in-depth theoretical analysis of standing wave Thermoacoustic refrigerators. This consists of detailed parametric studies, transient state analysis and a design using available simulation software. Design and construction of a Thermoacoustic refrigerator using a commercially available electro-dynamic motor is also presented.

Urbanization has improved the way for higher levels of comfort and standard of living. Rapid urbanization has thus caused an increase in the number of vehicles, refrigeration systems & Air Conditioners .On the other hand, is causing another set of problems including fuel consumption, CFC & HFC emissions, reduction in natural resources, environmental pollution, which leads to global warming etc. We need to consider the existence of a future generation and plan the utilization of our environment and resources wisely.

No moving parts for the process, so very reliable and a long life span. Simple & Compact design .Environmentally friendly working medium (air, noble gas) as there is no CFC's, HFC's emission. The use of air or noble gas as working medium offers a large window of applications because there are no phase transitions. Use of simple materials with no special requirements, which are commercially available in large quantities and therefore relatively cheap. On the same technology base a large variety of applications can be covered

INDEX

List of Symbols

Symbol	Meaning (SI Unit)
a	Sound velocity
δ_k	Thermal penetration depth
δ_{kn}	Normalized Thermal penetration depth
δ_v	Viscous penetration depth
c_p	Heat capacity or Specific heat (in this thesis mostly for stack)
β	Thermal expansion coefficient
T_m	Mean Temperature
ΔT_m	Temperature difference
k	Wave number
ΔT_{mn}	Normalized Temperature difference
Γ	Normalized temperature gradient
L_s / Δx	Stack Length
L_{sn}	Normalized Stack Length
ε_s	Stack heat capacity correction factor

σ	Prandtl number
Π	Perimeter
p_o	Dynamic pressure amplitude
p_m	Average Pressure
y_o	Half Stack spacing
l	Half plate thickness
K_s	Thermal conductivity of stack
K	Thermal conductivity of working fluid
ρ_s	Density of stack
f_k	Rott function
$(\nabla T)_{crit}$	Critical mean-temperature gradient
$x_s\ (x_m)$	Mean stack position from the pressure
γ	Isobaric/isochoric
f	frequency
ρ	Angular frequency
λ	Wavelength of acoustic standing wave
B	Blockage ratio/stack porosity
D	Drive ratio

Q_{cn}	Normalized Cooling Power
W_n	Normalized acoustic power
COP	Coefficient of performance
TA_{area}	Thermoacoustic area
VIS_{area}	Viscous area
TA (T_A)	Ambient temperature
TH (T_H)	Hot temperature
TC(T_C)	Cold temperature

Chapter No. 1

INTRODUCTION

1. INTRODUCTION

Background

Nikolaus Rott (1980) defined thermoacoustic as studies generally dealing with effects in acoustic in which heat conduction and entropy of a medium play a role.

If a system converts acoustic into energy, it is called a thermoacoustic refrigerator while a system converting energy to acoustic is called a thermoacoustic prime mover. There are two modes of a thermoacoustic system: the small standing wave thermoacoustic and traveling wave thermoacoustic. This study will focus on the standing wave thermoacoustic.

In 1777, Byron Higgins discovered thermoacoustic. Even though this is not a refrigeration system, the thermoacoustic effects have initiated investigations. For example, Sondhauss in the year 1850 had started a thermoacoustic oscillation research which was the best research of this category. Table 1 shows some of the studies done so far.

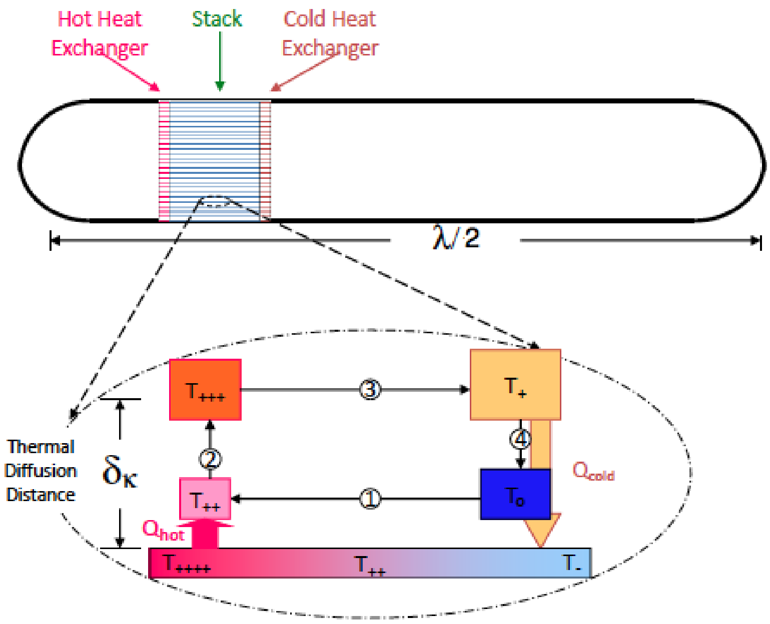

Fig 1

Importance of the stack

The stack is considered as the heart of a thermoacoustic system. Development and continuous improvement of it can better the overall performance of a thermoacoustic system. The heat transfer process crucial to thermoacoustic effects occurs in and near the stack region and current technology of the stack material and geometry has room for improvement based on the background completed. Various researchers have recommended various stack gap using latest discovery of the best performance stack material (i.e. Mylar). Theoretical analysis has shown a pin-array as better than parallel plate but the spiral roll kind is easiest to be fabricated with an acceptable ease. This study will look into possibility of using locally available materials with ease of assembly to produce optimized thermoacoustic effects.

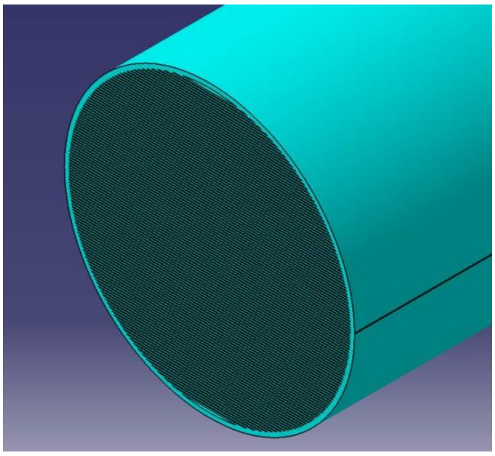

Fig 2

Objectives

The objective of this project is to identify the optimized stack geometry (material) of a thermoacoustic system and improve the overall efficiency of the thermoacoustic system.

Scope

The scopes are:

- To analyse the factors that affects the thermal performance of current thermoacoustic stacks.
- To design and manufacture stacks for various materials
- To perform tests and analyses on the stack performance based on the temperature difference attained across the stack
- To develop this system for automobile and refrigeration commercial use

Chapter No. 2

LITERATURE REVIEW

LITERATURE REVIEW

Bheemsha - Design of the Resonator Tube and Buffer Volume for Thermoacoustic Refrigerator, International journal of Advanced Scientific and Technical Research Issue 1, Vol 2 December 2011 ISSN **2249-9954 Page**

- The work reported here deals with the design of a resonator and buffer volume for a Thermoacoustic Refrigerator (TAR) as an attempt to address the future generation environment friendly energy system.

- The motivation of the design of thermoacoustic refrigerator explains the reasons for carrying out the work illustrating its benefits and how the performance of the TAR in future can be made efficient in comparison with the performance of a conventional refrigerator.
- An attempt has been made to design the TAR resonator tube and buffer volume.

- Further modelling is done by using CATIA .

- Design of a resonator and buffer volume for a Thermoacoustic Refrigerator (TAR) as an attempt to address the future generation environment friendly energy system.

- An attempt has been made to design the TAR resonator tube and buffer volume.

THERMOACOUSTIC COOLING WITH NO REFRIGERANT

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- The Report has placed sustainability of energy resources and environmental degradation on a common global agenda.

- Increasing awareness has spurred much research into alternative clean energy technologies.

- Thermoacoustic cooling as an environmentally friendly refrigeration system is one of the research areas being pursued.

- Sustainability, green technology, and renewable energy have been among the household words discussed by governments across the globe this last century.

- The Report has placed environmental issues on a common political agenda for active participation of all towards a sustainable world.

- Thermoacoustic cooling have been achieved quite simply without any refrigerants or use of a compressor under atmospheric conditions.

- Although the temperature drop below ambient was small, the clean technology poses as a potentially attractive alternative to the conventional system in view of the increasing concern over the degradation of the environment caused by refrigerants from the cooling industries.

Swift GW, —Thermoacoustic engines, Journal of Acoustic Society of America, 84, pp.

1146-80, 1988.

- Thermoacoustic heat engines (TAEs) are potentially advantageous drivers for thermoacoustic refrigerators (TARs).

- Connecting TAEs to TARs means that waste heat can effectively be utilized to provide cooling, and increase overall efficiency. However, this is currently a niche technology.

- Improvements can be made through a better understanding of the interactions of relevant design parameters. This work develops a novel mathematical programming model to optimize the performance of a simple TAE.

- The model consists of system parameters and constraints that capture the underlying thermoacoustic dynamics. We measure the performance of the engine with respect to several acoustic and thermal objectives(Including work output, viscous losses and heat losses).

- Analytical solutions are presented for cases of single objective optimization that identify globally optimal parameter levels.

- They also considered optimizing multiple objective components simultaneously and generate the efficient frontier of Pareto optimal solutions corresponding to selected weights.

Thermoacoustic Refrigeration for the Automotive Industry
Luke Zoontjens GradIEAust Carl Q. Howard, Anthony C. Zander, Ben S. Cazzolato
School of Mechanical Engineering The University of Adelaide, South Australia

- Thermoacoustic refrigeration is an emerging ‘green’ technology and thermoacoustic devices are broadly divided into two distinct classes, but both involve an exchange between acoustic and thermal energy.

- Using a simple loudspeaker, intense sound waves in excess of 180 decibels of sound pressure are formed inside the refrigerator, maintaining a temperature 12°C below ambient with just 700kPa (7 bars) of compressed air.

- Future studies later this year will also explore the full capabilities of the TAR using helium gas and significantly higher acoustic power inputs from a thermoacoustic heat engine.

- The scalability of the technology means that products resulting from this research could include tiny coolers for CPUs to combined domestic air-conditioning and hot water services using solar heat.

- Such refrigeration systems should produce significantly greater benefits to the environment and user alike.

Construction and performance of a thermoacoustic refrigerator M.E.H. Tijani, J.C.H. Zeegers, A.T.A.M. de Waele * Department of Applied Physics, Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, Netherlands

- During the last two decades thermoacoustic refrigeration is explored as a new cooling technology.

- Thermoacoustic refrigerators are systems which use sound waves to produce cooling power.

- They consist of a loudspeaker, attached to one end of an acoustic resonator(tube), which is closed at the other end

  .

- The loudspeaker sustains an acoustic standing wave in the resonator

- The construction of the different parts of the refrigerator is described in detail.

- The system has been assembled and the first performance measurements have been done.

- The measurements show that the system behaves very well as expected

Chapter No. 3

STACK AND ITS GEOMETRY

3. STACK AND ITS GEOMETRY

Thermoacoustic stack

Thermoacoustic stack is the passage through which the gas particles will flow. Temperature difference will be created on either side of the stack. Figure 3.2 shows the thermoacoustic cycle occurring between gas parcel and resonator wall. Fig. 3.1 shows the position of stack present in the set up. The gas particles travel in the stack to create a hot end and cold end in the stack. Stack is the heart of the thermoacoustic system. Various type of stack can be used in the set up depending upon the efficiency required. There are three key parameters of stack –

1) Geometry
2) Dimensions
3) Material

All of them are discussed in the chapter in detail.

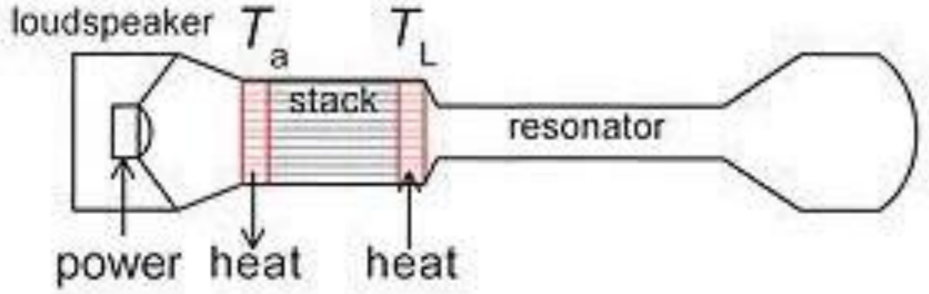


Fig 3: Stack in thermoacoustic set up

The figure traces the basic thermoacoustic cycle for a packet of gas, a collection of gas molecules that act and move together. Starting from point 1, the packet of gas is compressed and moves to the left. As the packet is compressed, the sound wave does work on the packet of gas, providing the power for the refrigerator.

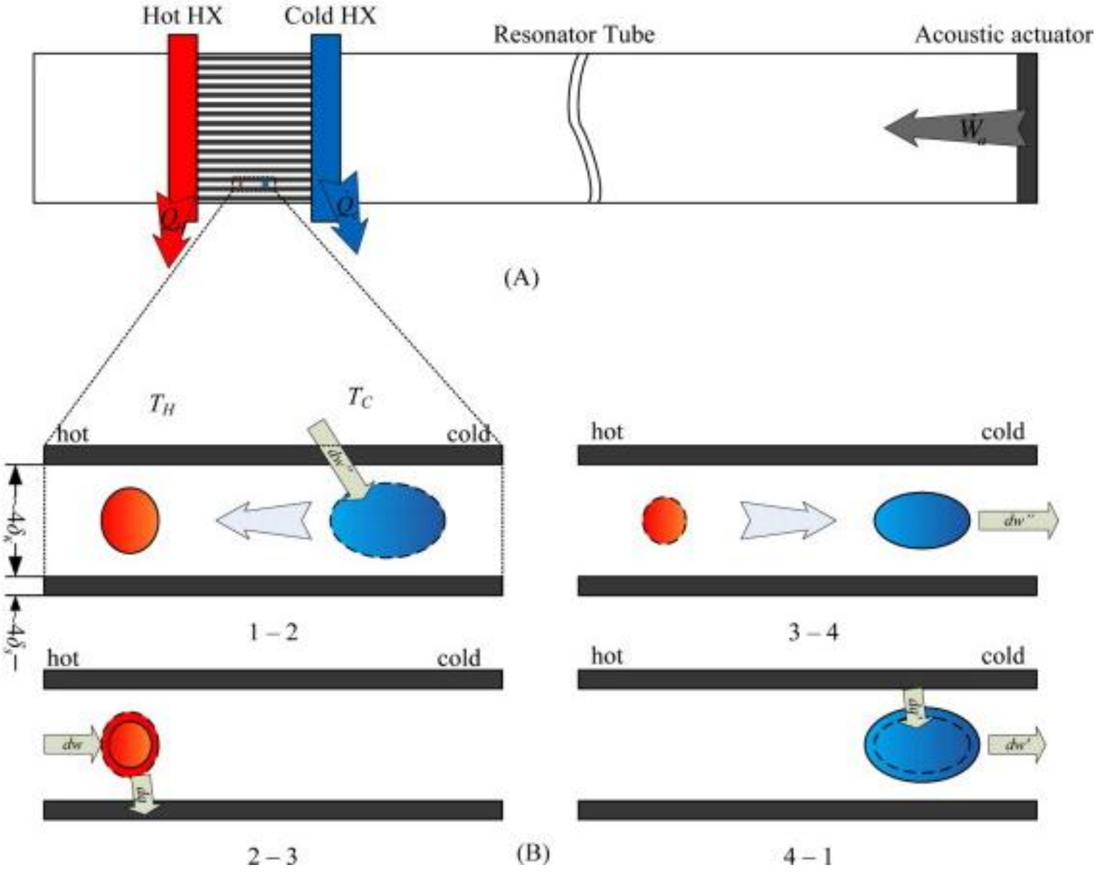


Fig 4

Stack Description

Figure , shows a cross section of a parallel plate stack. The separation between one to the other plate is called plate separation or gap, $2y_o$ while the plate thickness is symbolized by $2l$.

Figure shows the length of the stack, L_S and the stack parameter, Π is given by the equation

$$\Pi = \frac{A}{y0+l}$$

One important parameter in the stack is the blockage ratio or sometimes called the stack porosity. This is given by the equation

$$B = \frac{y0}{y0+l}$$

This parameter is the ratio of the unblocked area with the total area. A high value of B will decrease the thermoacoustic area. But this will increase the amount of the gas parcel in the system. Increasing B will make the stack plate where thermoacoustic effects occur small but the gas parcels is more. So the blockage ratio requires a compromise between blockage area and total area.

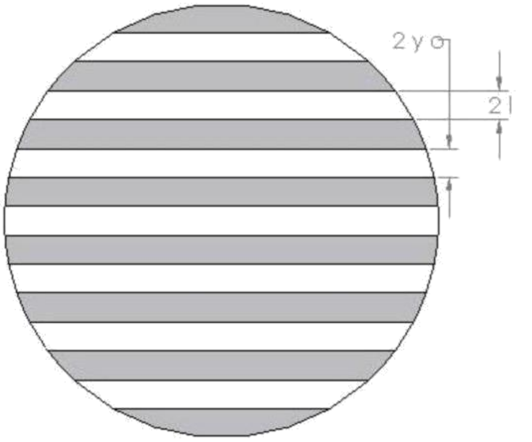


Fig 5

Many stack geometry have been proposed by researchers. Figure shows some of the geometry that has been used.

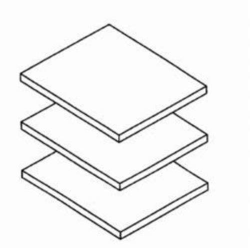


Fig 6

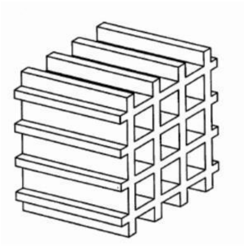


Fig 7

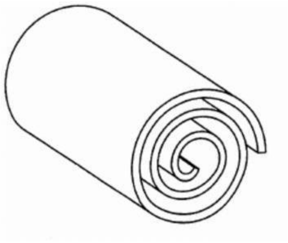


Fig 8

Stack type, (a) Parallel plate, (b) Square Honey Comb, (c) Rolled sheet (spiral round) (R. M. Keolian and G.W.Swift (1995)

Stack Design

A simple design may not be easy to fabricate. Some of the parameters to be considered are:

- Stack spacing or Separation/gap, ($2y_o$)
- Average Pressure (p_m)
- Stack Position, (x_s)
- Stack thickness (l), Stack length (L_S)and Blockage ratio (B)

The dimensions of a stack spacing, $2y_o$ for a thermoacoustic system depends on the Rott function, f_k (discussed later) to get the relation between half of the stack plate spacing, y_o and thermal penetration depth, δ_k. given by

$$\delta k = \sqrt{\frac{2k}{\rho m\ Cp\ \omega}} = \sqrt{\frac{k}{\rho m\ Cp\ \pi f}}$$

Where,

K = Gas thermal Conductivity

ρ_m = Gas density

c_p = Gas heat capacity

$\kappa = K/\rho_m\ c_p$

ω = angular frequency, = $2\pi f$

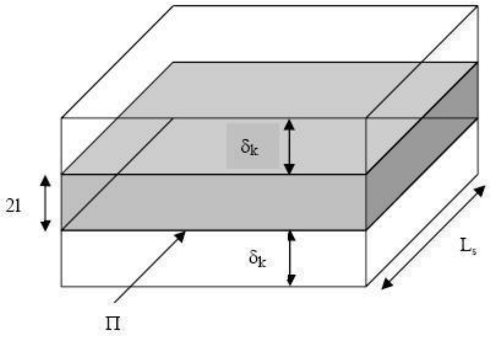
Thermal penetration depth approximates the distance that the heat can diffuse through the fluid during a time 1/πf (2/ω). This means the gas situated much farther than δk from the solid body cannot communicate thermally with that body. This will make the gas respond adiabatically to the acoustic wave. A large value maximizes the thermoacoustic area. Sometimes this is referred to as useful area and thermoacoustic area.

While viscous penetration depth is the distance over which momentum can diffuse in time 1/πf (2/ω). This is given by the following equation. Sometimes this is known also as dissipate or lossy or losses area.

$$\delta v = \sqrt{\frac{2\mu}{\rho m\, \omega}} = \sqrt{\frac{2\mu}{\rho m\, \pi f}}$$

The optimum stack spacing according to Arnott (1991) is about 2.2δk. According to Tijani (2001) the optimal stack spacing is about 3δk. while Swift (1988) stated that it is 4δk. That reason of this uncertainty is because the Arnott's is based on theory and numerical while Tijani make the conclusion based on the experimental result. While Swift based his on ease of fabrication. But the values proposed are still in the range of 2δk to 4δk which is proposed by Wheatley (1985).

Fig 9



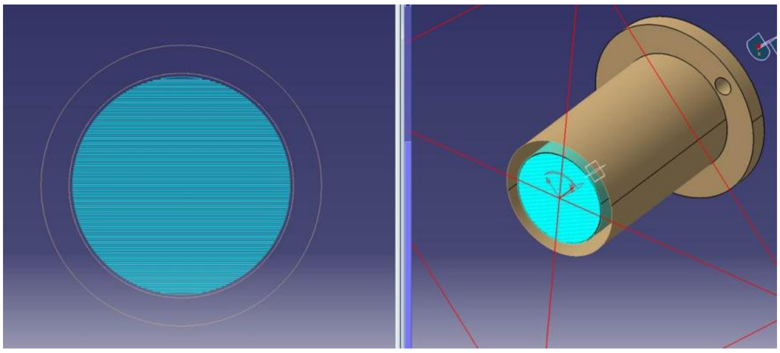


Fig 10

Factors affecting stack performance-

Geometry

(a) Circular
(b) Parallel
(c) Honey comb
(d) Pin array

Design

(a) Stack thickness, $2l$
(b) Stack gap, 2yo
(c) Blockage ratio, B
(d) Pressure
(e) Stack length, Ls
(f) Stack position, xs

Material

(a) Thermal conductivity, k
(b) Heat capacity, Cp

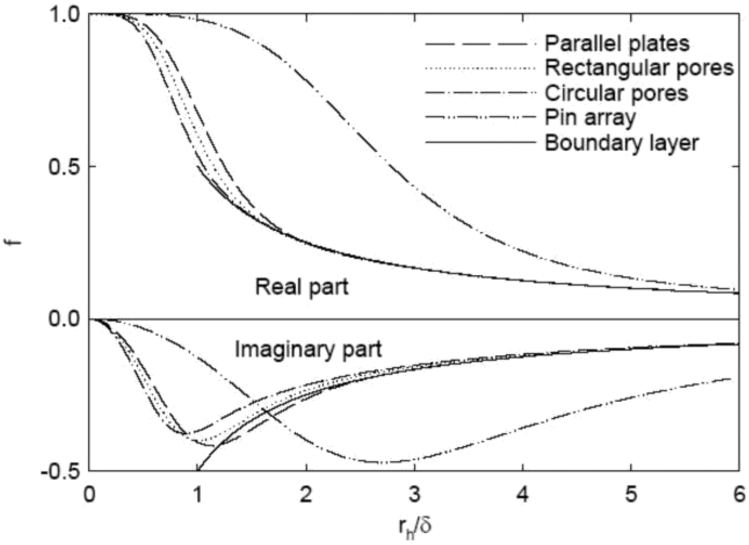


Fig11: Rott's Function for some geometry (G.W. Swift 2001)

A geometry with a maximum $\mathrm{Im}(-f_k)$ is desired. It is because of the similar pattern with the boundary layer in the Figure.

Thermoplastic Properties for Stack

Thermoplastic having thermal capacity low and heat capacity high, which gives the cooling effect

Table 1: Thermoplastic Properties

	Thermoplastic	Thermal conductivity	Specific heat
1	Polylactic acid (PLA)	0.13W/m-k	1800J/kg-k
2	Acrylonitrile-Butadiene-Styrene	0.19 W/m-k	1675 J/kg-k
3	Mylar or Hostaphan	0.15 W/m-k	1350 J/kg-k
4	Polyamide nylon 6,6	0.25 W/m-k	1670 J/kg-k

Combinations of stacks-

Different combinations of stack can be used at a single time to get a greater efficiency. The combinations of stacks that we considered are as follows –

- Parallel Stack
- Honey comb Stack

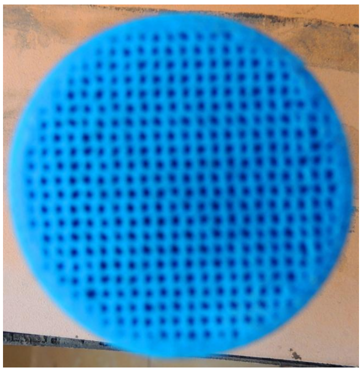


Fig 12

Fig 13

Figure a show the circular stack geometry and figure b shows the circular type stack geometry. Both the geometries can be combined by aligning them in front of each other so as to create a better effect. Combination of stacks or selection of stacks depends on various factors.

Chapter No. 4

Gases and other components

4. GASES AND OTHER COMPONENTS

GASES

The values of Prandtl number are smaller for inert gases compared to others. That is why most of the researchers use the inert gas because of the low Prandtl number.

Values of Prandtl number for different gases.

Gases	Prandtl number, Pr (σ)
Air	0.713
Argon	0.667
Ammonia (NH3)	0.889
Carbon dioxide (CO2)	0.764
Carbon monoxide (CO)	0.694
Fluorine (F2)	0.74
Helium (He)	0.664
Hydrogen (H2)	0.706
Methane(CH4)	0.74
Nitrogen (N2)	0.721
Oxygen (O2)	0.730
Refrigerant 12 (Freon 12, CCl2F2)	0.8
Refrigerant 22 (Freon 22, CHCl2F2)	0.77

Table 2: Values of Prandtl number for different gases

We considered the following combinations for the selection of gas -

- Helium + Argon
- Helium
- Nitrogen

The gases are selected on the basis of their availability, cost and other factors.

Properties of the gases -

Property	Helium	Neon	Argon	Krypton	Xenon	Radon
Density (g/dm^3)	0.1786	0.9002	1.7818	3.708	5.851	9.97
Boiling point (K)	4.4	27.3	87.4	121.5	166.6	211.5
Melting point (K)	0.95	24.7	83.6	115.8	161.7	202.2
Enthalpy of vaporization (kJ/mol)	0.08	1.74	6.52	9.05	12.65	18.1
Solubility in water at 20 °C (cm^3/kg)	8.61	10.5	33.6	59.4	108.1	230
Atomic number	2	10	18	36	54	86
Atomic radius (calculated) (pm)	31	38	71	88	108	120
Ionization energy (kJ/mol)	2372	2080	1520	1351	1170	1037
Allen electronegativity	4.16	4.79	3.24	2.97	2.58	2.60

Table 3: Properties of the gases

Few more details of gases taken into consideration

Helium

Helium is a chemical element with symbol **He** and atomic number 2. It is a colourless, odorless, tasteless, non-toxic, inert, monatomic gas, the first in the noble gas group in the periodic table. The He boiling and melting points are the lowest among all the elements.

Helium is the second lightest element and is the second most abundant element in the observable universe, being present at about 24% of the total elemental mass, which is more than 12 times the mass of all the heavier elements combined. Its abundance is similar to this figure in the Sun and in Jupiter. This is due to the very high nuclear binding energy (per nucleon) of helium-4 with respect to the next three elements after helium. This helium-4 binding energy also accounts for why it is a product of both nuclear fusion and radioactive decay. Most helium in the universe is helium-4, and is believed to have been formed during the Big Bang. Large amounts of new helium are being created by nuclear fusion of hydrogen in stars.

Argon

Argon is a chemical element with symbol **Ar** and atomic number 18. It is in group 18 of the periodic table and is a noble gas. Argon is the third most common gas in the Earth's atmosphere, at 0.934% (9340 ppmv), making it over twice as abundant as the next most common atmospheric gas, water vapour (which averages about 4000 ppmv, but varies greatly), and 23 times as abundant as the next most common non-condensing atmospheric gas, carbon dioxide (400 ppmv), and more than 500 times as abundant as the next most common noble gas, neon (18 ppmv).

Nitrogen

Nitrogen is a chemical element with symbol **N** and atomic number 7. It is the lightest pnictogen and at room temperature, it is a transparent, odorless diatomic gas. Nitrogen is a common element in the universe, estimated at about seventh in total abundance in the Milky Way and the Solar System. On Earth, the element forms about 78% of Earth's atmosphere and is the most abundant uncombined element. The element nitrogen was discovered as a separable component of air by Scottish physician Daniel Rutherford in 1772.

SPEAKER

Fig 14 PMMC Speaker

Speaker is essential part in Thermoacoustic system as it the source through which the sound is generated. The speaker to be used must be of the frequency between 250 Hz to 400 Hz.

Below is the example of how speaker i.e. sound waves disturb the surrounding medium.

In an electronic signal, high values represent high positive voltage. When this signal is converted to a sound wave, you can think of high values as representing areas of increased air pressure. When the waveform hits a high point, this corresponds to molecules of air being packed together densely. When the wave hits a low point the air molecules are spread more thinly.

In the diagram below, the black dots represent air molecules. As the loudspeaker vibrates, it causes the surrounding molecules to vibrate in a particular pattern represented by the waveform. The vibrating air then causes the listener's eardrum to vibrate in the same pattern. Voilà — Sound!

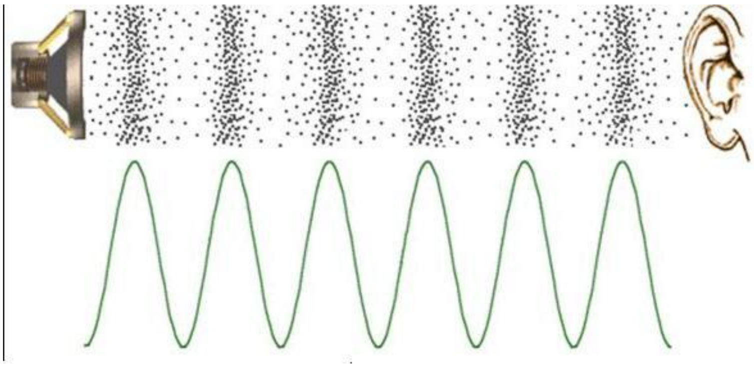


Fig 15: Sound Waves

Sound velocity(a) :

$$a = \sqrt{\frac{\mathrm{R} \times \gamma \times \mathrm{T}}{\mathrm{M}}}$$

HEAT EXCHANGER

A heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air.

In thermoacoustic refrigeration there are two heat exchangers used, both adjacent two stacks. The temperature difference produces in the stack is absorbed by the heat exchangers to produce refrigeration effect. It is made up of copper tubes of 10 mm and 5mm.

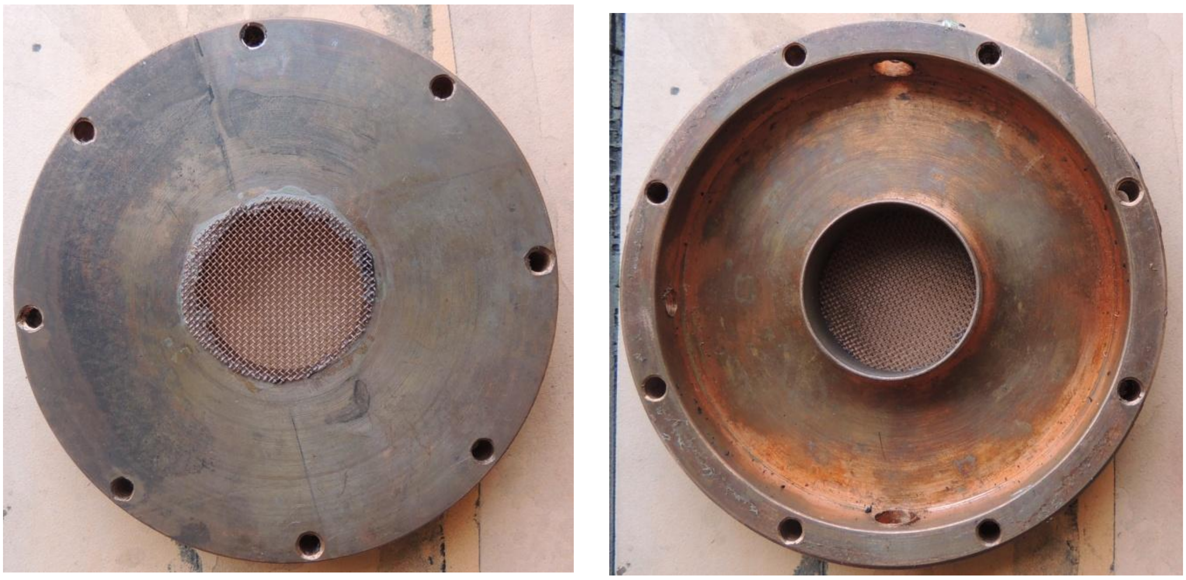


Fig 16: Heat exchanger used in the system

RESONATOR TUBE-

The design of the resonator also plays a big role in the thermoacoustic efficiency. Resonator length is calculated by the wavelength, λ (whether λ/2 or λ/4). The wavelength is the distance between repeating units of a propagating wave of a given frequency. Figure shows an example of λ/2 resonators. The optimization of resonator shape will not be considered here. But for simplicity a λ/4 (λ is wave length) type of tube is used. This is because the λ/4 will only dissipate half the energy compared to the λ/2 tube (Hofler, 1986).

The total length of the resonator is

$$L=\frac{\lambda}{4}$$

The length of resonator tube used in the system is 260 mm.

Fig 17 Resonator tube

3.3 Resonator

The design of the resonator also plays a big role in the thermoacoustic efficiency. Resonator length is calculated by the wavelength, λ (whether λ/2 or λ/4). The wavelength is the distance between repeating units of a propagating wave of a given frequency. Figure 1.6 shows an example of λ/2 resonators. The optimization of resonator shape will not be considered here. But for simplicity a λ/4 (λ is wave length) type of tube is used. This is because the λ/4 will only dissipate half the energy compared to the λ/2 tube (Hofler, 1986).

$$\lambda = \frac{a}{f}$$

$$\text{Resonator Length(LR)} = \frac{\lambda}{4} \text{ OR } \frac{\lambda}{8} \text{ OR } \frac{\lambda}{20}$$

For this tabletop refrigeration, the gas will always be air. So the properties for Air at 27°C or 300K are:

$K = 26.3 \times 10^{-3}$ W/m.K ρ_m
= 1.18 kg/m^3

c_p = 1005.5 J/kg.K

$\mu = 184.6 \times 10^{-7}$ Ns/m^2 a =
349.16m/s^2

Using these value λ and L are determined using by equations 2.3 and 2.4.

$$\lambda = \frac{349.16}{400} = 0.8729$$

$$\lambda/4 = 0.218m$$

$$= 21.8cm$$

BUFFER VOLUME-

Buffer volume is expanded part of resonator tube which is primarily used to cool the gas particles through expansion process and then the gas particles oscillate back to the stack from the buffer volume.

Fig 18 Buffer volume

THERMOCOUPLES –

Fig 20 K type Thermocouples

Thermocouples are mounted on both the heat exchangers to measure the temperature difference between the two ends of the stack.

AMPLIFIER-

Fig 21 an Amplifier

An Amplifier is used in the project to generate signals for the loudspeaker, which, in turn produce sound waves which moves the gas particles present in the thermoacoustic tube.

Chapter No. 5

FABRICATION

5. FABRICATION

Fabrication

To get the thermal performance of a stack, the refrigeration system needs to be fabricated and tested. The fabrication consists of the tabletop and fabrication of the stack.

The fabrication follows the one proposed by D.A. Russell and P.Weibull (2001). It consists of 5 parts. Nylon Rod used as the resonator, a loudspeaker to transfer the sinusoidal wave, the cover for the base of the resonator and an o-ring to seal the loudspeaker and resonator. A schematic system is shown in Figure .

As seen from Figure , the hot junction, T_H , is placed about 1cm above the stack to measure the hot temperature, while the cold junction, T_C is placed about 1cm below the stack. The ambient temperature, T_A is measured somewhere near the system in about 1meter distance away.

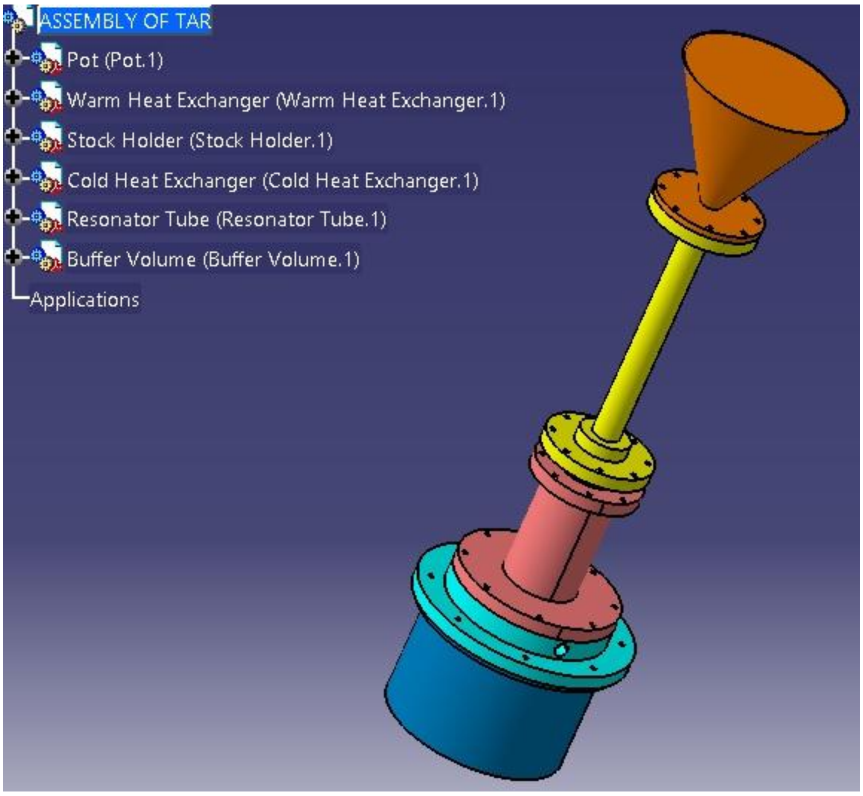


Fig 22 : Thermoacoustic refrigeration.

The figure fabricated shown in figure 3.2, is for testing of the stack in this study. This will make the stack assembly and disassembly for other types of stack simpler. The easily available parts are another factor in selecting the tabletop as a device to measure the stack performance. The position of the stack is placed using the Swift (2001) suggestion, $\lambda/20$, about 4.37cm. The stack fabrication parts are considered as one of the difficult parts in the project. This is because the stack is small in dimension with small separation. Table 3.1 shows some of the stack material and geometry to be fabricated.

Stack Material	**Stack Geometry**
Mylar	Parallel plate Spiral
Straw	Honeycomb

Table 4 Stack Material

The fabricated stack will be placed in the tabletop thermoacoustic refrigeration in Figure 3.2 and the tabletop thermoacoustic refrigeration is ready to be tested. The procedures of fabricating the stack consist of three types of stack:

Using the simplification proposed by Wheatley, $2y_0$ should be around $2\delta_k \sim 4\delta_k$ .Thus the

range for his study will be 0.266mm ~ 0.532mm. However, the fishing line available is either 0.4mm or 0.50 mm and these are the lines that will be used in the experiments. The stack sheet is cut into a long 50mm width piece, as shown in Figure 3.3. Many pieces of these may be glued together to form a long piece to be rolled into a spiral stack later (Figure 3.4). Many pieces of 50mm length fishing length fishing line are then cut and glued onto the stack material that has already been prepared. Glue is then applied thinly over the lines to avoid additional gap beside the diameter of the line. A core is added to make rolling of the stack easier, as was done by Hofler (T.J. Hofler, 1986) shown here in figure

Stack was also done by the help of latest technology . 3D printing is used to make an accurate stack along with very small dimensions . PLA (Polylactic Acid) is available material in 3D spool which has been used in manufacturing of Stack.

Fig 23 : Mylar film Stack

Fig 24 : Fishing line

Fig 25 : The mylar spiral stack with core

Fabrication of the parallel plate is harder than the spiral stack because the tack pieces must be cut to fit the resonator tube before assembly. A fishing line is used to hold the parallel plate stack together. A schematic of parallel stack is shown in Figure 3.6.

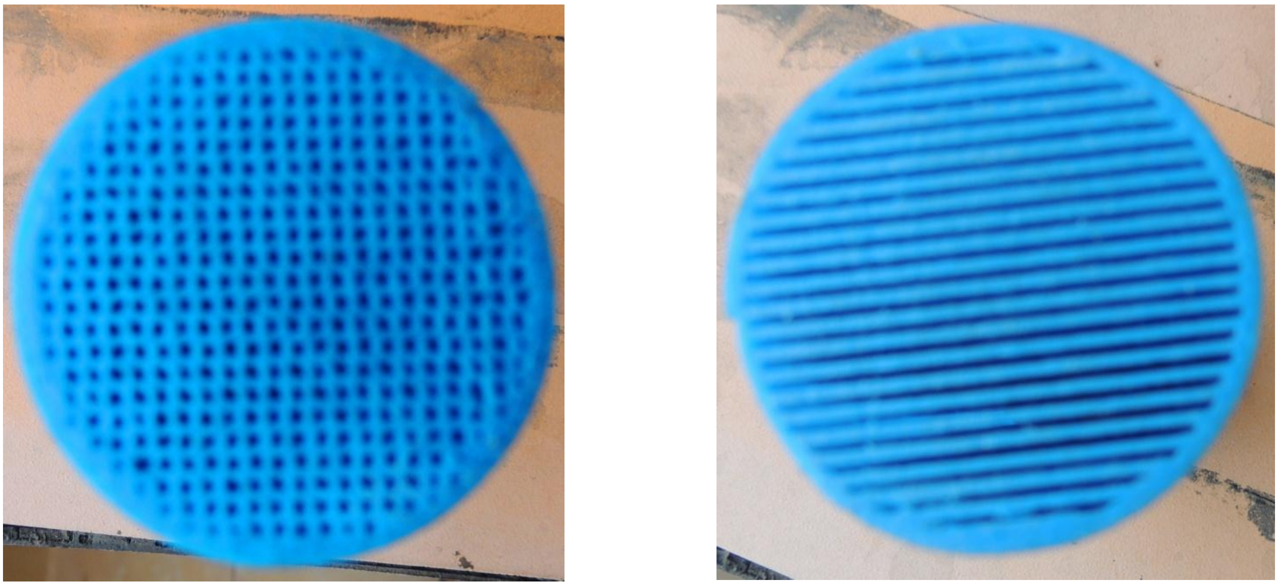
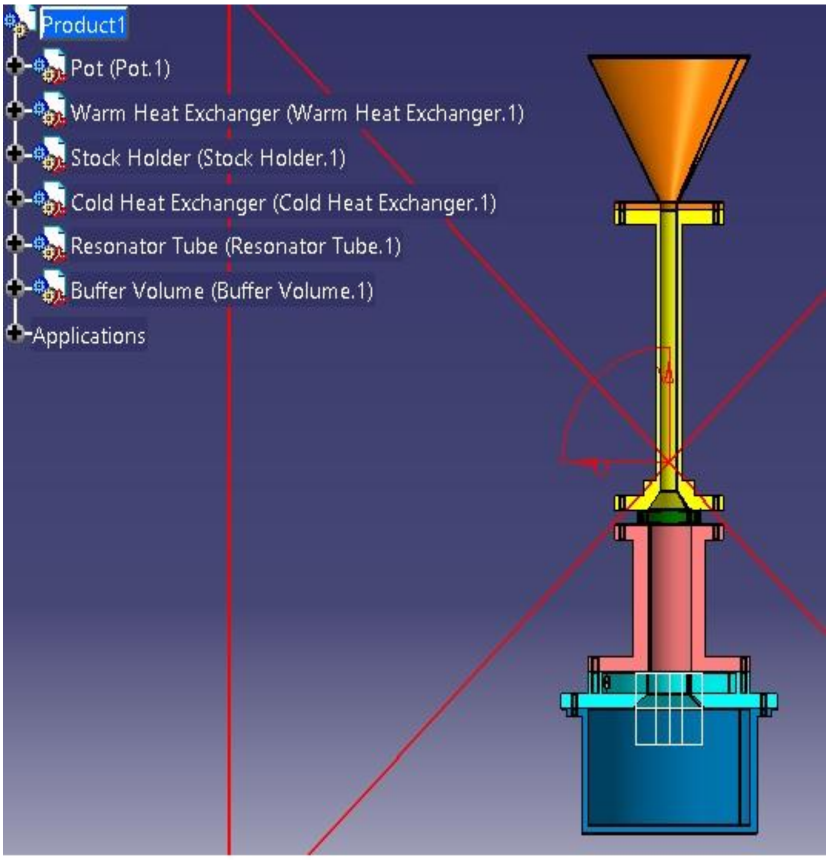


Fig 26 : 3D Printed Stack types

Buffer volume :- Buffer Volume is a conical shape device made up of SS 304 material having capacity 1000 m^3

Fig 27 : Buffer volume

Fig 28 : Assembly of Thermoacoustic refrigeration system



Chapter No. 6

BILL OF MATERIALS

SR NO.	**NAME OF COMPONENT**	**MATERIAL**	**COST (IN RS)**	**QUANTITY**
1	**GAS CONTAINER**	**MILD STEEL**	**4570**	1
2	**SPEAKER**	**PMMC**	**920**	**2**
3	**HOT HX**	**COPPER**	**1850**	**1**
4	**COLD HX**	**COPPER**	**2230**	**2**
5	**STACK HOLDER**	**NYLON ROD**	**890**	**1**
6	**STACK**	**PLA**	**4600**	**2**
7	**RESONATOR TUBE**	**NYLON ROD**	**1370**	**1**
8	**BUFFER VOLUME**	**SS 304**	**2000**	**1**
9	**FLANGES**	**SS 304**	**4520**	**4**
10	**THERMOCOUPLE 2 INCHES**	**K-TYPE**	**1000**	**5**
11	**GAS CONTROL VALVE**	**BRASS**	**1735**	**1**
12	**NRV**	**BRASS**	**150**	**1**
13	**COPPER TUBE AND HOSES**	**COPPER,NYLON**	**560**	**2**

14	**PRESSURE GAUGE**	**--------**	**950**	**3**
15	**FABRICATION COST**	**--------**	**12000**	**-------**
16	**MISCELLANEOUS**	**---------**	**1230**	**--------**
TOTAL COST:- RS. 40,580				

Table No 5

Chapter No. 7

CONCLUSION AND RECOMMENDATIONS

7. CONCLUSION AND RECOMMENDATIONS

Conclusions

This is not an entire listing of most favorable thermoacoustic refrigeration system, whereas it's only a summary of optimization. No doubt each effort is an important contribution to thermoacoustic refrigeration. This supposed not to be assumed optimization in conventional sense, nevertheless its only parametric study. In each possibility, all most favorable design is a local optimum as the optimization execute by each researcher can be considered with only one variable while maintaining other parameters the same. To develop more effective system and decrease price, improvements must be required into stack design, resonator and small but more efficient heat exchanger for fluctuating stream. Furthermore, it necessary to developed an open system which will decrease or eliminate the utilization of heat exchanger plus it will decrease complication and price. Thermoacoustic refrigerators are likely to be lightweight, compact, and contain no harmful refrigerants. These aspects will make it a very appealing option in the future.

Recommendations

The recommendations regarding this study to increase the system efficiency are

Future studies will also explore the full capabilities of the TAR using helium gas and significantly higher acoustic power inputs from a thermoacoustic heat engine. The scalability of the technology means that products resulting from this research could include tiny coolers for CPUs to combined domestic air-conditioning and hot water services using solar heat. Such refrigeration systems should produce significantly greater benefits to the environment and user alike.

Chapter No.8

FUTURE SCOPE

Future Scope :-

The use of inexpensive, household items to construct the refrigerators could explain such low efficiency. If other materials were used, it is possible that the factor that could be adjusted for optimization. The stack works best when it is centered on a region in the tube where the standing wave produces the highest pressure (and thermal) forces. Experimenting with different frequencies and stack placements could yield greater efficiency. We also concluded that the shape and length of the resonator tube was a major factor in the efficiency of the device. Improvements to the resonator tube would involve further research into the effects that differently shaped tubes would have on the thermo-acoustic effect. Perhaps a resonator tube which was tapered to focus the intensity of the wave and therefore increase both the pressure and temperature maximum would increase effectiveness. However, as stated above further research is required to ascertain the resonator tube shape of maximum efficiency. Other tube factors that should be explored include tube diameter and length. Due to the correlation between the resonator tube and the frequency used these two factors would have to be experimented with simultaneously. If peak efficiency was to be achieved, the most optimal solution would be to model the acoustic properties by computer simulation and predict efficient tube-frequency combinations in that manner.

Chapter No. 9

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REFERENCES

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Fig 26 : Full assembly of Thermoacoustic Refrigeration System

Photo with members and guide