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Experimental Investigation of Thermoacoustic Refrigeration System

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ABSTRACT:-Thermo acoustic have been known for over years but the use of this phenomenon to develop engines and pumps is fairly recent. Thermo acoustic refrigeration is one such phenomenon that uses high intensity sound waves in a pressurized gas tube to pump heat from one place to other to produce refrigeration. In this type of refrigeration all sorts of conventional refrigerants are eliminated and sound waves take their place. All we need is a loud speaker and acoustically insulated tube. Also this system completely eliminates need for lubricants and results in 40% less energy consumption. Thermo acoustic heat engines have the advantage of operating with inert gases and with little are no moving parts, making them highly efficient ideal candidate for environmentally safe refrigeration with almost zero maintenance cost. Now we will look into a thermo acoustic refrigerator, its principle and functions.

KEY WORDS : Thermo acoustic Refrigeration , , Resonator.

I. INTRODUCTION:-

Over the past two decades, physicists and engineers have been working on a class of heat engines and compression-driven refrigerators that use no oscillating pistons, oil seals or lubricants. These so called thermo acoustic devices take advantage of sound waves reverberating within them to convert a temperature differential into mechanical energy or mechanical energy into a temperature differential. Such materials thus can be used, for example, to generate electricity or to provide refrigeration and air conditioning. Because thermo acoustic devices perform best with inert gases as the working fluid, they do not produce the harmful environmental effects such as global warming or stratospheric ozone depletion that have been associated with the engineered refrigerants such as CFCs and HFCs. Recent advances have boosted efficiencies to levels that rival what can be obtained from internal combustion engines, suggesting that commercial thermo acoustic devices may soon be a common place.

The entire features mentioned above is possible only because sound waves in thermo acoustic engines and refrigerators can replace the piston and cranks that are typically built into any machinery. These thermo acoustic devices produce or absorb sound power, rather than the shaft power characteristic of rotating machinery making it mechanically simple.

BASIC FUNCTIONING:- In a nut shell, a thermo acoustic engine converts heat from a high-temperature source into acoustic power while rejecting waste heat to a low temperature sink. A thermo acoustic refrigerator does the opposite, using acoustic power to pump heat from a cool source to a hot sink. These devices perform best when they employ noble gases as their thermodynamic working fluids. Unlike the chemicals used in refrigeration over the years, such gases are both nontoxic and environmentally benign. Another appealing feature of thermo acoustics is that one can easily flange an engine onto a refrigerator, creating a heat powered cooler with no moving parts at all.

The principle can be imagined as a loud speaker creating high amplitude sound waves that can compress refrigerant allowing heat absorption. The researches have exploited the fact that sound waves travel by compressing and expanding the gas they are generated .

THERMO ACOUSTIC EFFECT:-Acoustic or sound waves can be utilized to produce cooling. The pressure variations in the acoustic wave are accompanied by temperature variations due to

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compressions and expansions of the gas. For a single medium, the average temperature at a certain location does not change. When a second medium is present in the form of a solid wall, heat is exchanged with the wall. An expanded gas parcel will take heat from the wall, while a compressed parcel will reject heat to the wall.

As expansion and compression in an acoustic wave are inherently associated with a displacement, a net transport of heat results. To fix the direction of heat flow, a standing wave pattern is generated in an acoustic resonator. The reverse effect also exists: when a large enough temperature gradient is imposed to the wall, net heat is absorbed and an acoustic wave is generated, so that heat is converted to work.

The principle may find applications in practical refrigerators, providing cooling, heat engines providing heat or power generators providing work. A great advantage of the technique is that there are no or only one moving part, in the cold area, which results in high reliability and low vibration levels. Also the use of inert gases make them environmentally safe and hence more in demand.

FUNCTIONING IN DETAIL:-

Thermo acoustic refrigerators now under development use sound waves strong enough to make your hair catch fire, says inventor Steven L Garrett. But this noise is safely contained in a pressurized tube. If the tube gets shattered, the noise would instantly dissipate to harmless levels. Because it conducts heat, such intense acoustic power is a clean, dependable replacement for cooling systems that use ozone destroying chlorofluorocarbons (CFCs). Now a scientist Hofler is also developing super cold cryocoolers capable of temperatures as low as -135˚F (180˚K). he hopes to achieve -243˚F (120˚K) because such cryogenic temperatures would keep electronic components cool in space or speed the function of new microprocessors.

The interaction between heat and sound has been underestimated even by Sir Isaac Newton. This became clear, when Laplace corrected Newton's earlier calculation of the speed of sound in air. Newton had assumed the expansions and compressions of a sound wave in a gas happen without affecting the temperature. Laplace accounted for slight variations in temperature that in fact take place, and by doing so he derived the correct speed of sound in air, a value that is 18% faster than Newton's estimate.

A thermo acoustic refrigerator functions as follows. First, customized loudspeakers are attached to cylindrical chambers filled with inert, pressurized gases such as xenon and helium. At the opposite end of the tubes are tightly wound "jelly rolls" made of plastic film glued to ordinary fishing line. When the loudspeakers blast sound at 180 decibels, an acoustic wave resonates in the chambers. As gas molecules begin dancing frantically in response to the sound, they are compressed and heated, with temperatures reaching a peak at the thickest point of the acoustic wave. That's where the super hot gas molecules crash into the plastic rolls. After transferring their heat to the stack, the sound wave causes the molecules to expand and cool. "Each one of these oscillating molecules acts as a member of a 'bucket brigade,' carrying heat toward the source of the sound," says Garrett. Cold temperatures can then be tapped for chilling refrigerators, bedrooms, cars, or electronic components on satellites and inside computers, according to Garrett. Someday, he says, turning up the air-conditioner could be accomplished by adjusting a volume-control knob.

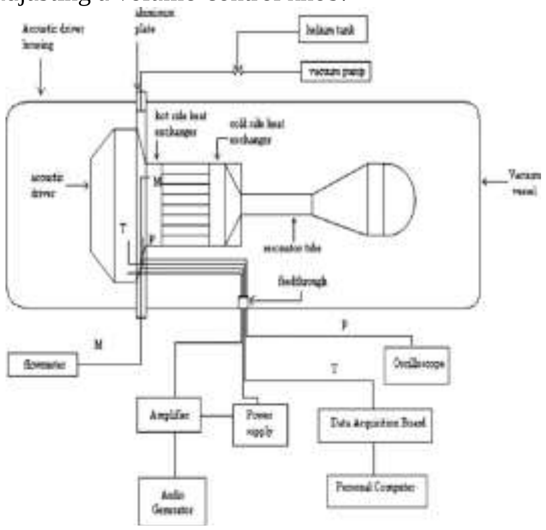

Fig 1 Functioning of a TA Refrigerator

The Space Thermo Acoustic Refrigerator was the first electrically-driven thermo acoustic chiller designed to operate autonomously outside a laboratory. It was launched on the Space Shuttle Discovery (STS-42) on January 22, 1992. The design was an extension of the first thermo acoustic refrigerator built at Los Alamos National Laboratory as the Ph.D. thesis project of Thomas J. Hofler. Dr. Hofler is currently a member of the physics faculty at the Naval Postgraduate School in Monterey, CA.

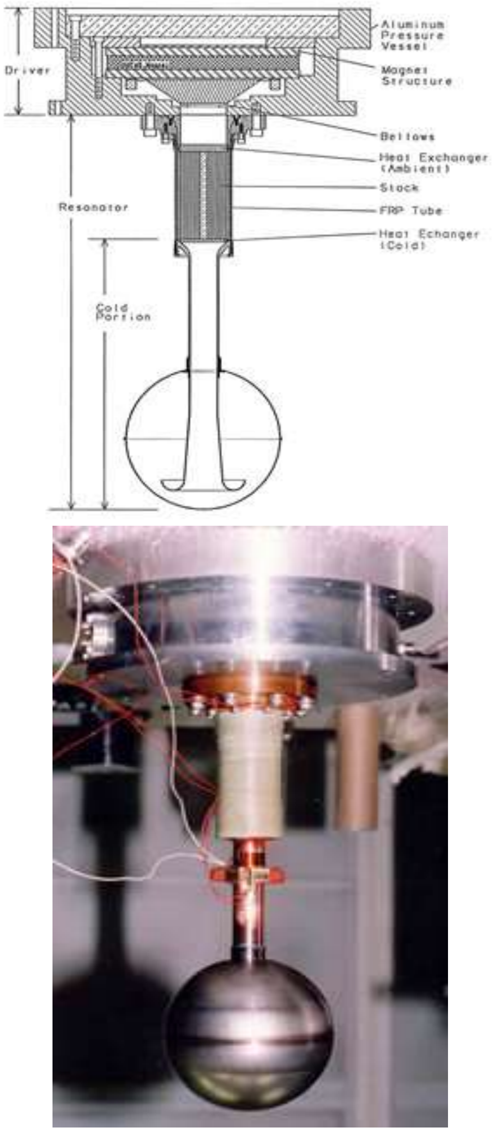

Fig 2 A Space Thermo Acoustic Refrigerator

The refrigerator is driven by a modified compression driver that is coupled to a quarter-wavelength resonator using a single-convolution electroformed metal bellow. The resonator contains the heat exchangers and the stack. The stack is 3.8 cm in diameter and 7.9 cm in length. It was constructed by rolling up polyester film (Mylar™) using fishing line as spaces placed every 5 mm. The device was filled with a 97.2% Helium and 2.7% Xenon gas mixture at a pressure of 10.The major parts of a thermo acoustic refrigerator are loud speakers and resonators. Pictorical representations of both are given below.

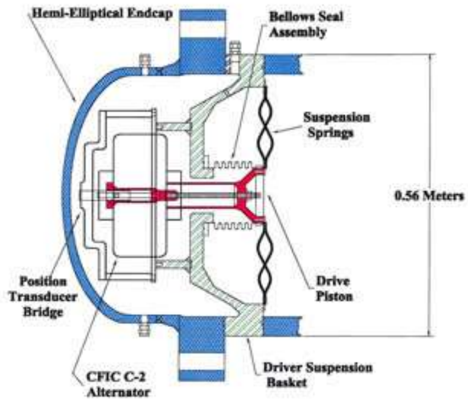

Fig 4 A LOUD SPEAKER
Figs 5 A RESONATOR

In contrast, inside conventional refrigerators and air conditioners, CFC gas is compressed and heated by an electrically driven pump, then cooled and condensed by a heat exchanger in a process known as a "Rankine cycle." When the liquefied gas is depressurized, it evaporates and drops to a much cooler temperature. Moving through the freezer coils of a food compartment, the cold fluid picks up heat, starting the cycle all over again.

ThermoCouple : A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction. A thermocouple produces a temperature-dependent voltage as a result of the Seebeck effect, and this voltage can be interpreted to measure temperature. Thermocouples are widely used as temperature sensors.Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self powered and require no external form of excitation. The main limitation with thermocouples

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is accuracy; system errors of less than one degree Celsius (°C) can be difficult to achieve.
Thermocouples are widely used in science and industry. Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes. Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in safety devices for gas-powered appliances.

Fig: Thermocouple

Amplifier: An amplifier, electronic amplifier or (informally) amp is an electronic device that can increase the power of a signal (a time-varying voltage or current). It is a two-port electronic circuit that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a proportionally greater amplitude signal at its output. The amount of amplification provided by an amplifier is measured by its gain: the ratio of output voltage, current, or power to input. An amplifier is a circuit that has a power gain greater than one.

An amplifier can either be a separate piece of equipment or an electrical circuit contained within another device. Amplification is fundamental to modern electronics, and amplifiers are widely used in almost all electronic equipment. Amplifiers can be categorized in different ways. One is by the frequency of the electronic signal being amplified. For example, audio amplifiers amplify signals in the audio (sound) range of less than 20 kHz, RF amplifiers amplify frequencies in the radio frequency range between 20 kHz and 300 GHz, and servo amplifiers and instrumentation amplifiers may work with very low frequencies down to direct current. Amplifiers can also be categorized by their physical placement in the signal chain; a preamplifier may precede other signal processing stages, for example. The first practical electrical device which could amplify was the triode vacuum tube, invented in 1906 by Lee De Forest, which led to the first amplifiers around 1912. Today most amplifiers use transistors.

Fig Amplifier

Acrylic pipe : Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances which can flow—liquids and gases (fluids), slurries, powders and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members.Plastic pipework is used for the conveyance of drinking water, waste water, chemicals, heating fluid and cooling fluids, foodstuffs, ultra-pure liquids, slurries, gases, compressed air, irrigation, plastic pressure pipe systems, and vacuum system applications.

Fig Acrylic pipe

Before World War II, ammonia and sulfur dioxide were commonly used in refrigerators, explains Gregory W. Swift, a thermo acoustics expert at Los Alamos National Laboratory in New Mexico. But these substances were soon replaced with CFCs, which are noncorrosive, nonflammable, and relatively nontoxic, Swift says. Unfortunately, he adds, CFCs leak from cooling systems, destroying the atmospheric ozone that protects the earth's surface from ultraviolet radiation. Damage to the ozone shield may result in adverse human health effects including cancers, cataracts, immune system deficits, and respiratory effects, as well as diminish food supplies and promote increases in vector borne diseases. mass.

CHALLENGES BEFOR THE PROJECT:-

Even though thermo acoustic devices uses low cost components and require only one moving part, making them inexpensive and maintenance free systems they have certain challenges before them. But with time researches must overcome them.

One of the main challenges faced is regarding the efficiency. The efficiency of thermo acoustic refrigerators and engines is very low. Thermo acoustic refrigerators gives only one-fourth the efficiency compared to conventional refrigerators. The coefficient of performance of the most advanced thermo acoustic refrigerator is only around 1 compared to 3 to 4 of conventional refrigerators.

Since, they use electricity to drive a pump that moves working gas, conventional refrigerants represent 6% of the nation's annual electricity consumption. Similarly, the loud speakers inside a thermo acoustic refrigerator also must be activated by electric power. The best thermo acoustic coolers built thus far use twice as much electricity as conventional refrigerants. Though much greater efficiency is theoretically possible, the claim that the thermo acoustic refrigerators will ever catch up with traditional Rankine cycle designs is in doubt. Complex physical factors such as the friction generated by gas molecules churning back and forth inside a chamber place fundamental limits on the efficiency of thermo acoustic refrigerators. Losses also occur because of acoustic distortions generated at levels above 155 decibels.Another major problem is that a thermo acoustic refrigerator is "either fully on or off". That is it gets too cold when thermostat is turned on and too hot when it is off.

IMPROVEMENTS MADE:-

In order to improve the efficiency, regenerators are used. The function of a regenerator is to store thermal energy during part of the cycle and return it later. This component can increase the thermodynamic efficiency to impressive levels, but its mechanical complexity is greater. In a regenerator used some thermal energy was converted to acoustic energy, though not enough to make up for the accompanying losses.The extra stress given in using standing waves also paved to be fruitful. Amplification became much easier while using standing waves. This increased the level of temperature gradient setup thereby providing more refrigeration effect.An increased voltage and reduced current gave better performances than usual. Moreover intense working is going on in developing sound by piezoelectric effect which would considerably reduce electricity hazards.With these workings it was found that the efficiency of the engine improved markedly. At best it ran at 42% of the maximum theoretical efficiency, which is about 40% better than earlier thermo acoustic devices had achieved and rivals what modern engines have.

MERITS OF THE TECHNOLGY:-

Although the working principle of thermo acoustic technology is quite complex, the practical implementation is relatively simple. This offers great advantages with respect to the economic feasibility of this technology. Other advantages are

1. No moving parts for the process, so very reliable and a long life span.
2. Environmentally friendly working medium (air, noble gas)
3. The use of air or noble gas as working medium offers a large window of applications because there are no phase transitions.

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4. Use of simple materials with no special requirements, which are commercially available in large quantities and therefore relatively cheap.
5. On the same technology base a large variety of applications can be covered.

APPLICATIONS:-

Speaking of its practical applicability, prototype of thermo acoustic refrigerators have operated on the Space Shuttle and abroad a Navy warship. And a powerful thermo acoustic engine has recently demonstrated its ability to liquefy natural gas on a commercial scale.In practice there is a large variety of applications possible for both thermo acoustic engines and refrigerators and combination of these. Below, some concrete examples are given of possible applications:

a. Liquefaction of natural gas:
Burning natural gas in a thermo acoustic engine generates acoustic energy. This acoustic energy is used in a thermo acoustic heat pump to liquefy natural gas.

b. Chip cooling:
In this case a piezoelectric element generates the sound wave. A thermo acoustic heat pump cools the chip.

c. Electronic equipment cooling on naval ships:
In this application, a speaker generates sound waves. Again a thermo acoustic pump is used to provide the cooling.

d. Electricity from sunlight:
Concentrated thermal solar energy generates an acoustic wave in a heated thermo acoustic engine. A linear motor generates electricity from this.

e. Cogeneration (combined heat and power):
A burner heats a thermo acoustic engine, therewith generating acoustic energy. A linear motor converts this energy to electricity. Waste heat of burner (flue gases) can be used to supply heat.

f. Upgrading industrial waste heat:
Acoustic energy is created by means of industrial waste heat in a thermo acoustic engine. In a thermo acoustic heat pump this acoustic energy is used to upgrade the same waste heat to a useful temperature level.

Though it probably won't be useful for car air conditioning systems any time soon since they are too bulky and heavy, it may prove useful for "niche applications", such as cooling satellite sensors or super fast computers. In addition to being useful on shipboard, this technology could be adapted for soft drink machines, medicine storage, computer chips and food transport companies.

II. CONCLUSION:-

Thermo acoustic engines and refrigerators were already being considered a few years ago for specialized applications, where their simplicity, lack of lubrication and sliding seals, and their use of environmentally harmless working fluids were adequate compensation for their lower efficiencies. This latest breakthrough, coupled with other developments in the design of high power, single frequency loud speakers and reciprocating electric generators suggests that thermo acoustics may soon emerge as an environmentally attractive way to power hybrid electric vehicles, capture solar energy, refrigerate food, air condition buildings, liquefy industrial gases and serve in other capacities that are yet to be imagined.

In future let us hope these thermo acoustic devices which promise to improve everyone's standard of living while helping to protect the planet might soon take over other costly, less durable and polluting engines and pumps. The latest achievements of the former are certainly encouraging, but there are still much left to be done.

REFERENCES:-

[1]. G.W. Swift,"What is thermoacoustics? A brief description". Condensed Matter and Thermal Physic Group. Los Alamos National Laboratory, Los Alamos, New Mexico. 2004.
[2]. M.E.H. Tijani, J.C.H. Zeegers, A.T.A.M. de Waele, "Design of thermoacoustic refrigerators". Elsevier,
[3]. Cryogenics 42 (2002) 49–57.
[4]. F. Zink, J. S. Vipperman, L. A. Schaefer, "Environmental motivation to switch to thermoacoustic refrigeration". Applied Thermal Engineering 30 (2010) 119-126
[5]. E. C. Nsofor, A. Ali, "Experimental study on the performance of the thermoacoustic refrigerating system". Applied Thermal Engineering 29 (2009) 2672-2679.
[6]. http://hyperphysics.phy-astr.gsu.edu/hbase/sound/tralon.htm