''Thermoacoustic Refrigeration as a component of sustainable future development: a feasible target?''

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1. Abstract

The expanding use of air conditioning units contributes significantly to the increase of greenhouse gases emissions as well as the ozone depletion. To decrease the use of the environmental hazardous refrigerating systems, studies are focalizing in the development of alternative refrigeration technologies and systems. An approach in the category of alternative techniques is thermoacoustic refrigeration which represents a promising cooling technology. The main concept of this technology is that it transfers thermal energy from a hot source to a cold source by utilizing sound or acoustic work.

Thermoacoustic refrigeration systems have not only practical, but also environmental advantages in contrast with the conventional ones. Although they carry out difficulties during the design phase, they are easy to construct. The main advantage of a thermoacoustic refrigerator in comparison to a mechanical refrigerator is the use of environmentally friendly gases. Such gases obliterate the use of coolant, which includes harmful chlorofluorocarbons (CFC's) that destroy the ozone. In spite of the fact that the last few years thermoacoustic systems have been developed in a sufficient level, increasing the energy and cooling efficiency of thermoacoustic refrigeration units, the technology has not yet reached "technical maturity".

In this context, the project aims to examine the prospect of the thercomacoustic refrigeration technique as a component of sustainable future development. More specifically, the current research of the thermoacoustic refrigeration systems in different fields of application will be presented and analyzed in depth. Furthermore, a comparison between the TR and the conventional refrigeration systems will be attempted as well as a survey through questionnaire form will be conducted.

2. Aims & Objectives

The aim of the project is to examine the prospect of the thercoacoustic refrigeration (TR) as a component of sustainable future development. In this context, the current research of the TR systems in different fields of application will be presented and analyzed in order to identify any possible problems or barriers that should be eliminated. Moreover, a comparison between the TR and the conventional systems will be attempted.

In order to achieve this aim, a set of objectives has been established, as follows:

- Introduction into alternative refrigeration techniques and the necessity of their development. During this frame, the importance to combat climate change through the reduction of 'greenhouse' gases, the environmental impacts of the convectional refrigeration techniques as well as the need to explore and develop alternative refrigeration methods will be presented.
- Analysis of the thermoacoustic phenomenon and the TR. In this context, the description of the basic principles of the thermoacoustic phenomenon and the TR, the modeling of the TR, the pros and cons, the environmental benefits and economical aspects of the TR will be presented.
- Presentation and analysis of the current experimental work including the variants of TR, the theoretical modeling, the numerical simulation modeling of the phenomenon and the design and construction issues.
- Evaluation of the applicability, effectiveness, economy, potential opportunities, possible ones and presentation of the expert's view for further development of the TR systems. In this frame the conduct of a survey with mailed questionnaires as well as the evaluation of the results will be attempted.

3. Methodology

The methodology of the project is developed in two stages. The first one is associated with the theoretical background of the Thermoacoustic Refrigeration. In this phase TR technique will be thoroughly examined from the technical, environmental and economical points of view. The examination will be based on the status of the as it results from the critical reading of the reliable sources that will be gathered during the literature review. technology according to information from reliable sources that will be gathered during the literature review, as well as on the international experience from the application of the TR systems, in different fields, as it results from the respective published papers.

The second stage is involved with the conduct of a survey with mailed questionnaires in order to examine, through the evaluation of the valuable information, the potential opportunities, possible ones and expert's view for future development of the TR systems. The development of the questionnaire will be based on scientific and technological knowledge

4. Background

Climate change is already happening and mankind is facing one of the greatest environmental, social and economic threats. According to the Kyoto Protocol, the GHG emissions must be reduced significantly as the main responsible for the climate change.

Buildings continue to have an enormous impact on resource use and the environment, as energy use in buildings is a significant source of greenhouse gas (GHG) emissions. According to Organization for Economic Co-operation and Development countries (OECD), buildings worldwide account for as much as 45% of energy consumption and about 35- 40% of national CO_2 [1].

It is widely known that conventional refrigeration and air conditioning systems release significant amounts of environmentally noxious emissions in order to achieve comfortable indoor conditions. Specifically, the hydrofluorocarbons (HFCs) as well as the chlorine from Chlorofluorocarbons (CFCs), which have been used as working fluid in conventional air conditioning systems for over 60 years, are destroying stratospheric ozone and contribute to global warming. However, in an age of environmental crises, it is becoming increasingly important to design and develop refrigerating systems considering environmental impacts.

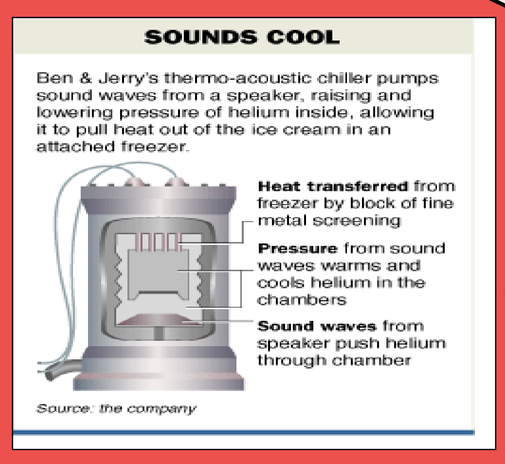
Lately, there has been a lot of interest in the thermoacoustic refrigeration (TR) technology, which is in stage of development during the last decades, due to thermoacoustic refrigerators "simple configuration, reliable operation, and environmentally friendly working gas" [2]. This technology, as an approachable form of alternative technologies, use sound waves to pump heat from a low temperature source to a high temperature sink.

Thermoacoustic is a category of science involving with the conversion of heat energy into sound energy. The TA heat engine is a device that converts heat energy in sound or acoustic work and the TA refrigerator is a device that transfers heat by utilizing sound or acoustic work [3]. A way to classify TA refrigerators is based on the source of the acoustic energy input. If the acoustic energy is provided by a TA engine, the refrigerator is called thermoacoustically-driven thermoacoustic refrigerator [4]. On the other hand, if the acoustic energy is provided by an acoustic driver (a loudspeaker), it is termed as acoustically-driven thermoacoustic refrigerator. During the past decades, several acoustically-driven thermoacoustic refrigerators have been developed [4].

Current theoretical studies have created the forceful potential of thermoacoustic (TA) devices in energy conservation and significant decrease of hazardous emissions. A research concludes that a saving of 16 PJ per year, which is equal to save more than 5 billion m3 of natural gas, would be achieved if TA devices could use all the industrial waste heat above 140 °C in Netherlands [5]. It is calculated that annually for the operation of vehicle air-conditioners in the US over 32 billion liters of fuel is consumed. Also the recent vehicle refrigeration systems use R-134, with a global warming potential still 1300 times that of carbon dioxide [6].

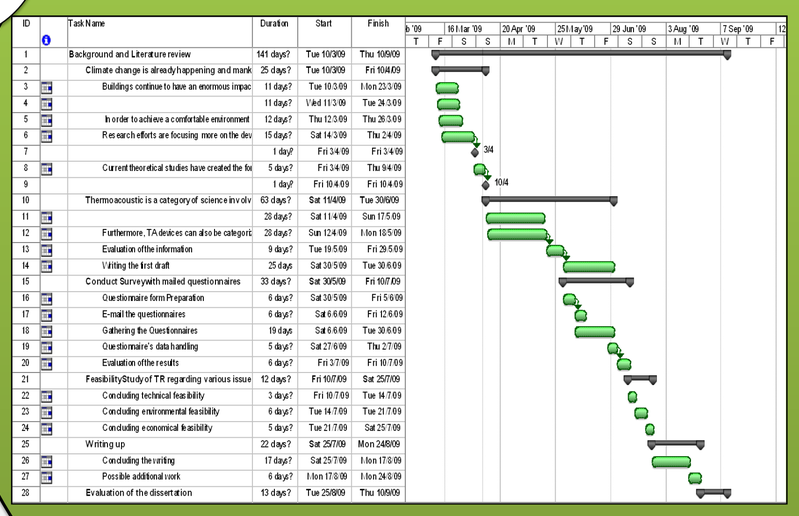
Although,thermoacoustic refrigerators have not been massively produced, they are already being used. One of the most popular prototype refrigerators is an ice cream freezer that was constructed by Pennsylvania State University and is used by an ice-cream store in United States.

Available: www.Thermoacouticscorp.com



Available: http://radio.weblogs.com.

Gantt Chart



ID	Task Name	Duration	Start	Finish
1	Background and Literature review	141 days?	Tue 10/3/09	Thu 10/8/09
2	Climate change is already happening and mank	25 days?	Tue 10/3/09	Fri 10/4/09
3	Buildings continue to have an enormous impac	11 days?	Tue 10/3/09	Mon 23/3/09
4		11 days?	Wed 11/3/09	Tue 24/3/09
5	In order to achieve a comfortable environment	12 days?	Thu 12/3/09	Thu 26/3/09
6	Research efforts are focusing more on the dev	15 days?	Sat 14/3/09	Thu 2/4/09
7		1 day?	Fri 3/4/09	Fri 3/4/09
8	Current theoretical studies have created the fo	5 days?	Fri 3/4/09	Thu 9/4/09
9		1 day?	Fri 10/4/09	Fri 10/4/09
10	Thermoacoustic is a category of science inv olv	63 days?	Sat 11/4/09	Tue 30/6/09
11		28 days?	Sat 11/4/09	Sun 17/5/09
12	Furthermore, TA devices can also be categori	28 days?	Sun 12/4/09	Mon 18/5/09
13	Evaluation of the information	9 days?	Tue 19/5/09	Fri 29/5/09
14	Writing the first draft	25 days	Sat 30/5/09	Tue 30/6/09
15	Conduct Survey with mailed questionnaires	33 days?	Sat 30/5/09	Fri 10/7/09
16	Questionnaire form Preparation	6 days?	Sat 30/5/09	Fri 5/6/09
17	E-mail the questionnaires	6 days?	Sat 6/6/09	Fri 12/6/09
18	Gathering the Questionnaires	19 days	Sat 6/6/09	Tue 30/6/09
19	Questionnaire's data handling	5 days?	Sat 27/6/09	Thu 2/7/09
20	Evaluation of the results	6 days?	Fri 3/7/09	Fri 10/7/09
21	Feasibility Study of TR regarding various issue	12 days?	Fri 10/7/09	Sat 25/7/09
22	Concluding technical feasibility	3 days?	Fri 10/7/09	Tue 14/7/09
23	Concluding environmental feasibility	6 days?	Tue 14/7/09	Tue 21/7/09
24	Concluding economical feasibility	5 days?	Tue 21/7/09	Sat 25/7/09
25	Writing up	22 days?	Sat 25/7/09	Mon 24/8/09
26	Concluding the writing	17 days?	Sat 25/7/09	Mon 17/8/09
27	Possible additional work	6 days?	Mon 17/8/09	Mon 24/8/09
28	Evaluation of the dissertation	13 days?	Tue 25/8/09	Thu 10/9/09

5. Conclusions

The attempts made for the development of thermoacoustic refrigeration technology will possible change the setting over the years. The advantages from the development of this technology are many, indicating the necessity for further growth. Pollution of the environment and reduction hazardous emissions is some of the problems that could be eliminated by the application of TR systems. The matter of evaluation is also based on these factors, which they define the quality of living and could create a better and healthier place to live.

The project will be concluded on the feasibility of the TR systems in several issues, such as environmental, economical and technological, in order to be developed in the future. Also, suggestions will arise as the outcome of the research regarding possible best suited applications and fields of applications.

References

[1] Available: www.oecd.org

[2] Sun, Daming, Limin Qiu, B. Wang, and Yong Xiao, *Transmission characteristic of acoustic amplifier in thermoacoustic engine,* (2008).

[3] M. Wetzel, C. Herman, *Design optimization of thermoacoustic refrigerators*. Int J Refrig (1997) 20:3-21.

[4] H. Babaei, K. Siddiqui, *Design and optimization of thermoacoustic devices,* Energy Conversion and Management 49 (2008) 3585 – 3598.

[5] Available: http://www.ecn.nl/fileadmin/ecn/units/eei/Onderzoeksclusters/Restwarm tebenutting / b-07-007.pdf.

[6] VH. Johnson, *Heat generated cooling opportunities in vehicles,* Society of AutomotiveEngineers (2002).