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Feasibility Study of Heat Driven Cooling Based Thermal Energy Storage

Lenka Bhargavi[1], Karteek Naidu Mariserla[2]
#1Student of M.Tech in Mechanical Engineering Department with specialization in Thermal Engineering,
#2 Assist.Prof, Department of Mechanical Engineering in Gokul group of Institutions, Bobbili, vizianagaram, AP.

Abstract:
Human needs are boundless, yet assets that satisfy human needs are restricted. In light of this reason, thought of manageability in use of vitality is of massive significance. In this perspective, utilization of renewable vitality, decrease of vitality use, and lessening/end of utilization of fossil powers are supported. Space cooling has the most astounding share (40% to 60%) from aggregate vitality utilization in a business building, and there is an expanding pattern of this offer. Hot and muggy atmosphere noticeably wins in the city Colombo, India. Then again, India encounters an extensive increment of vitality interest and power duty rates yearly, and these increments have noteworthy effect on the economy. Along these lines, the requirement for discovering vitality productive, renewable and financially savvy arrangements is clear. In like manner, a study was completed to evaluate the techno financial achievability of warm vitality stockpiling incorporated warmth driven cooling. Warm vitality stockpiling and ingestion chillers are monetarily accessible, and have the measure towards maintainability. It was found that the most widely recognized ventilating applications among a few others are in office structures, and in this manner the fundamental center of this study is on a regular office building in Colombo city. The study's consequence can be summed up and connected to other office structures in the city. Trace700 programming apparatus was utilized to display and to reenact distinctive framework choices, and to research techno-monetary execution. Results demonstrate that Cool warm stockpiling coordinated thermally determined assimilation chillers have
A critical vitality and expense sparing potential. Moreover biogas is turned out to be a sound vitality hotspot for warm vitality supply for the chiller, all going for a maintainable future. The model created May be reached out to the diverse climatic conditions and expense structures.

Keywords: Sustainable energy, Absorption chillers, Thermal energy storage, Space cooling

Introduction:

In India, larger part of business and state segment structures are situated in Colombo city limits, which has the sultriest and the stickiest atmosphere. In this manner, cooling is one of the primary necessities to keep up agreeable indoor atmosphere. In building segment, Heating Ventilation and Air Conditioning (HVAC) frameworks have the most noteworthy offer of aggregate power bill. It is in the scope of 40% to 60% [1]. All elevated structure in the territory have introduced ventilating frameworks of different sorts. Then again, India encounters a significant ascent in power duty rates every year and the national interest for power for ventilating has been expanding throughout the years. Moreover India, which is a signatory to Kyoto convention, is obliged to take after strict regulations that it sets tying focuses for lessening Green-House Gas (GHG) outflows.

As needs be, this study is centered on exploring ways and intends to minimize vitality utilization in a run of the mill office using so as to build in Colombo territory a powerful ventilating framework. The utilization of Thermal Energy Storage (TES) and ingestion chillers is examined here. Reasons in selecting these innovations are as per the following.

1. To build use of renewable vitality or waste vitality.
2. To minimize power request.
3. To give earth well-disposed and clean innovation arrangements.
4. To perform practicality study for business accessibility.
5. To be on the bleeding edge innovation with whatever remains of the world.

System Description And Control Strategy

Figure 1 shows a schematic representation of the system used. The main system components are a thermal energy, a storage tank, an absorption chiller, heat exchanger, and auxiliary units. There are four different modes for the system operation. When thermal energy is available for collection and there is a load demand, heat is supplied directly from the collector to the heating or cooling unit. When thermal energy is available for collection and there is no heat or cooling demand, heat is stored in the storage unit. On the other hand, if thermal energy is not available for collection and there is a load demand, storage then supplies heat to the heating or cooling unit. However, if storage temperature is not sufficient, the heating or cooling load is supplied by the auxiliary source.

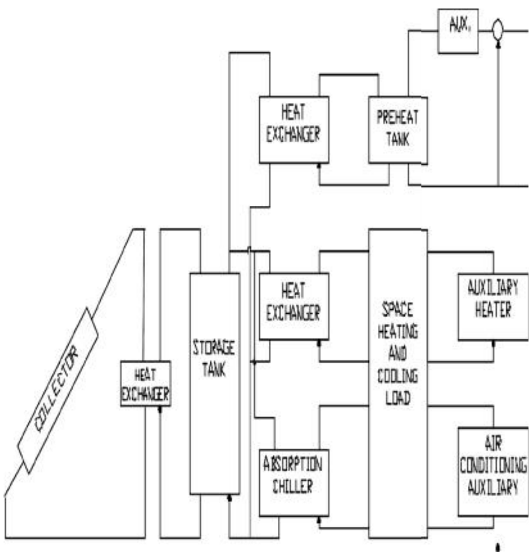

Figure Schematic diagram of the Heat Driven Cooling Based Thermal Energy Storage

Figure shows a schematic of a single-effect lithium bromide water absorption chiller. The main components of the absorption unit are; generator, condenser, evaporator, absorber, and low temperature heat exchanger. The lithium bromide solution is pumped from the absorber to the generator where the water is boiled off. The heat source is passed in a counter-flow arrangement through the generator to boil off water vapour from the LiBr-H_2O solution. A cooling water loop is needed to condense the water vapour boiled off from the generator and to aid in the absorption of water vapour back into the LiBr-H_2O solution. This cooling water is passed first through the absorber and then the condenser. The evaporator takes in low-pressure cold water and produces a cooling effect by evaporating the water and passing it to the absorber. A circulation pump is used to ensure complete wetting of the tubes.

The chiller model is based on a commercially available LiBr-H_2O absorption chiller system, Arkla model WF-36. The Arkla chiller has a nominal cooling capacity of three tons (37980 kJ/h). Units of different capacity are approximated by scaling the Arkla performance. Hot water is supplied to the air conditioner at a temperature of 87°C (minimum), 93°C (maximum) and leaves this unit 10.5°C cooler than the supply and returns to the storage (or to the auxiliary heater if storage is below 77°C). Whenever hot water from storage is cooler than 87°C, the auxiliary heat is supplied to raise its temperature to 87°C. When storage is cooler than 77°C, it is not used, and the auxiliary heater carries the full cooling load. The coefficient of performance (COP), and the ratio of actual cooling capacity to the rated capacity (f), depend on the generator temperature and the condensing water inlet temperature. Both COP and f are found from curve fits to the Arkla WF-36 performance. The cooling tower is modelled using a constant approach to ambient wet bulb temperature. In addition, a constant COP model of a vapour compression air conditioner is included as a secondary cooling auxiliary so that the energy required to meet space cooling is provided even if the absorption machine cannot meet the full load.

Financial Analysis

The financial viability of a solar system depends on many factors. One of the most important factors is the cost of the conventional fuel energy. The economic calculations for this study are based on life cycle savings (LCS) method (Duffie& Beckman, 1991). There are two variables which characterize the life cycle savings method: the duration of the analysis and the discount rate. The discount rate is defined as the rate of return which can be obtained from the best alternative investment. The life cycle savings of a solar system (LCS) over a conventional system can be defined as the difference between the reduction in fuel costs and the increase in expenses resulting from the additional investment for the solar system and is given by the following equation:

$$LCS = P_1 C_F L F_t - P_2 (C_A \; A_c + C_E)$$

where P_1 is the factor relating life cycle fuel cost to first year fuel cost savings, P_2 is the factor relating life cycle by additional capital investment to initial investment, C_A is the thermal energy investment cost which is directly proportional to collector area, C_E is the thermal energy investment cost which is independent of collector area, C_F is the unit cost of delivered conventional energy for the first year of analysis, L is the total load, and F_t is the total solar fraction of the solar system. For a particular locality and set of economic conditions, the economic analysis can be used to evaluate the economic feasibility of the solar system in terms of the life cycle savings. For example, optimization is made with respect to collector area to obtain the maximum life cycle savings for a given locality and a set ofcollector parameters. However, when two parameters were considered simultaneously, optimization was made in terms of the life cycle cost and not the life cycle savings.

Thermal Energy Storage System

Storage provides mean of shifting a peak load in the day time from the off peak period typically at night [3]. This study focuses on cool thermal storage. Usually, cool thermal storage consists of a vessel or a tank filled with storage medium. This energy storage medium can be water, ice or other phase change material (PCM) (eutectic salt and organic material such as paraffin). The cool thermal storage system can be either full storage or partial storage. This means the system may provide all the cooling demand, or part of the demand during on-peak hours. The partial storage systems can work either as load levelling or demand limiting. Chillers in the load levelling mode are operated at full capacity on peak (cooling) demand day [4], thus minimizing the space and cost required by the TES system. The demand limiting strategy provides middle ground between full storage and load levelling strategies [4]. Furthermore, operating system can be distinguished to storage priority and chiller priority. As the name implies in chiller priority system, the load is mainly provided by the chiller, whereas in the storage priority system, load is preferably provided by the thermal storage.

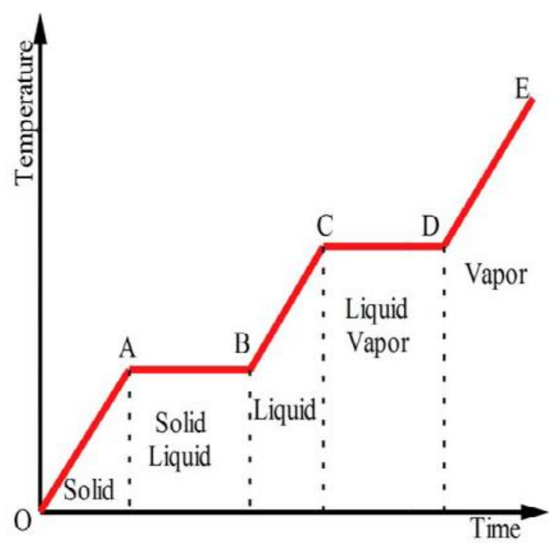

Figure. Temperature-time diagram for the heating of a substance

Material and Method

Types of PCM

Figure 4 illustrated a classification of PCMs, but generally speaking PCMs can be broadly classified into two types: Organic PCMs e.g. Paraffin Wax and Inorganic PCMs e.g. Salt Hydrates [7-9].

Early efforts in the development of latent TES materials used inorganic PCMs. These materials are salt hydrates, including Glauber's salt (sodium sulphatedecahydrate), which was studied extensively in the early stages of research into PCMs [10,11].

The phase change properties of inorganic PCMs are shown in table 1 [9-12] and the most promising selection of organic.

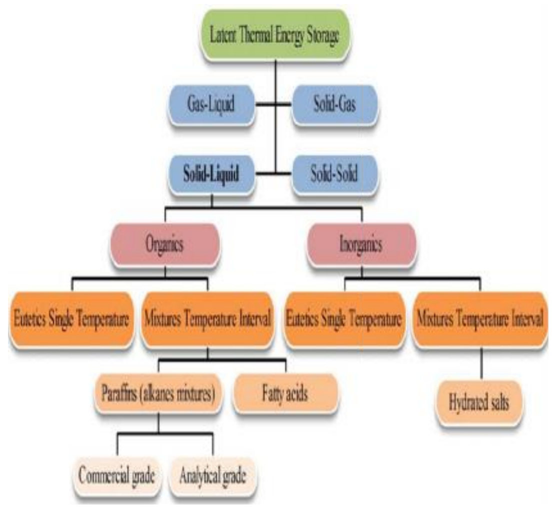

***Figure**. Classification of PCMs*

PCMs Properties

Inorganic PCMs have some attractive properties including: high latent heat values; higher thermal conductivity; not flammable; lower in cost in comparison to organic compounds; high water content means that they are inexpensive and readily available. However, their unsuitable characteristics have led to the investigation of organic PCMs for this purpose. These include: corrosiveness; instability; improper re-solidification; suffer from decomposition and super cooling affects their phase change properties. As they require containment, they have been deemed unsuitable for impregnation into porous building materials.

Nucleating and thickening agents can be added to Inorganic Phase change materials to minimize super cooling and decomposition. Unlike conventional sensible thermal storage methods, PCMs provide much higher energy storage densities and the heat is stored and released at an almost constant temperature. PCMs can be used for both active and passive space heating and cooling systems.

Organic PCMs have a number of characteristics which render them useful for latent heat storage in certain building elements. They are more chemically stable than inorganic substances, they are non-corrosive, they have a high latent heat per unit weight, they are recyclable, they melt congruently and they exhibit little or no super cooling i.e. they do not need to be cooled below their freezing point to initiate crystallization.

Moreover, they have been found to be compatible and suitable for absorption into various building materials, as will be discussed in more detail later. Although the initial cost of organic PCMs is higher than that of the inorganic type, the installed cost is competitive. However, these organic materials do have their quota of unsuitable properties. The most significant of these characteristics is: low thermal conductivity, high changes in volume during phase change, they are flammable and they may generate harmful fumes on combustion. Other problems, which can arise in a minority of cases, are a reaction with the products of hydration in concrete, thermal oxidative ageing, odour and an appreciable volume change.

Appropriate selection and modification have now eliminated many of these undesirable characteristics. It has been found that the thermal oxidative ageing of PCMs concerned can be inhibited by the use of a proper antioxidant. Research is still underway to assess the flammability and fume generation of some of the more effective PCMs such that a fire rating may be established. Also, efforts are being made to extend the number of PCMs which are compatible with concrete.

PCMs have not always re-solidified properly, because some PCMs get separated and stratify when in their liquid state. When temperature dropped, they did not completely solidify, reducing their capacity to store latent heat. These problems are overcome by packaging PCM in containers and by adding thickening agents. To solve some of the problems inherent in inorganic PCMs, an interest has turned towards a new class of materials: low volatility, anhydrous organic substances such as paraffin's, fatty acids and polyethylene glycol. Those materials were more costly than common salt hydrates and they have somewhat lower heat storage capacity per unit volume. It has now been realized that some of these materials have good physical and chemical stability, good thermal behaviour and adjustable transition zone.

PCM Assisted Under-Floor Electric Heating System

In order to investigate the thermal performance of the under-floor electric heating system with the shape-stabilized PCM plates, an experimental house with this system was set up in Tsinghua University, Beijing, China. The experimental house was equipped with the under-floor electric heating system including shape stabilized PCM plates. It had a double glazed window facing south, covered by black curtain. The roof and walls were made of polystyrene wrapped by metal board. The under-floor heating system included polystyrene insulation, electric heaters, PCM, some wooden supporters, air layer and wood floor.

Under-floor electric heating system with shape-stabilized PCM plates is presented in figure 10. Different from conventional PCM, shape-stabilized PCM can keep the shape unchanged during phase change process. Therefore, the PCM leakage danger can be avoided. This system can charge heat by using cheap nighttime electricity and discharge the heat stored at daytime.

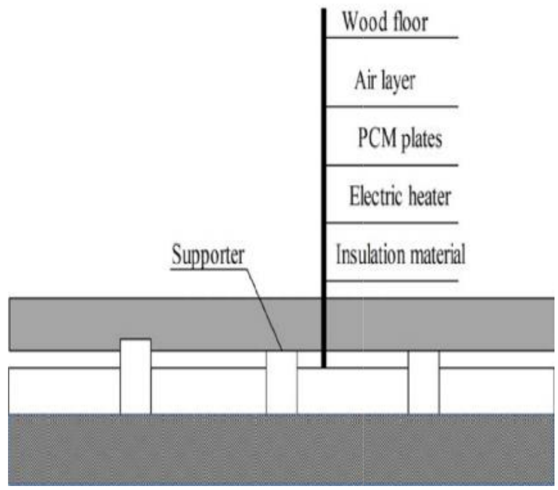

Figure. *Schematic of electric floor heating system*

Methodology

The main objective of this study is to establish a techno economic feasibility of thermal energy storage integrated with an absorption chiller, which is the method employed to minimise energy consumption in a typical office space in Colombo. This is compared with traditional mechanical chillers and conventional thermal energy storage systems. The system parameters are compared to evaluate performance. The concept which used to conduct this study is indicated by Figure 1.

The seven storied building, is 26m high, has a total floor area 2250 m^2 with the space of 1775 m^2 being air conditioned. The building mainly consists of office spaces, an auditorium located on top-most floor and the library on a mezzanine floor. Except the lobby, toilet and service areas (i.e. plant rooms, pump room, etc.) all others are air conditioned. The air conditioning system utilises water cooled chiller having capacity of 100 ton (350 kW).The orientation of the building is 45° from North to the anti-clockwise direction.

In this study existing water cooled chiller is replaced by an absorption chiller and cool thermal storage. The air conditioning system is modelled with the building, the system lay outs and technical data of existing cooling tower, condenser water piping system, chilled water piping system, duct system, and air handling units.

PCM Integrated In Combined Heating and Cooling System

The Sustainable Energy Centre at University of South Australia (2000) started work with PCMs in the mid 1990's with the development of a storage unit that can be used for both space heating and cooling. The night time charging and day time utilization process during both heating and cooling seasons for a storage system comprising of two different PCMs integrated into a reverse cycle refrigerated heat pump system utilizing off peak power. As the air is forced through the system it undergoes a two-stage heating or cooling process. ove comfort conditions (by freezing) at daytime. During summer, the airflow direction is reversed and the system stores cold energy at night and it releases the cool air below comfort temperature at daytime., this study encourages the use of sustainable energy sources and eliminating the use of fossil fuels. Therefore in order to supply the thermal energy required to drive the absorption chiller it was intended to use free or waste energy. Solar, waste incineration and bio gas were observed as possible alternatives in this regard. Preliminary screening for selection of appropriate design was carried out considering the criteria indicated below.

Conclusion

The incorporation of PCMs into building elements takes the advantage of latent TES for additional energy savings. The development of energy-storing building is a solution to the on-going quest for energy conservation, and also to improving the indoor environment in which people work and live. In terms of thermal comfort, it is envisaged that the indoor environment of a building which uses PCM construction materials will have significantly lower mean radiant temperatures and more thermal stability, having less likelihood of overheating and fewer temperature fluctuations.

Thermal improvements in a building due to the inclusion of PCMs depend on the type of PCM, the melting temperature, the percentage of PCM mixed with conventional material, the climate, design and orientation of the construction of the building. The optimization of these parameters is fundamental to demonstrate the possibilities of success of the PCMs in building materials.

1. Using flat plate collector equipped with honeycomb material significantly reduces the optimum area required for solar heating and cooling systems.
2. Great portions of the total heating and cooling loads are satisfied by solar energy at the optimum conditions and the overall system efficiency is within the previously published results.
3. The cost of unit energy for solar heating and cooling systems approximately equals to 64 % of the corresponding cost of the conventional fuel at the current prices.
4. The results of the present study should encourage wide utilization of solar energy systems which will help in reducing environmental pollution.

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