TECHNOLOGICAL POTENTIAL OF SMALL SCALE ICE THERMAL STORAGE BASED AIR CONDITIONING SYSTEM IN THE GENERATION PHASE FOR HOTEL & ENTERTAINMENT INDUSTRY OF SRI LANKA

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December 2018

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Thesis submitted in partial fulfillment of the requirement for the degree
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DECLARATION

The research work submitted in this dissertation is my own investigation except where otherwise stated. This dissertation has not been accepted for any degree and not concurrently submitted for any degree in a university or any other institution.

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I endorse the declaration by the candidate.

Prof. R. Attalage

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my principal supervisor Prof. Rahula Attalage for his continuous & very sincere tireless expertise guidance and direction throughout this research project. I am very much thankful to all the lecturers who gave me wealth of knowledge during the course of Building Services Engineering. Further I am very much thankful to various industry experts whom I met during this research project. I would like to express my sincere thanks to my colleagues of the course who generously shared their knowledge and experiences with me.

Finally I am very much thankful to my wife, children & parents for their encouragement, support plus patience during the period of my work for this research project.

ABSTRACT

Demand for electricity during a day, varies with the time due to various factors. Electricity demand of Sri Lanka for a typical day could easily be divided into three main categories. One segment characterizes a very high sudden demand increase during later in the evening, and sharp decrease of the demand during the mid night until the next day early morning time and average daily demand during the day time. As a remedial action in facing this change of demand, electricity service providers generally encourage users to reduce the demand through different measures and also shift their consumption during the high demand period to the low demand period. This is achieved by introducing different electricity tariffs based on the time of the day. As Air Conditioning systems demand considerable percentage of building electricity consumption, Cold Thermal Storage technologies is an ideal candidate for electrical load shifting applications of buildings. This study explores the technological feasibilities and also reviews the engineering economics of building small scale Ice Thermal Storage based air conditioning system in the generation phase which has average capacity of 32 Ton Hours. The development of small scale thermal storage based air conditioning system is progressed through a detailed research work and final design was reviewed of its economic feasibility to be used for hotel rooms & 100 capacity movie theaters under Hotel & General electricity tariff structures respectively.

This study further investigates in particular the ice building process in a water filled, limited length horizontal rectangular enclosure with the constant temperature glycol circulation system at the top & bottom surfaces. The rates of ice building on top and bottom surfaces were mathematically modeled based on the equations published by Et al. P. Bhargavi & Et al. Liang Yong. The dimensionless equations were then converted to dimensional and set of equations were derived to find the ice thickness Vs time, temperature profile along ice thickness at a given time and several other associated parameters necessary to calculate the heat transfer during water freezing. The goal was to find the maximum achievable ice thickness during 6.5 hours period and total energy extracted by the glycol circuit. Three glycol temperatures of -12C, -6C and -3C were considered and 3 data sets were built.

By considering a given glycol temperature, the built ice thickness was calculated and tabulated for 6.5 hours period at 20 minutes intervals. Thereafter the temperature profile along the ice thickness was tabulated during the end of each 60 minutes (1 hour) up to 6 hours and final data set was tabulated at the end of 6.5 hours. Here the temperature profile was estimated at every 2.5 mm distance along the built ice thickness. The width & length of water filled rectangle enclosure was selected as 10 cm & 110 cm respectively and this unit is called Primary Ice Making Chamber. The height was selected based on the final built ice thickness which was decided based on temperature

of glycol circuit. Finally relevant total energy extracted and final ice volumes were calculated for 3 different glycol circuit temperatures.

In order to achieve the uniform ice thickness inside the Primary Ice Making Chamber, counter flow arrangement was introduced to glycol circuits placed at top & bottom surfaces of it. Still there is a drop of final ice volume. The volume reduction was calculated and relevant total energy removed by the glycol circuit was calculated. This was repeated for 3 different glycol temperatures. The glycol circuits were designed and relevant flow rates were calculated to maintain the heat transfers for 3 designs scenarios. Finally 3 ice thermal storage designs were evaluated. The cost of manufacturing was calculated for all three designs. The operational cost was calculated for all three cases under hotel tariff for using at hotels and under general tariff for using at Movie Theaters. It was revealed that the price of chiller contributes to more than 50% of the cost of manufacturing for all 3 designs.

The payback period for the use case of hotel rooms under hotel tariff was found to be 4.3 years. The use case of Movie Theater has a 3.4 years payback period. This clearly indicates the further possibility of reducing the payback period under both cases used by cutting down the capital cost of chillers. When these units are manufactured on an industrial scale, it would further reduce the cost of chillers by volume discounts. This study makes a clear indication that small scale ice thermal storage systems are economically feasible.

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LIST OF ABBREVIATIONS

CTS	Cold Thermal Storage
CEB	Ceylon Electricity Board
GP-2	CEB General purpose tariff for each individual point of supply delivered and metered at 400/230 Volts nominal and where the contract demand exceeds 42 KVA.
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
TR	Ton of Refrigeration
Ton Hr	Ton Hours
TES	Thermal Energy Storage
PIMC	Primary Ice Making Chamber
ATES	Aquifer Thermal Energy Storage
CIMC	Composite Ice Making Chamber
M	Mass
P	Density
V	Volume
M	$p * V$
C_p	Specific heat

Nomenclature used for mathematical model

b	Wall of the capsule
c	Specific heat
h	Thickness of the capsule
Hs	Solidification latent heat of ice
k	Thermal conductivity
l	Liquid phase change material
m	Freezing point of water
S	Solidification thickness
Ste	Stephan number
S	Solid phase change material (ice state)
t	Time
T	Temperature
x	Longitudinal coordinate
X	Dimensionless longitudinal coordinate
y	Solidification thickness of ice
α	Thermal diffusivity
θ	Dimensionless temperature
ρ	Density
τ	Dimensionless time

LIST OF APPENDICES