THERMAL ANALYSIS OF AN AIR-TO-AIR HEAT RECOVERY UNIT FOR REDUCED ENERGY CONSUMPTION IN BALANCED VENTILATION SYSTEM

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ABSTRACT: *HVAC has become very essential in these days. But this system consumes a lot of energy, so this high energy consumption is to be minimized. One of the methods is to use the waste heat. Three different heat recovery units have been used in order to characterize their performance such as HRW-1800-MS-270, HRW-1700-MS-200 and HRW-2000-SG-200. Analysis has been carried out over the weather conditions of Karachi. Among all of these, HRW-1800-MS-270 showed the best performance. Cooling load is reduced by 50% with the use of HRW-1800-MS-270. Designed CFM decreases by 19% by using HRW-1800-MS-270. BHP of fan motor is decreased by 19% by the use of HRW-1800-MS-270. HRW-1800-MS-270 reduces the annual energy consumption of cooling coil by 18%. Reduction in annual energy consumption of heating coil is 41% if HRW-1800-MS-270 is incorporated into the system. HRW-1800-MS-270 reduces the annual energy consumption of supply fans by 18%.*

Keywords: HVAC, heat recovery, heat exchanger, cooling coil load, heating coil load

1 INTRODUCTION

Heating, ventilating and air conditioning systems (HVAC) have become necessary to provide better indoor air quality. It is a process of treating the air to maintain the desired temperature and humidity to a comfort level. HVAC is one of the high energy consumption field where a considerable amount of energy is utilized to maintain the desired temperature and humidity. Energy crises is a main concern worldwide and is more significant in Pakistan. Current shortfall of electricity is 7000 MW. This issue does not appear to be resolved in the near future. In the last few years, urbanization and industrialization have increased to a certain extent and because of this energy consumption has risen remarkably. Almost one third of society's energy consumption is utilized by air conditioning. More precisely, major portion of energy is consumed to cool and dehumidify fresh air. Researchers have focused to minimize this high energy consumption. Latest technologies are becoming popular to save energy. There are many techniques currently in use to reduce this energy consumption. One of the ways to reduce this high energy consumption is to reuse the waste heat. In the present research the heat recovery in the HVAC system of a hospital building is considered. Heat recovery will be carried out by a heat recovery wheel which is a type of heat exchanger positioned between the streams of supply and exhaust air. It is comprised of a honeycomb medium of heat absorbing material. It slowly rotates between the supply air stream and the exhaust air stream. It picks the heat from one air stream during the first half of rotation and delivers the heat to the other air stream during the second half of rotation. Researchers have already worked in this field. Younness El Fouih [1] studied HRV unit integrated in residential and commercial buildings to characterize its annual performance. Shahram Delfani [2] experimentally evaluated four different types of air conditioning systems and calculated the energy consumption for various outdoor climatic conditions in hot and humid regions. He concluded that using heat recovery, energy consumption will reduce about 11–32%. Mardiana-Idayu [3] reviewed energy recovery technologies for building applications according to the concept and classification of heat or energy recovery. José Fernández-Seara [4] analyzed experimentally an air-to-air heat recovery unit equipped with a plate heat exchanger (PHE). An experimental facility was designed to reproduce the typical outdoor and exhaust air conditions with regard to temperature and humidity. The unit was tested under balanced operation conditions, as commonly used in practice. Yanming Kang [5] recommended critical temperatures of air-to-air heat recovery systems for supermarkets in winter. He also discussed the heat recovery system for four cities in different climate zones of China. Ke Zhong [6] considered four different climate zones of China. The annual composition of energy consumption of fresh air was evaluated in the eight selected cities. An Nguyen [7] studied three methods of recovering sensible heat during heating and ventilation process. From the experiments performed,
coefficient of performance for without heat recovery, sensible heat exchanger, single and double heat recoveries were 2.88, 3.20, 3.18 and 3.28 respectively. The results showed that double heat recovery shows the best COP performance. C.-A ROULET [8] addressed energy recovery with air handling units from a theoretical point of view. The results of measurements on 13 units were presented and in the best three cases, heat recovery efficiency was between 60 and 70% and in the three worst cases, the efficiency was less than 10%. Main objective of this research is to verify that either the use of heat recovery wheel is useful or it uses more energy than it saves. The focus is on the use of heat recovery wheel to characterize its annual performance on the basis of different parameters. Renato M. Lazzarin [9] evaluated that possible sensible and total heat recovery depends on the climate and on the operating period. Total heat recovery is limited in winter by the humidity of the supply air; this lowers the exchange capacity in the heating period. J.Y. Wu [10] investigated, the energy performance of ERV along with the availability of ERV both for Beijing and Shanghai weathers in China in terms of the ratio of heat recovery to energy supply by HVAC devices and ERV, with different indoor temperature set-points. Simulation results show that the seasonal average of the ratio is linear with indoor temperature set-points. Gaoming Ge [11] evaluated that the energy and economic performance of an ERV depends on its effectiveness, cost, maintenance as well as other parameters such as climate, building design and HVAC system

parameters. The results illustrated that an ERV with 75% sensible and 60% latent effectiveness can reduce the peak heating load by 30%, the peak cooling load by 18%, the annual heating energy usage by 40% and the annual cooling energy usage by 8%, with a payback period of 2 years.

Junjie Liu [12] analyzed the performance of ERV in different climatic zones in China. The energy saving performances of the ERV were studied with five different outdoor climatic conditions, the enthalpy efficiency, fan power consumption of ERV and fresh air change rate.

2 MATERIALS AND METHODOLOGY

A building was considered for this purpose. Peak cooling coil load, design airflow CFM and the fan motor BHP were calculated for the sizing of the HVAC system. Proceeding further annual energy consumption by cooling, heating, supply fan, lighting and other electrical equipments were determined through simulation tool. Research has been carried out for the weather conditions of Karachi because Typical Metreological Year 2 file was only available for this city of Pakistan. Dri Rotors Selection software was used for research.

Until now calculations were made without using heat recovery. After that heat recovery units were incorporated into the system. Now all the above mentioned parameters were determined with the inclusion of heat recovery units into the system. Analysis has been carried out by using three different types of heat recovery units which are as follows

- HRW-2000-SG-200
- HRW-1700-MS-200
- HRW-1800-MS-270

In the above code, HRW is the abbreviation for heat recovery wheel and the values after HRW e.g. 2000mm, 1700mm are the diameters of wheels. SG denotes for silica gel and MS for Ecosorb 300 (Molecular Sieve 3A). Values after SG or MS e.g. 200mm and 270mm are the depths of wheels. Two different types of desiccants have been used for the analysis:

- First one is the Silica Gel
- Second desiccant is the Ecosorb 300 (Molecular Sieve 3A)

2.1 Silica Gel

It is a natural desiccant and has high adsorption capacity but for this cross contamination is at a much higher rate. It is mostly used in industrial applications wherein cross contamination concerns are low.

2.2 Ecosorb 300 (Molecular Sieve 3 A)

It is being used in more than 95% of the applications. It ensures selective adsorption of moisture only and hence reduces cross contamination to least. It is recommended for all commercial applications involving human occupancy and now widely used including hospitals and several.

3 RESULTS AND DISCUSSIONS

3.1 Cooling Load

Cooling load of the system without heat recovery was 81 tons as shown in the fig.3.1. While inclusion of recovery units into the system, reduces the load of the cooling coil. Cooling load reduces to 49.2 tons by using 1700-MS-200 recovery unit. With the use of 2000-SG-200 unit, cooling load reduces to 46.8 tons. Cooling load reduces to least i.e. 40.6 tons by using 1800-MS-270.

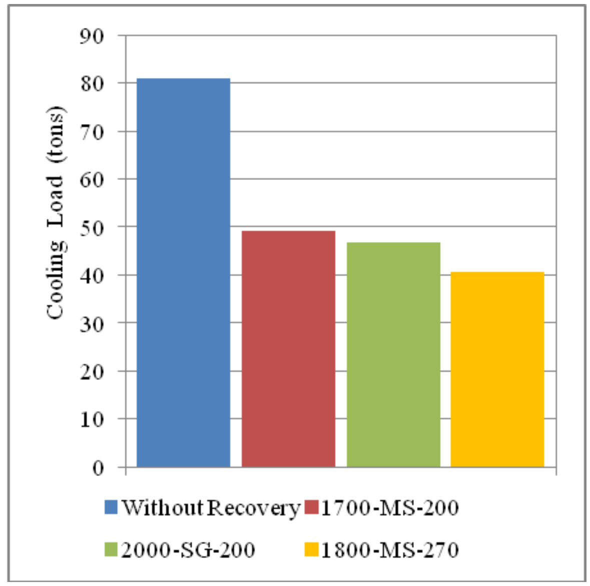

Fig. 3.1 Cooling Load

3.2 Design Airflow

Design CFM of air required to maintain a better indoor air quality was 9500 without using recovery unit as shown in the fig.3.2. If we use recovery unit 1700-MS-200, CFM reduces to 7848. 2000-SG-200 yields the same value. While CFM of required air reduces down to 7688 by the use of 1800-MS-270.

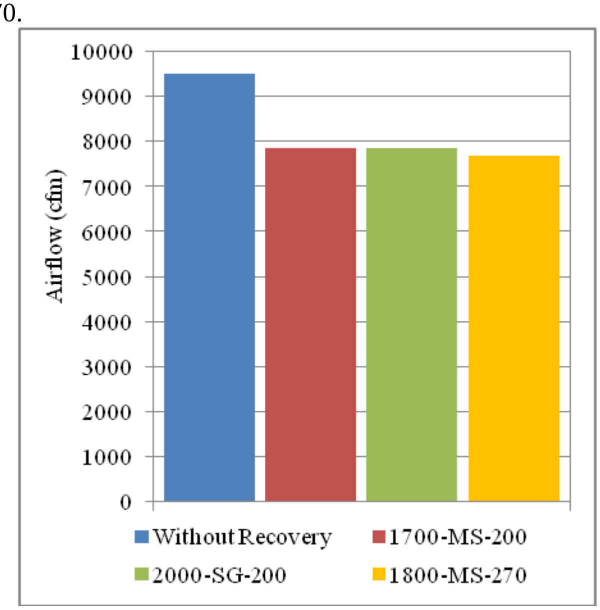

Fig. 3.2 Design Airflow

3.3 Fan Motor Sizing

Fan motor required for the system without recovery unit was of 1.75 BHP as shown in the graph below. Motor size reduces to 1.44 BHP by using 1700-MS-200. When the recovery unit 2000-SG-200 was incorporated into the system, fan motor of same BHP was required. Use of recovery unit 1800-MS-270 gives the minimum value of fan motor BP i.e. 1.41.

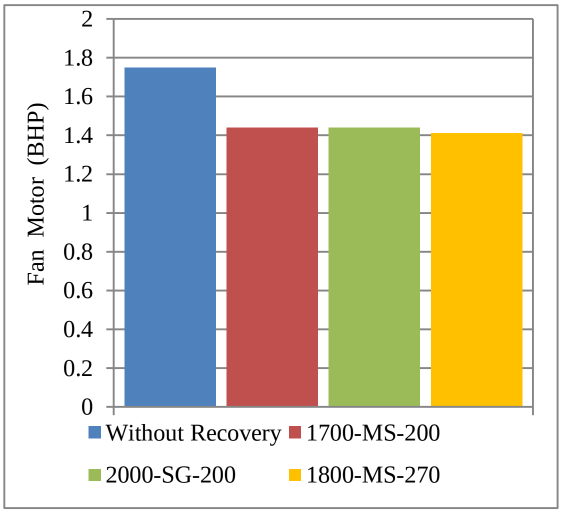

Fig. 3.3 Fan Motor Sizing

3.4 Annual Energy Consumption by Cooling Coil

Energy that will be consumed throughout the year by the cooling coil of the system without heat recovery unit will be 1286.3 MBTU as shown in the fig.3.4. While annual energy consumption by cooling coil is 1071.4 MBTU by 1700-MS-200 as well as by 2000-SG-200. System using 1800-MS-270 recovery unit gives less energy consumption i.e. 1051 MBTU

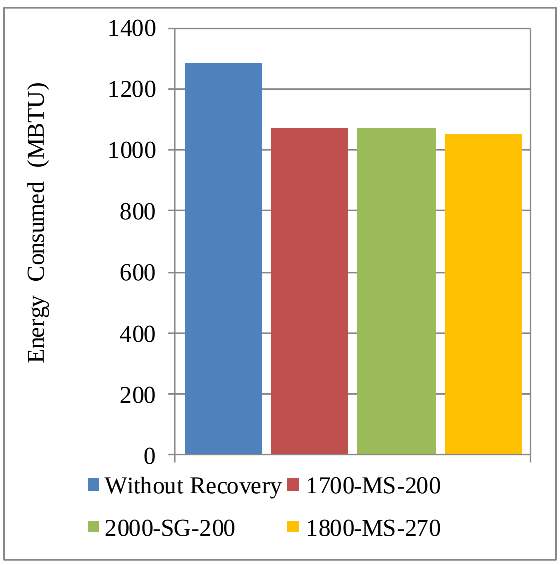

Fig. 3.4 Annual Energy Consumption by Cooling Coil

3.5 Annual Energy Consumption by Heating Coil

Energy that will be consumed throughout the year by the heating coil of the system without heat recovery unit will be 184.5 MBTU as shown in the fig.3.5. While annual energy consumption by heating coil is 115.8 MBTU by 1700-MS-200 as well as by 2000-SG-200. System using 1800-MS-270 recovery unit gives less energy consumption i.e. 108.5 MBTU

3.6 Annual Energy Consumption by Supply Fan

Energy that will be consumed throughout the year by supply fans of the system without heat recovery unit will be 3797 kWh as shown in the fig.3.6. While annual energy consumption of supply fans is 3163 kWh by 1700-MS-200 as well as by 2000-SG-200. System using 1800-MS-270 recovery unit gives less energy consumption i.e. 3101 kWh

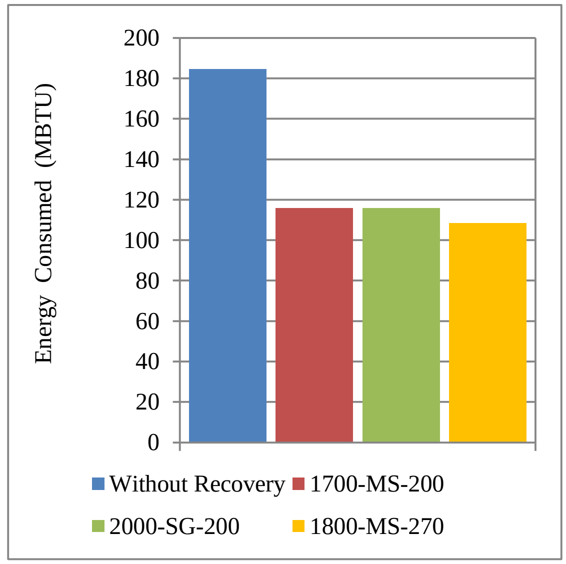

Fig. 3.5 Annual Energy Consumption by Heating Coil

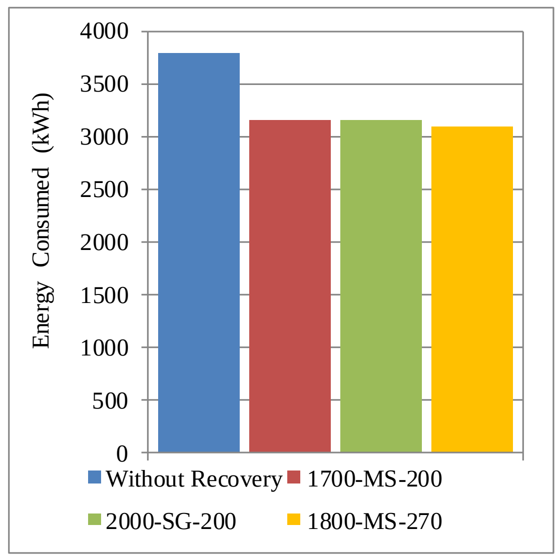

Fig. 3.6 Annual Energy Consumption by Supply Fan

4 CONCLUSIONS

Recovery unit with Ecosorb 300 (Molecular Sieve 3A) as desiccant, has better efficiency. Maximum heat recovery is possible by using HRW-1800-MS-270. Cooling load reduces by 50% with the use of HRW-1800-MS-270. While by using HRW-1700-MS-200 cooling load decreases only by 39% and by using HRW-2000-SG-200 cooling load decreases by 42%. In reduction of designed CFM of airflow, HRW-1800-MS-270 shows the best performance. CFM decreases by 19% by using HRW-1800-MS-270. Both HRW-1700-MS-200 and HRW-2000-SG-200 decreases CFM equally by 17%. BHP of fan motor is decreased by 19% by the use of HRW-1800-MS-270. While both HRW-1700-MS-200 and HRW-2000-SG-200 decreases BHP of fan motor equally by 18%. HRW-1800-MS-270 reduces the annual energy consumption of cooling coil by 18%. Reduction in annual energy consumption is 17% by using either HRW-1700-MS-200 or HRW-2000-SG-200. Reduction in annual energy consumption of heating coil is 41% if we incorporate HRW-1800-MS-270 into the system. This reduction minimizes to 37% by using HRW-1700-MS-200 or HRW-2000-SG-200. HRW-1800-MS-270 reduces the annual energy consumption of supply fans by 18%. Annual energy consumption is decreased by 17% by using either HRW-1700-MS-200 or HRW-2000-SG-200.

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