Research on the Integration Characteristics of Cooling Energy Recovery from Room Exhausting Cool Air in Summer

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Abstract: Currently, the design and construction of buildings and building energy systems are far from reasonable. The requirement and consumption of primary energy resources is aggravated, the use of building energy is free and wasteful, and pollution of the earth's atmosphere from building energy consumption is also aggravated. Therefore, the research and applications of energy efficiency and environmentally benign building energy systems are very important and urgent. Until now, much work on building energy conservation methods, measures and evaluations have been done by people in many countries. Some theoretical achievements have been already put into practice, but most of them put undue emphasis on some parts of the whole system. The complete idea of building energy conservation by integrating the building energy systems has not been put forward, and unequivocal guidance and a complete evaluation index and theoretical system for building energy consumption and its impact on the environment have not been formed. In this paper, we make further suggestions for improvement, and present some new concepts such as building energy flow, building mass flow, couple recovering of building discharge energy, integrated system of building energy , factor of building energy integration I, and effect factor on atmospheric environment of building energy F. The positive effects of these new concepts and methods on traditional approaches are also predicted. Theoretical research on an energy recovery unit that recovers cooling energy from indoor exhausting cool air in summer has been done in this paper, and demonstrates great advantages of its integration characteristics of building thermal systems.

Key words: exhausting cool air; energy recovery; integration characteristics; factor of building energy integration I ; effect factor on atmospheric environment of building energy F

1. INTRODUCTION

According to the development level of science and technology up to nowadays , the primary energy resources that can be developed and utilized efficiently by mankind are very much limited , the primary energy resources should be very much treasured by us , their development and utilization should be carefully planned and savelly used, wasteful using of energy in all kinds of activities of people should be stopped and should be even absolutely forbidden for the aim of better existing and development of mankind ourselves.

In present situation, the design and construction of buildings , the design and operation of building energy systems , are far from enough reasonable .In that way , the requirement and consumption of the primary energy resources are aggravated , the using of building energy is freely and wasteful , meanwhile the pollution to the earth atmosphere from building energy consumption is going on aggravated, therefore , the research and applications of energy efficiency and environmentally benign building energy systems are very important and urgent.

Up to now , many works have been done on building energy saving methods , measures and evaluations by people in many countries , some of theoretical achievements have been already put into practice , e.g., evaluation index of Coefficient of Heat Loss , evaluation index of PAL (Perimeter Annual Load) , evaluation index of CEC (Coefficient of Energy Consumption for Air-conditioning) , etc. ,
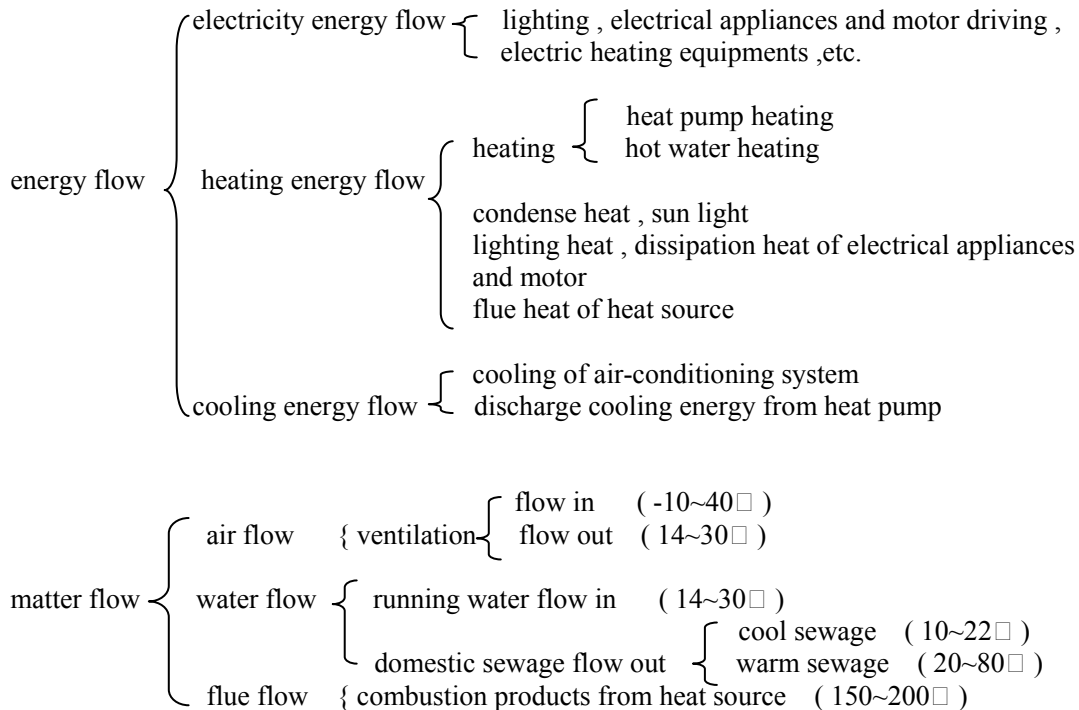
and some of economical evaluation methods of life cycle cost recovering based on above evaluation indexes .But these methods and indexes are preliminary , bit by bit , and partial , most of them put undue emphasis on the shape and the structure of building , the thermal insulation of architecture , the tightness of doors and windows , and the efficient characteristics of just one individual energy system , etc. , the complete idea of building energy saving by integrating the building energy systems has not been founded , the unequivocal guidance and complete evaluation index and theoretical system of building energy consumption and its impact on atmospheric environment have not been formed .For the better development of theory and techniques , an effort is try to make in this paper , attempt to propose two new concepts , the factor of building energy integration I , and the impact factor on outdoor atmospheric environment from building energy consumption F , traditional methods of building energy saving are not considered in this paper .

2. THE CONCEPT OF BUILDING ENERGY INTEGRATION

Building energy consumption amount takes a considerable part of the national total energy consumption , in developed countries , this proportion is about 30~40% , the year 2000 , in China , building energy consumption (including heating , cooling , refrigeration , family electrical appliances , lighting , cooking , hot water supplying , etc.) approximately equals to 1.79 ton coal , the percentage of the national total energy consumption was about 13.6% , this was the nationwide average value , in some large cities , this percentage might be 25% , with the development of our country , this energy consumption percentage may go on increasing .

2.1 Energy Flow and Matter Flow in a Building

To satisfy the basic requirements of existence, comfort and variety activities of people , certain amount of energy flow and matter flow must be allocated in a building , such as:

energy flow
- electricity energy flow
  - lighting , electrical appliances and motor driving , electric heating equipments ,etc.
- heating energy flow
  - heating
    - heat pump heating
    - hot water heating
  - condense heat , sun light
  - lighting heat , dissipation heat of electrical appliances and motor
  - flue heat of heat source
- cooling energy flow
  - cooling of air-conditioning system
  - discharge cooling energy from heat pump

matter flow
- air flow { ventilation
  - flow in   (-10~40   )
  - flow out   (14~30   )
- water flow
  - running water flow in   (14~30   )
  - domestic sewage flow out
    - cool sewage   (10~22   )
    - warm sewage   (20~80   )
- flue flow   { combustion products from heat source   (150~200   )

Here we take the outdoor atmospheric temperature at that time as the datum temperature, the energy that the temperature is above this datum temperature is called thermal energy, the energy that the temperature is below this datum temperature is called cold energy. we can get the view from the above arrange figure that the matter flow and the energy flow in a building often being coupled, e .g. thermal energy is coupled with the hot flue, thermal energy is coupled with the flow out ventilation air in winter, cold energy is coupled with the flow out ventilation air in summer , thermal energy is coupled

with the flow in running water in winter , cold energy is coupled with the flow in running water in summer , etc . .According to the characteristics of energy demands condition and energy facilities arrangement in a building , these thermal energy and cold energy can be further recovered and be further re-used to meet the needs of building user before they directly discharged outside the building . But up till present moment , the arrangement and the settlement of energy flow and matter flow are unreasonable , those thermal energy and cold energy in a building that can be fully utilized coordinately are not be efficiently used , they usually discharged directly to outside the building as the waste heat or waste cold , this kind of manner not only cause the vast waste of energy therefore aggravate the requirement of primary

$F = 1 - I,$

$\sum | Ew |$ ————The value sum total of unrecovered thermal energy and cold energy within a building;

$\sum | Ewr |$ ———— The value sum total of recovered thermal energy and cold energy within a building;

$\sum | Ewd |$ ———— The value sum total of discharged thermal energy and cold energy from a building without necessary recovered.
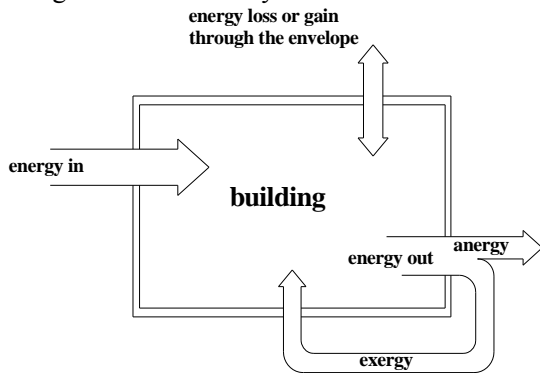

Fig.1 Total energy flow of a building

Energy in——means all energy supplying to the building $\sum | Es |$ including energy flow in and energy within matter flow in.

Energy out——means the value sum total of unrecovered(waste) thermal energy and cold energy within a building $\sum | Ew |$.

Anergy —— means the value sum total of discharged thermal energy and cold energy from a building without necessary recovered $\sum | Ewd |$.

Exergy —— means the valve sum total of recovered thermal energy and cold energy within a building $\sum | Ewr |$.

When the I value is high , that means the integrative degree of building energy is high , the recovery rate of building waste heat and waste cold is

energy consumption , but also cause the negative effect on outdoor atmospheric environment , such as the " Heat island effect " of large cities.

2.2 The New Concepts of Building Energy Integration

In order to better describe and solve the problem of building energy saving and outdoor environment protection , it is necessary to present two new concepts , i.e. , factor of building energy integration I , and effect factor on atmospheric environment of building energy F .

$$I = \frac{\sum | Ewr |}{\sum | Ew |} = 1 - \frac{\sum | Ewd |}{\sum | Ew |} , \quad \begin{array}{c}(\,0<I<1\,)\\ (\,0<F<1\,)\end{array}$$

high , the negative effect on outdoor atmospheric environment from building energy discharge is low , therefore the value F is low ; When the value I is low , that means the integrative degree of building energy is low , the recovery rate of building waste heat and waste cold is low , the negative effect on outdoor atmospheric environment from building energy discharge is high , therefore the value F is high .

3. THE MEASURES OF RECOVERY OF BUILDING WASTE HEAT AND WASTE COLD (BUILDING ENERGY INTEGRATION)

3.1 Heat recovery from air discharge of kitchen and the combustion flue flow from heat source, I_1;

3.2 Heat recovery from the waste heat produced by electric machinery, electric appliances, and lighting equipments, I_2;

3.3 Cold energy recovery from running water supplying in summer and thermal energy recovery from running water supplying in winter, I_3 ;

3.4 Heat recovery from hot sewage, I_4;

3.5 Heat recovery from indoor air exhausting in winter and cooling energy recovery from indoor air exhausting in summer, I_5;

3.6 Condenser heat recovery of air-conditioning system in summer and cold energy produced by evaporator in winter, I_6; factor of building energy integration：

$I = W_1 \times I_1 + W_2 \times I_2 + W_3 \times I_3 + W_4 \times I_4 + W_5 \times I_5 + W_6 \times I_6$

$= \sum_{i=1}^{6} W_i \times I_i,$

here I_i is the partial factor of building energy integration and W_i is the respective weight coefficient.

The study of I_5 is emphasized in this paper.

4. EXAMPLE ANALYSIS

An office room model with an energy recovery unit (that recovers cooling energy from indoor exhausting cool air) is suggested in Handan city. Room size: Va = length×width×height = $5.9×3.65×3.91＝84.2m^3$. In an air-conditioning room, fresh air G′ from outside is required, at the same time, certain amount of indoor air G should be exhausted to outside, G′=G is supposed. Heat exchange between intake outdoor air and discharge indoor air occurs within the heat recovery unit. Comparative high temperature outdoor air may be cooled by low temperature indoor air within the heat recovery unit, in this way great amount of cool energy may be recovered and the load of room air-conditioner may be reduced. The amount of cooling energy recovery depends on flow rate of intake outdoor fresh air, the efficiency of heat recovery unit ε, etc.

The cooling energy within exhausting cool air without heat recovery is

$$Q_{ex}=G\ C_p(T_{o\tau}-T_i)=\rho V\ C_p(T_{o\tau}-T_i)$$

The cooling energy recovery by heat recovery unit

$$Q_{re}=G'\ C_p(T_{o1\tau}-T_{o2})=\rho V'\ C_p(T_{o1\tau}-T_{o2})=\varepsilon\rho V\ C_p(T_{o\tau}-T_i)$$

the efficiency of heat recovery unit $\varepsilon=\dfrac{T_{o1\tau}-T_{o2}}{T_{o\tau}-T_i}$,

$T_{o1\tau}=T_{o\tau}$, here ε is equivalent to I_5

here ρ — density of air, ρ=1.16kg/m^3 ;

C_p— specific heat of air, C_p =1.005kJ/(kg·K);

G — mass flow rate of air, kg/ h;

V — volume flow rate of air, m^3/h;

T_i — indoor set temperature, T_i =26

Tab 1. Hourly temperature of outdoor air (from Dest data base, July 15, Handan city)

time	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
$T_{o\tau}$	31.5	33.1	35.0	37.7	39.2	39.4	39.7	40.0	40.1	40.1	39.0

Tab 2. Hourly cooling energy recovery (Q_{re}: kJ/h, V=30 m^3/h)

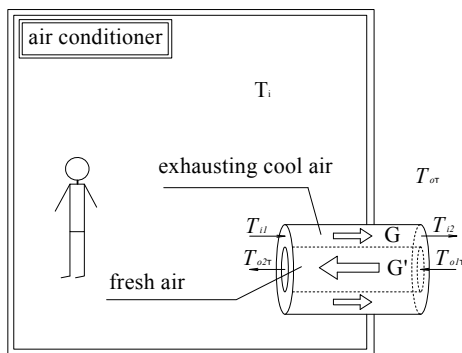| ε \ Q_{re} \ τ	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00
0.7	134.6	173.8	220.3	286.4	323.2	328.1	335.4	342.7	345.2	345.2	318.3
0.8	153.9	198.7	251.8	327.4	369.3	374.9	383.3	391.7	394.5	394.5	363.7
0.9	173.1	223.5	283.3	368.3	415.5	421.8	431.2	440.7	443.8	443.8	409.2

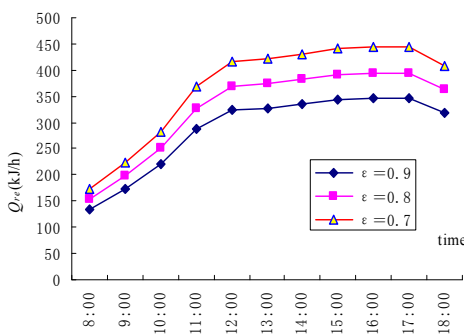**Fig.2 Cooling energy recovery by energy recovery unit**

Fig.3 Hourly cooling energy recovery

Some conclusions can be made out from the analysis above:

4.1 The amount of cooling energy within indoor exhausting cool air is quite large, within the calculating day it can reach the value of 4504.6 kJ / d, discharge indoor cool air directly to outdoor is very wasteful ;

4.2 In this case in summer, when the efficiency of heat recovery unit ε is 0.7(also I_5 is 0.7), The cooling energy recovery by heat recovery unit within a day can reach the value of 3153.2 kJ / d
when the efficiency of heat recovery unit ε is 0.8(also I_5 is 0.8), The cooling energy recovery by heat recovery unit within a day can reach the value of 3603.7 kJ / d
when the efficiency of heat recovery unit ε is 0.9(also I_5 is 0.9), The cooling energy recovery by heat recovery unit within a day can reach the value of 4054.2 kJ / d

4.3 In this case, the usage of heat recovery unit that recovers the cooling energy within indoor exhausting cool air is not only good for energy recovery, but also good for the load reduction of room air conditioner.

5. CONCLUSION

From the analysis above, some conclusions can we get, the total amount of building energy consumption is very large, and it is going on increasing in the future. But now our disposition of energy flow in a building is far from perfect, some

are even unreasonable, great potentialities of energy saving and energy recovering are existing, many improvements need us to do. If our schemes and technical approaches are reasonable, waste (unused) energy of a building can be recovered and reused to the maximum, the consumption of building energy can be further reduced, the ratio of building energy saving can be further raised, meanwhile, the impact of building energy consumption on atmospheric environment can be reduced to the minimum.

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