ENERGY SAVING EFFECT BY CENTRAL VENTILATION WITH TOTAL HEAT RECOVERY INSTALLED IN A DETACHED HOUSE

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ABSTRACT

Total heat exchanger model based on experimental results was incorporated in the entire building model with the stay and internal generation of heat and with window opening-closing schedule, and energy-saving effects of total heat exchangers were evaluated including regional features in Japan. Regional differences were found in the effects, and it was found that the reduction rate of heating and cooling loads was in the range of about 2 – 15%, and the reduction amount of heating and cooling loads was in the range of about 0.1 – 11 GJ. Also, based on the fact that cooling load increases due to the installation of total heat exchanger in the regions under cold climatic conditions, the buildings in the regions with warm climate designed in the high air-tightness and high insulation specification. As a result, it was found that heating load was reduced by about 35%.

KEYWORDS

Simulation, Total heat exchanger, Mechanical ventilation, Thermal road, Energy conservation

INTRODUCTION

In association with the revision of the Building Standard Law of Japan, the installation of mechanical ventilation equipments in houses is now obligatory as a rule. Heat exchanger is useful in reducing thermal load of heating and cooling with high electric power consumption because it reduces fresh air load, and much expectation is placed - especially on its energy saving effect in cold regions. Some heat exchangers used in ventilation systems, often called “total heat exchangers” or “enthalpy exchangers”, are designed so that water vapor as well as heat is transferred between airstreams. For heat exchanger, trial calculation can be made on energy saving effect from heat exchange effectiveness and enthalpy exchange effectiveness. However, overall analysis is not performed on the influence on energy saving effect from the factors such as weather conditions, heat insulation property and air-tightness, inside wall airflow characteristics, starting and stopping of heating and cooling, stay and internal generation of heat schedule, etc. Also, evaluation is not made on energy saving effect throughout the year.

It is difficult to lead to the conclusion by investigation through actual measurement while it is possible by using computer simulation “NETS” (Okuyama 1999). In the present study, evaluation has been made on energy saving effect when total heat exchanger is adopted for detached houses in Japan.

MODEL OF TOTAL HEAT EXCHANGER UNIT

In total heat exchanger unit (hereinafter referred as “unit”), fine chink or gap is present in every component. Air leakage from the gap is one of the factors to cause heat transfer or water vapor transfer, and it seems that this exerts strong influence on heat exchange effectiveness and enthalpy exchange effectiveness. For this reason, we first constructed an airflow network model, and after reproducing airflow rate and volume of air leakage at each component (unit), a heat network model and a water

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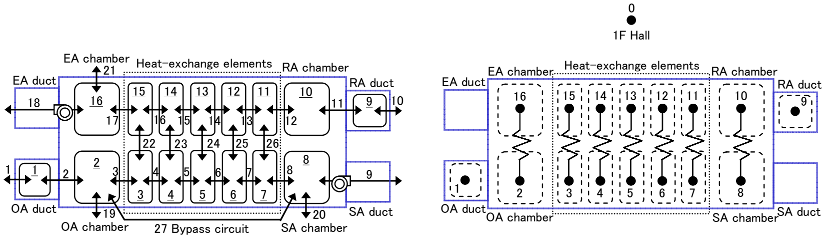
vapor network model were constructed. Regarding the airflow network, we assumed a model structure as shown in Figure 1. The interior space of the unit was divided to zones, and each path between zones was expressed as given in the equation:

$$\Delta P = \zeta \frac{\rho}{2}\left(\frac{Q}{A}\right)^{\eta} \qquad (1),$$

where ΔP is differential pressure [Pa], ζ is pressure loss coefficient [-], ρ is air density [kg/m^3], Q is airflow rate [m^3/s], A is cross sectional area [m^2], η is pressure loss exponent [-]

The experimental results in the past were referred, and, based on the results of the experiment (Kurabuchi et al. 2006, 2007), pressure loss coefficient at heat-exchange elements were distributed analytically. The gap characteristics of each path are given as summarized in Table 1. Because the experiment on heat and water vapor could not be performed, modeling was carried out according to catalog performance characteristics. Heat and water vapor network models except air transfer are shown in Figure 1. And heat and water vapor characteristics are shown in Table 2.

Table 3 shows the comparison of the results of the calculation with catalog values, and catalog values



The arrow and figure mean a flow path and its number, and the figure with an underline indicates a zone number.
OA=Outdoor Air. SA=Supply Air. RA=Return Air. EA=Exhaust Air

Figure 1 Model of total heat exchanger unit
(Left figure: Airflow network model. Right figure: heat and water vapor network model)

Table 1 Gap characteristics of total heat exchanger

Pass No.	System	Part	Zone No.	ζ	η
1†1	OA-SA	Outdoor－OA duct	Outdoor-1	－	－
2	OA-SA	OA duct－chamber	1-2	31601	2.000
3 to 8	OA-SA	Heat-exchange element resistance	2-3,3-4 4-5,5-6 6-7,7-8	491	1.542
9†1	OA-SA	SA chamber－Indoor	8-Each room	－	－
10†1	RA-EA	Indoor－RA duct	Hall_1-9	－	－
11	RA-EA	RA duct－chamber	9-10	5628	2.000
12 to 17	RA-EA	Heat-exchange element resistance	10-11,11-12 12-13,13-14 14-15,15-16	387	1.413
18†1	RA-EA	EA chamber－Outdoor	16-Outdoor	－	－
19	Air leakage of the casing	OA chamber	Hall_1-2	684567	1.030
20		SA chamber	Hall_1-8	163899	1.169
21		EA chamber	Hall_1-16	85103	1.000
22 to 26	Air leakage of the element	Heat-exchange element advection	3-15,4-14 5-13,6-12 7-11	453311	1.086
27†2	OA-SA	Bypass circuit	2-8	14605	2.000

From references [2], it sets up as A (cross sectional area)=1 m^2.

†1 It is based on the design of each duct.

†2 The flow path 27 is an assumption value when the bypass circuit open. When the bypass circuit opens, the flow pass 3 closes.

Table 2 Heat and water vapor characteristics of total heat exchanger

Node No.	System	Part	Heat conductance[W/K]	Water vapor conductance[kg/s(kg/kg)]
2-16	OA･EA chamber	Between chamber	0.78875	0
3-15 4-14 5-13 6-12 7-11	Heat-exchange element	Heat-exchange element	34.8837	0.025
8-10	SA･RA chamber	Between chamber	0.78875	0
0-2	OA-SA	Hall_1－Casing	1.04	－
0-8	OA-SA	Hall_1－Casing	1.04	－
0-10	RA-EA	Hall_1－Casing	1.04	－
0-16	RA-EA	Hall_1－Casing	1.04	－

Table 3 Comparison of a catalog value and calculation [%]

Item	Heat exchange effectiveness	Enthalpy exchange effectiveness
Catalog	62.0	57.0
Calculated	62.7	55.6

Table 4 Transition of various kinds of effectiveness by change of pressure balancing [%]

Item	Net air volume rate	Heat exchange effectiveness	Enthalpy exchange effectiveness
Rating	95.0	62.7	55.6
OA P.L×2	92.5	64.7	59.6
EA P.L×2	94.5	62.7	57.0
RA P.L×2	95.5	62.5	56.6
SA P.L×2	95.7	62.6	56.6

P.L=Pressure loss at the rating

are almost correctly reproduced. Further, the resistance of the duct system connected with the unit was increased on this model, and the changes of efficiency were calculated. The results are given in Table 4.

MODEL OF TOTAL BUILDING

Object residence

The house under study is “a case study model plan urban type” as shown in Figure 2. Total floor area is 122.1 m^2, and air volume of the total building is 286.2 m^3.

Weather data and wind pressure coefficient

As the weather data, the Expanded AMeDAS Weather Data [3] was used. As wind pressure coefficient, measured values from wind tunnel experiment by assuming the surrounding environment of the model as urban area are used.

Energy-saving standards of residence

Taking the Japanese Energy Conservation Standards of 1999 as reference, the energy-saving standards in each regional area were set up as shown in Table 5. Due consideration was given on air-tightness of fittings, and the standards were set up so that effective leakage area (C value) could be satisfied for the whole building in each case.

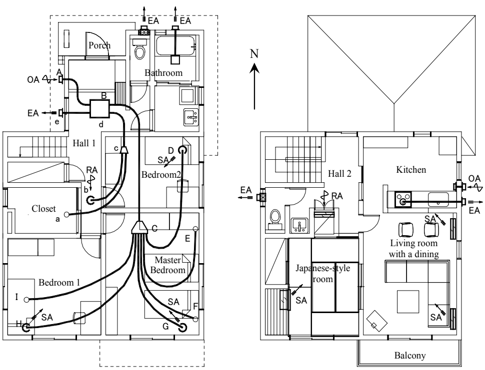


Figure 2 Plan and ventilation systems

Table 5 Setting of energy saving

Region†1	Q value [W/m^2K]	C value [cm^2/m^2]	Air tightness of opening†2
Ⅰ	1.4(1.6 or less)	2.0(2.0 or less)	A-4 (A-4)
Ⅱ	1.4(1.9 or less)		
Ⅲ	2.1(2.4 or less)	5.0(5.0 or less)	A-3 (A-3 or A-4)
Ⅳ	2.1(2.7 or less)		
Ⅴ			
Ⅵ	3.4(3.7 or less)		

†1 Japanese Energy Conservation Standards of 1999

The numerical values in a parenthesis are reference values of Japanese Energy Conservation Standard of 1999.

Q value is specific heat loss coefficient.

C value is effective leakage area of skin.

†2 Japanese Industrial Standard (JIS A 4702 and JIS A 4706)

Solar radiation

It is assumed that there is no influence from sunshine on southern side and northern side (neglecting the influence from adjacent building). On eastern side and on western side, adjacent buildings are very close and it is assumed that there shall be no sunshine. As solar radiation shading for the opening, lace curtains (transmission: 0.53) and eaves (roof and balcony) were considered.

Water vapor transfer model

Water vapor node within wall was not provided (moisture transmission of wall was neglected). It was simplified to the model only for water vapor node in each zone, and it was assumed that the transfer of water vapor between these water vapor nodes should depend only on airflow rate by airflow network.

Stay type and inside heat generation schedule

The schedule is classified to weekdays and to holidays, and sensible heat generation rate and water vapor generation amount for every 15 minutes are set for each room (Toriumi et al. 2006).

PLANNING OF VENTILATION SYSTEMS

General ventilation equipment

General ventilation equipment was designed by incorporating total heat exchanger unit in Figure 2. Air is supplied to each room via ventilation equipments, and air is sent back from hall via undercut of internal doors. Air supply amount to each room depended on pressure balance and varied in the range of 0.5 to 1.0 air changes per hour (ACH).

Local ventilation equipments

Range hood fan is designed in such manner that it is operated when there is sensible heat generation of about 2,000 W (suggesting that cooking is going on) in accordance with “the stay type internal heat generation schedule”. The ceiling fan of bathroom is designed to be operated when washroom and bathroom are used and to be stopped during sleep.

CALCULATION MODEL

Calculation model and mode

As the calculation model, two types were used: “mechanical type” not to perform natural ventilation except cleaning purpose due to conditions of location, and “general type” for natural ventilation (cross-ventilation), which is considered as the standard for heating and cooling purpose (Table 6).

Heating and cooling

The setting of temperature and humidity for heating and cooling was based on Table 7. Operation and stop were performed on “the stay type and internal heat generation schedule”. The rooms under study of heating and cooling conditions were: all rooms in the areas I – II, and the rooms where occupants stay in all other areas.

Table 6 Combination of opening during cross-ventilation

Part	General type			Mechanical type		
	Ordinary	Cleaning	Sleeping	Ordinary	Cleaning	Sleeping
Windward opening	Open window	Open window	Open window^{+}	Close window	Open window	Close window
Interior wall	Close door	Close door	Close door	Close door	Close door	Close door
Leeward opening	Open window	Open window	Open window^{+}	Close window	Open window	Close window

“Open window^{+}” is the condition as for which 25cm of one side opened window.

For the windows, opening area is multiplied by the discharge coefficient of screen window (0.5), and the discharge coefficient during cleaning is 0.65

Cross-ventilation should be used by opening windows when outdoor air temperature is 20 - 25°C during the cooling period except the sleeping time and windows should be opened when outdoor air temperature is 18 - 26°C during the heating period.

Cross-ventilation at the time of sleeping should be used by opening windows when outdoor air temperature is 25 - 28°C during the cooling period.

Table 7 Temperature and relative humidity setting of air conditioning

Condition	Mechanical type	General type
Cooling (At the time of sleeping)	26℃, 60%RH (28℃, 70%RH)	26℃, 60%RH or cross-ventilation (28℃, 70%RH or cross-ventilation)
Heating (At the time of sleeping)	22℃ (18℃)	(22℃ or cross-ventilation) —

The relative humidity of heating period is a result.

Setting temperature for heating in the non-stay rooms in the areas I – II was 18℃.

RESULTS ANALYSIS AND DISCUSSION

Energy saving effect by the total heat exchanger in a warm area

The results of calculation of annual cooling and heating load in Tokyo are shown in Table 8. Calculation was made on the period when daily average air temperature was 15℃ or lower, and this was defined as a period requiring heating. The period other than the heating period was defined a period requiring cooling. For “Mechanical type”, calculation was made on the cases of “Non total heat exchanger”

(Non-HEX), the cases with total heat exchanger (HEX) and the cases with enthalpy control total heat exchanger (HEX enthalpy). For “the general type”, calculation was made only on the cases with total heat exchanger (HEX). In “the mechanical type”, “a HEX” and “b non-HEX” were compared with each other, and evaluation was made on energy saving effect of the total heat exchanger. In the heating season of December and January - March when temperature difference between indoor and outdoor is big, heating load reducing effect is about 10%. In the mid-term of May - June and September - October, cooling load ratio is over 100%, and total heat exchanger gives reverse effect. This is because return air enthalpy exceeds outdoor air enthalpy due to the behavior of total building system caused by internal heat generation, sunshine and space between rooms, and heat recovery gives reverse effect. Regarding the period from July to August, enthalpy difference between outdoor air and return air is small due to similar phenomena, and effects are reversed depending on the time. Thus, almost no effect to reduce cooling load is seen due to the installation of total heat exchanger.

Table 8 Calculation result of annual heating and cooling load in a warm area

Region (Place)	Calculation model		Calculation condition		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year sum values[MJ]	Heating and cooling load
					Monthly integrated values [MJ]													
Ⅳ (Tokyo)	Mechanical type	a Non-HEX	Heating	q_S	4470	3735	3395	831	0	0	0	0	0	220	1492	3110	17252	26471
			Cooling	q_S	0	0	0	52	337	575	2191	2385	1190	370	24	0	7124	[MJ]
				q_L	0	0	0	5	5	139	659	881	369	37	0	0	2095	217
				q_T	0	0	0	57	343	714	2851	3266	1559	407	24	0	9219	[MJ/m^2]
		b HEX	Heating	q_S	4056	3380	3064	718	0	0	0	0	0	194	1292	2790	15494	
			Cooling	q_S	0	0	0	60	377	634	2228	2423	1227	400	28	0	7378	24748
				q_L	0	0	0	5	9	145	582	761	336	38	0	0	1876	[MJ]
				q_T	0	0	0	66	386	779	2810	3184	1563	438	28	0	9254	203
		Load ratio (b/a*100) [%]			90.7	90.5	90.3	88.3	112.6	109.2	98.6	97.5	100.3	100.9	87.1	89.7	93.5	[MJ/m^2]
		Reduction amount (a-b) [MJ]			414	355	331	104	-43	-66	41	81	-4	-5	196	319	1723	
		c HEX (enthalpy)	Heating	q_S	4056	3380	3064	718	0	0	0	0	0	194	1292	2790	15494	
			Cooling	q_S	0	0	0	52	340	581	2201	2405	1200	371	24	0	7174	24512
				q_L	0	0	0	5	5	136	575	758	329	36	0	0	1844	[MJ]
				q_T	0	0	0	57	346	716	2776	3162	1529	408	24	0	9018	201
		Load ratio (c/a*100) [%]			90.7	90.5	90.3	87.3	100.9	100.4	97.4	96.8	98.1	96.1	86.8	89.7	92.6	[MJ/m^2]
		Reduction amount (a-c) [MJ]			414	355	331	113	-3	-3	75	103	30	25	200	319	1959	
	General type	d HEX	Heating	q_S	3345	2555	2373	577	0	0	0	0	0	182	990	2138	12162	
			Cooling	q_S	0	0	0	21	91	95	1951	2242	963	142	19	0	5525	19136
				q_L	0	0	0	0	1	11	479	683	260	15	0	0	1450	[MJ]
				q_T	0	0	0	21	92	106	2430	2926	1223	157	19	0	6975	157
		Load ratio (d/a*100) [%]			74.8	68.4	69.9	67.5	26.8	14.8	85.2	89.6	78.5	54.2	66.6	68.8	72.3	[MJ/m^2]
		Reduction amount (a-d) [MJ]			1125	1180	1021	289	251	608	421	340	335	287	506	971	7334	
		Load ratio (d/b*100) [%]			82.5	75.6	77.5	76.4	23.8	13.6	86.5	91.9	78.3	53.7	76.5	76.6	77.3	
		Reduction amount (b-d) [MJ]			712	825	691	184	294	673	380	258	340	293	310	652	5612	

q_S = Sensible heat load. q_L = Latent heat load. q_T = Thermal load = $q_S + q_L$

Energy-saving effects of total heat exchanger under enthalpy control

In case the return air enthalpy exceeded outdoor air enthalpy, a model with a bypass circuit was assumed, which did not pass through heat exchange elements of air supply system. It was so designed that, when the bypass circuit (flow pass 27) was opened, the normal flow pass (flow pass 3) would to be closed (Fig. 1). In the total exchanger model in the present study, the pressure in supply airstream was lower than the pressure in exhaust airstream. In this respect, the air in the exhaust air stream flowed into the supply airstream, and cooling load in May and June increased although the rate of the increase was less than 1% (Table 8).

Energy saving effect by cross-ventilation

Comparison is made between “b. HEX” in “the mechanical type” and “d. HEX” in “the general type”, and energy saving effects due to cross-ventilation are evaluated. In December and in January - March, windows are not opened except for the cleaning purpose. Heating load reducing effect of about 20% is caused from the stopping of the heating control (18°C) during sleep. Cooling load reducing effect of about 25% can be provided by cross-ventilation with windows opened.

Energy-saving effects when the high air-tightness and high insulation specification was improved

The heat insulation and air-tightness performance was improved so that C value would be turned from 5.0 cm^2/m^2 to 2.0 cm^2/m^2 and Q value would be turned from 2.1 W/m^{2}K to 1.4 W/m^{2}K. Energy-saving effects of total heat exchanger can be evaluated by heating and cooling load ratios of b/a and d/c. Insulation performance was improved and gap area decreased and energy-saving effects of total heat exchanger were improved from 6.5% to 9.3% (Table 9).

Energy-saving effects of the buildings due to the improvement of air-tightness and insulation performance can be assessed by heating and cooling load ratio c/a. When the value c/a was observed throughout the year, the effect to reduce the heating load was 37%. In contrast, the cooling load increased by about 5%, and the effect to decrease the heating and cooling load was turned to 22%.

When the air-tightness and insulation performance was improved, the effect to reduce the heating and cooling load was more than 20%, and energy-saving effect was higher than the case where total heat exchanger was installed. When the air-tightness and insulation performance was increased from the load ratio d/a and total heat exchanger was installed further, the reduction effect on heating and cooling load increased to nearly 30%.

Table 9 Heating and cooling load when changing insulation efficiency and air-tightness

Region (Place)	Calculation model		Calculation condition		Period integrated values [MJ] Jan.-Mar.	Apr.	May-Sep.	Oct.-Nov.	Dec.	Year sum values [MJ]	Heating and cooling load
Ⅳ (Tokyo)	C value 5.0 cm^2/m^2 Q value 2.1 W/m^2K	a Non-HEX	Heating	q_S	11600	831	0	1712	3110	17252	26471 [MJ] 217 [MJ/m^2]
			Cooling	q_S	0	52	6678	394	0	7124	
				q_L	0	5	2053	37	0	2095	
				q_T	0	57	8731	431	0	9219	
		b HEX	Heating	q_S	10500	718	0	1486	2790	15494	24748 [MJ] 203 [MJ/m^2]
			Cooling	q_S	0	60	6890	428	0	7378	
				q_L	0	5	1832	38	0	1876	
				q_T	0	66	8722	466	0	9254	
		Load ratio (b/a*100) [%]			90.5	88.3	99.9	91.1	89.7	93.5	
	C value 2.0 cm^2/m^2 Q value 1.5 W/m^2K	c Non-HEX	Heating	q_S	7541	478	0	940	1958	10916	20584 [MJ] 169 [MJ/m^2]
			Cooling	q_S	0	83	6911	521	0	7515	
				q_L	0	5	2106	40	0	2152	
				q_T	0	88	9017	562	0	9667	
		d HEX	Heating	q_S	6186	355	0	686	1576	8803	18662 [MJ] 153 [MJ/m^2]
			Cooling	q_S	0	106	7250	602	0	7958	
				q_L	0	7	1851	43	0	1902	
				q_T	0	113	9101	645	0	9859	
		Load ratio (d/c*100) [%]			82.0	82.8	100.9	88.7	80.5	90.7	
		Load ratio (c/a*100) [%]			65.0	63.8	103.3	70.1	63.0	77.8	
		Load ratio (d/b*100) [%]			58.9	59.8	104.3	68.2	56.5	75.4	
		Load ratio (d/a*100) [%]			53.3	52.8	104.2	62.1	50.7	70.5	

Heating and cooling load at various regional points in Japan

Heating and cooling load throughout the year was calculated at 25 regional points in Japan as shown in Table 10. The heating load was reduced by about 15% in the regional areas I and II, while the reduction effect was lower than 10% in the regional areas III to V. On the other hand, the cooling load ratio was more than 100% at all times in the regional areas I - III. In the areas IV and V, the load ratio was more than 100% in the intermediate period except July and August. In the absolute amount, the heating and cooling load reduction effect throughout the year was in the range of 7000 – 9700 MJ in the areas I and II, in the range of 2400 – 2800 MJ in the area III, 1600 – 2500 MJ in the area IV, and 1500 – 1700 MJ in the area V. It was 500 MJ in the area VI. Because the reduction amount of cooling load was extremely low compared with the reduction amount of heating load, the relation between the reduction amount of heating and cooling load and the heating degree-day (D18-18) was analyzed by plotting. As a result, strong correlation was found (Fig. 3 and Fig. 4).

Energy-saving effects of total heat exchanger in Japan

From the relational expression between the reduction amount of heating and cooling load and the heating degree-day, energy-saving effects of total heat exchangers in Japan were calculated. The reduction amount of heating and cooling load of total heat exchangers in Japan (a value obtained by subtracting carrier power increment 315 MJ from heat exchange elements) is given in Fig. 5, and the reduction rate of heating load is shown in Fig. 6.

Table 10 Calculation points

No.	Region	City name	Heating period	Cooling period
1	I	Asahikawa	Sep.17-Jun.8	Jun.9-Sep.16
2	I	Nemuro	Sep.21-Jul.19	Jul.20-Sep.20
3	I	Sapporo	Sep.25-Jun.9	Jun.10-Sep.24
4	I	Muroran	Oct.1-Jun.23	Jun.24-Sep.30
5	II	Morioka	Sep.29-May24	May25-Sep.28
6	III	Akita	Oct.6-May23	May24-Oct.5
7	III	Sendai	Oct.11-May16	May17-Oct.10
8	III	Fukushima	Oct.11-May5	May6-Oct.10
9	III	Matsumoto	Oct.3-May14	May15-Oct.2
10	IV	Utsunomiya	Oct.17-May5	May6-Oct.16
11	IV	Maebashi	Oct.19-May1	May2-Oct.18
12	IV	Tokyo	Nov.2-Apr.22	Apr.23-Nov.1
13	IV	Niigata	Oct.19-May10	May11-Oct.18
14	IV	Toyama	Oct.20-May5	May6-Oct.19
15	IV	Shizuoka	Nov.7-Apr.18	Apr.19-Nov.6
16	IV	Nagoya	Oct.28-Apr.24	Apr.25-Oct.27
17	IV	Osaka	Nov.4-Apr.17	Apr.18-Nov.3
18	IV	Hiroshima	Oct.28-Apr.26	Apr.27-Oct.27
19	IV	Yonago	Oct.23-May3	May4-Oct.22
20	IV	Takamatsu	Oct.29-Apr.26	Apr.27-Oct.28
21	IV	Kumamoto	Nov.2-Apr.14	Apr.14-Nov.1
22	V	Kochi	Nov.6-Apr.12	Apr.13-Nov.5
23	V	Fukuoka	Nov.3-Apr.20	Apr.21-Nov.2
24	V	Kagoshima	Nov.13-Apr.8	Apr.9-Nov.12
25	VI	Naha	Nothing	Jan.1-Dec.31

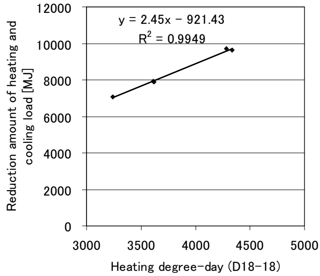


Figure 3 Reduction amounts of thermal load and heating degree-day (region □ - □)

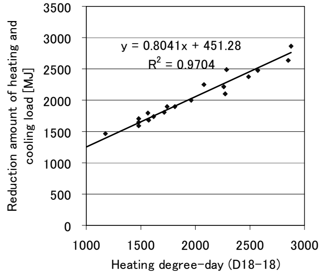


Figure 4 Reduction amounts of thermal load and heating degree-day (region □ - □)

CONCLUSIONS

In the present study, the energy-saving performance of total heat exchanger ventilation unit for a detached house was evaluated and confirmed by computer simulation. In the areas I and II, reduction effect of heating load was about 15% (6.5 – 11 GJ) when it was assumed that total heat exchangers were installed. In the areas I – III, cooling load increased at all times. In the areas III – V, when it was assumed that total heat exchangers were installed, reduction effect of heating load was slightly lower than 10% (1 – 3 GJ), while cooling load increased during the period when cooling was required except July and August. Also, when it was assumed that total heat exchangers with enthalpy control were installed, the effect was low because enthalpy difference between inside and outside of rooms was low. It appears that total heat exchangers are effective in the regions under cold climatic conditions because the reduction amount of heating and cooling load showed strong correlation to the heating degree-day. At the same time, it was made clear that heating load could be decreased by about 35% in the warm climate regions when the buildings are designed in the high air-tightness and high insulation specification of cold climate regions, and that cooling load can be reduced by about 20% by cross-ventilation.

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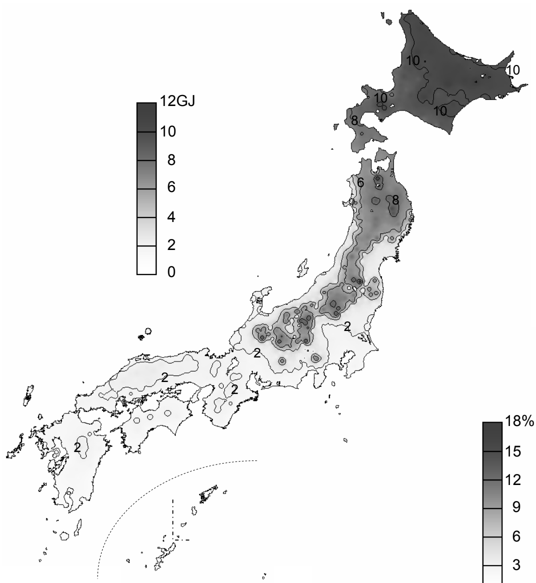

Figure 5 Reduction amount of heating and cooling load of total heat exchangers [GJ]

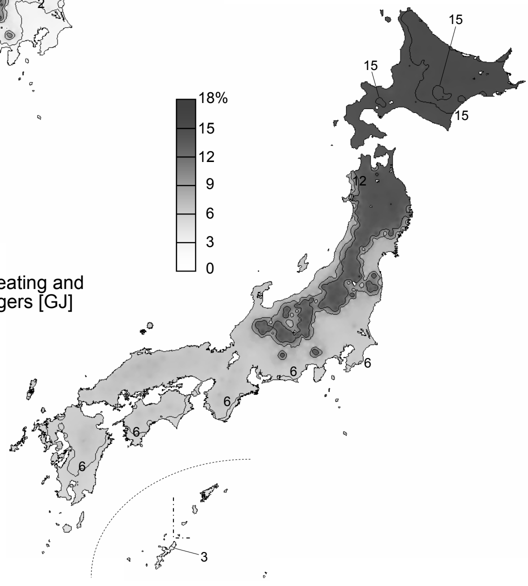

Figure 6 Reduction rate of heating and cooling load of total heat exchangers [%]