Influence of Transfer Efficiency of the Outdoor Pipe Network and Boiler Operating Efficiency on the Building Heat Consumption Index

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Abstract: This paper analyzes the influence of transfer efficiency of the outdoor pipe network and operating efficiency of the boiler on the building heat consumption index, on the premise of saving up to 65 percent energy in different climates. The results show that transfer efficiency is not influenced by the climate, and the influence is in accordance with that in other climates. The article also presents data on the energy consumption caused by the improvement of the transfer efficiency of the outdoor pipe network and the operating efficiency of the boiler, and the calculated formula for the building heat consumption index on the condition of saving 65 percent energy.

Key words: transfer efficiency of outdoor pipe network; operating efficiency of boiler; building heat consumption index

1. INTRODUCTION

The elementary goal, which is presented in Architecture Energy Saving Policy, China Architecture Technological Policy 1996-2010, pointed that the new design heating residential building should save energy 50% on the basis of local currency design energy consumption from 1996 to 2000. Heating residential buildings after 2005 should save another 30%, that is, save energy 65% on the basis of the first step of energy conservation, and the process shall be carried out according to three steps. In the past years, the emphasis has been put on the work of building envelope energy saving, more than the heating system energy saving. However, the latter should be done first before the work of building energy conservation. In cold area of china, the third step goal of energy conservation has much more difficulty than in the other weather areas, and it will not be achieved if we do not deepen the work of heating system energy saving. The Standard of Civil Buildings Energy Efficiency, which is published by Construction Ministry in 1986, presented that η_1 is 85% and η_2 is 55%. So we know that the heat used by the building effectively is only 46.75%, and heat loss is more, reaches to 53.25%. So, we should calculate and analyze transfer efficiency of outdoor pipe network and operating efficiency of boiler on the condition of energy saving 65%, and obtain how much they influence the building heat consumption index.

2. DERIVATION OF COMPUTING FORMULA

q_H, ε, $\eta_{1,}$ η_2 are used to present the building heat consumption index, total energy saving ratio of system, transfer efficiency of outdoor pipe network and operating efficiency of boiler, respectively. The energy consumption balance equation in the context of certain ε may be given as follows:

$$q_H^{'} / \eta_1^{'}\eta_2^{'} = (1-\varepsilon)\times q_H \times \eta_1\eta_2$$

It equals to the following:

$$q_H^{'} = (1-\varepsilon)\times q_H \ / \eta_1\eta_2 \times \eta_1^{'}\eta_2^{'}$$
$$= q_H \times (1-\varepsilon)/0.55/0.85 \times \eta_1^{'}\eta_2^{'}$$
$$= 2.14 \times (1-\varepsilon)\times q_H \times \eta_1^{'}\eta_2^{'}$$

Where, for some cities q_H is a constant. So the building heat consumption index is just relative to $\eta_1^{'}$ and $\eta_2^{'}$. The above equation can be simplified as follows:

$$q_H^{'} = k\eta_1^{'}\eta_2^{'}, \text{ and } k = 2.14\times(1-\varepsilon)\times q_H .$$

We know $\frac{\partial q_H^{'}}{\partial \eta_1^{'}} = k\eta_2^{'}$, $\frac{\partial q_H^{'}}{\partial \eta_2^{'}} = k\eta_1^{'}$ because of the definition of partial derivative, so partial derivative of $q_H^{'} = k\eta_1^{'}\eta_2^{'}$ is continuous and $q_H^{'} = k\eta_1^{'}\eta_2^{'}$ is derivable at the definition areas of $\eta_1^{'}$, $\eta_2^{'}$. So its derivative is

$$d(q_H^{'}) = k(\eta_1^{'} + d(\eta_1^{'}))(\eta_2^{'} + d(\eta_2^{'})) - k\eta_1^{'}\eta_2^{'}$$
$$= k\eta_2^{'}d(\eta_1^{'}) + k\eta_1^{'}d(\eta_2^{'}) + kd(\eta_1^{'})d(\eta_2^{'}) .$$

Ignore the $kd(\eta_1^{'})d(\eta_2^{'})$ and we get the formula (1):

$$d(q_H^{'}) = \left(\frac{\partial q_H}{\partial \eta_1^{'}}\right)_{\eta_2^{'}} d\eta_1^{'} + \left(\frac{\partial q_H}{\partial \eta_2^{'}}\right)_{\eta_1^{'}} d\eta_2^{'}$$
$$= k\left(\eta_2^{'}d(\eta_1^{'}) + \eta_1^{'}d(\eta_2^{'})\right)$$

3. DISCUSSION ON THE CHANGE OF $\eta_1^{'}$ AND $\eta_2^{'}$

The Standard of Civil Buildings Energy Efficiency points out $\eta_1^{'}$ is 0.9 and $\eta_2^{'}$ 0.68. We carry out following analysis subject to $\eta_1^{'}, \eta_2^{'}$ and adjust their values if necessary. In this way we can know how much the change of $\eta_1^{'}$ and $\eta_2^{'}$ influence the building heat consumption index.

3.1 When $\eta_1^{'}$ changes while $\eta_2^{'}$ remains the same, formula (1) can be simplified to as the following:

$$d(q_H^{'}) = \left(\frac{\partial q_H}{\partial \eta_1^{'}}\right)_{\eta_2^{'}} d\eta_1^{'} + \left(\frac{\partial q_H}{\partial \eta_2^{'}}\right)_{\eta_1^{'}} d\eta_2^{'} = k\eta_2^{'}d(\eta_1^{'}) \tag{2}$$

From the formula (1) we can see that the relationship between $d(q_H^{'})$ and $d(\eta_1^{'})$ is proportion when $\eta_2^{'}$ remains 0.68. So we just take into account what will happen when $d(\eta_1^{'})$ increases 1%, and the results are as follows:

3.2 When $\eta_2^{'}$ changes while $\eta_1^{'}$ remains the same, formula (1) can be simplified to:

$$d(q_H^{'}) = \left(\frac{\partial q_H}{\partial \eta_1^{'}}\right)_{\eta_2^{'}} d\eta_1^{'} + \left(\frac{\partial q_H}{\partial \eta_2^{'}}\right)_{\eta_1^{'}} d\eta_2^{'} = k\eta_1^{'}d(\eta_2^{'}) \tag{3}$$

From the formula (2) we can see that the relationship between $d(q_H^{'})$ and $d(\eta_2^{'})$ is proportion when $\eta_2^{'}$ remains 0.9. So we just take into account what will happen when $d(\eta_2^{'})$ increases 1%, and the results are as follows

Tab.1 The influence to building heat consumption index caused by the change of $\eta_1^{'}$

Cities	q_H	k	$d(\eta_1')$	$d(q_H')$	q_H'	$d(q_H')/q_H'$
Beijing	31.7	23.74	0.01	0.16	14.7	0.01
Xian	31.8	23.82	0.01	0.16	14.7	0.01
Shenyang	32.4	24.27	0.01	0.17	15.0	0.01
Harbin	33.7	25.24	0.01	0.17	15.6	0.01
Urumqi	34.3	25.69	0.01	0.17	15.9	0.01
Changchun	34.5	25.84	0.01	0.18	16.0	0.01
Lanzhou	38.6	28.91	0.01	0.20	17.9	0.01

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Tab.2 The influence to building heat consumption index caused by the change of $\eta_2^{'}$

Cities	q_H	k	$d(\eta_2')$	$d(q_H')$	q_H'	$d(q_H')/q_H'$
Beijing	31.7	23.74	0.01	0.21	14.7	0.015
Xian	31.8	23.82	0.01	0.21	14.7	0.015
Shenyang	32.4	24.27	0.01	0.22	15.0	0.015
Harbin	33.7	25.24	0.01	0.23	15.6	0.015
Urumqi	34.3	25.69	0.01	0.23	15.9	0.015
Changchun	34.5	25.84	0.01	0.23	16.0	0.015
Lanzhou	38.6	28.91	0.01	0.26	17.9	0.015

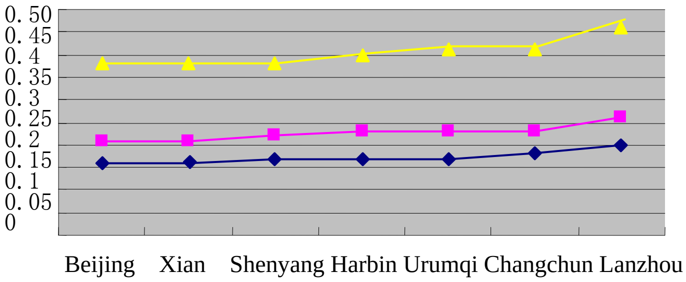
3.3 When $\eta_1^{'}$ and $\eta_2^{'}$ change at the same proportion, from the formula (2) we know that the relationship between $d(q_H^{'})$, $d(\eta_1^{'})$ and $d(\eta_2^{'})$ are all proportional. So we just consider the situation with the increasing $d(\eta_1^{'})$ and $d(\eta_2^{'})$ 1%, and the results are as follows:

Tab.3 The influence to building heat consumption index caused by the change of $\eta_1^{'}$ and $\eta_2^{'}$

Cities	q_H	k	$d(\eta_1')$	$d(\eta_2')$	$d(q_H')$	q_H'	$d(q_H')/q_H'$
Beijing	31.7	23.74	0.01	0.01	0.38	14.7	0.026
Xian	31.8	23.82	0.01	0.01	0.38	14.7	0.026
Shenyang	32.4	24.27	0.01	0.01	0.38	15.0	0.026
Harbin	33.7	25.24	0.01	0.01	0.40	15.6	0.026
Urumqi	34.3	25.69	0.01	0.01	0.41	15.9	0.026
Changchun	34.5	25.84	0.01	0.01	0.41	16.0	0.026
Lanzhou	38.6	28.91	0.01	0.01	0.46	17.9	0.026

4. CONCLUSIONS

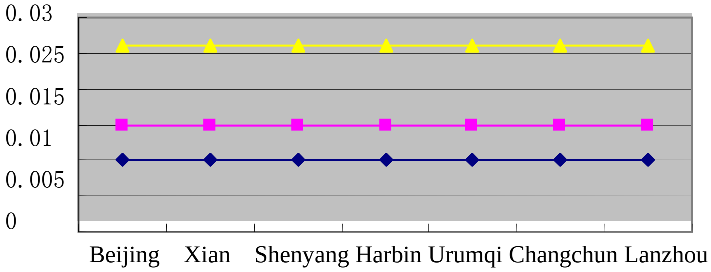
From the results above we can see that the absolute value of building heat consumption index increases about 0.23 W/m^2 when the operating efficiency of boiler increases 1% and it increases about 0.17 W/m^2 when transfer efficiency of outdoor pipe network increases 1%. And when operating efficiency of boiler and transfer efficiency of outdoor pipe network increase, the relationship between total energy consumption increment and operating efficiency of boiler and transfer efficiency of outdoor pipe network are proportion. That's to say, the total absolute energy consumption increment is $m\times0.23$+ $n\times0.17$, where m is the difference of boiler operating efficiency 0.68, n is the difference of outdoor pipe network transfer efficiency 0.9. Besides that, in different climate, the building heat consumption index increases 1% when transfer



▲ η_1 increases 1% ◆ η_2 increases 1%

■ η_1 and η_2 increases 1%

Fig.1 The absolute influence to the building heat consumption index taken by the change of η_1' and η_2'



▲ η_1 increases 1% ◆ η_2 increases 1%

■ η_1 and η_2 increases 1%

Fig.2 The relative influence to the building heat consumption index taken by the change of η_1' and η_2'

efficiency of outdoor pipe network increases 1%, and it increases 1.5% when operating efficiency of boiler increases 1%.