Heating Energy Meter Validation for Apartments

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Abstract: Household heat metering is the core of heating system reform. Because of many subjective and objective factors, household heat metering has not been put into practice to a large extent in China. In this article, the research subjects are second-stage buildings of the Kouan residential area in Baotou. Through the collection and processing of heat meters' data, reliability of data is analyzed, the main influencing factors for heat meters are discussed, and recommendations for heating pricing are presented.

Key words: household heat metering; variance analysis; adjacent rooms' heat transfer; heat price

1 INTRODUCTION

The project of "Selection and Cost Analysis of Energy Efficiency Reconstruction Technical Measures for Existing Buildings (Baotou Case)" was initiated in Oct, 2005. The project supported by Global Environmental Fund (GEF) and jointly organized by the World Bank (WB) and Ministry of Construction (MOC) of China. "Testing Research of Household Heat Metering" is sub-project. This project makes the secondary stage of Kouan district as testing object. Now the project has achieved preliminary achievement.

2 SITUATION OF TESTING RESIDENTIAL AREA

Kouan residential area located at Qinshan district Baotou city and the buildings are representational in Baotou. The secondary-stage buildings of Kouan residential area were constructed in 2000. There are heat meters and temperature sense valves in heat supply pipeline inlet of every door. The temperature control and heat metering can be implemented. So it is the ideal testing district.

The secondary-stage buildings of Kouan residential area have eight buildings (NO.6-NO.13). Number of households are 361. They are commodity buildings. Those buildings are masonry-concrete structure and six floors. Every two households have one stairs. The floor highness is 2.8m. Figure 1 is standard cells' illustration (two households).

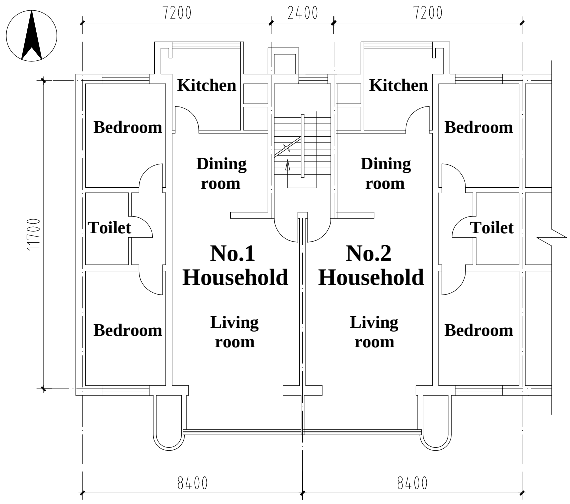

Fig 1 Standard cells' illustration

3 RELIABILITY ANALYZING OF HEAT METERS' DATA

By the arduous work of workers, project group gain the data of 361 heat meters of recent three heating seasons. The heat meters' model is M-CAL Compact DN20, *Danfoss Company*. They have been used for five years and the quality is reliable. But many influencing factors can effect heat meter' data. In other testing subjects, the situation of data distorting is existent. So reliability analysis is necessary.

In the analysis process we make use of mathematical statistics and EXCEL program.

In normal, rooms' position is main influencing factors of heat consumption. So whether heat meters' data of different position household exist obvious discrepancies can proof reliability of heat meters. The problem can come down to monistic single factor multilevel variance analysis. Now we analyze the avail of the position factor by heating meter data in the condition of confidence degree α=0.05.

All households divide five levels as different position. There are corner angle, gable wall, top, bottom and middle.

The math's model as followed [2]

$$X_{ij} = \mu + \tau_j + \varepsilon_{ij}$$

i = 1,…, r

j = 1, …, p

r=8（eight buildings）, p=5（five levels）

ε_{ij}——independent random variable

τ_j——position factor avail

Hypothesis: H0:τ1=τ2=τ3=τ4=τ5=0（no position factor avail）

The principle of data using is that all data are separate into forty (8×5) groups as different building number and levels. Then, Every group is sampled one data. The data is taken out randomly by EXCEL program and table 2 is one sample data.

Tab 1 Variance analysis data table of heating meters reliability analysis (w/m² • ℃)

Position Factor				
Angle	Edge	Top	Bottom	Middle
40.05	32.47	26.21	31.13	38.02
33.53	39.93	29.12	30.43	24.98
25.26	27.81	35.52	34.75	24.83
40.12	25.35	24.60	20.94	28.04
39.97	39.87	24.67	32.68	23.26
43.53	37.73	28.63	33.23	32.92
36.54	30.47	25.68	23.18	34.62
39.81	39.63	35.76	34.32	20.71

We use data analysis function of EXCEL program to make the single factor variance analysis for data in table 1.Table 2 is the analytic result.

Tab 2 Result of variance analysis

	SS	DF	MS	F	F crit
Factor	479	4	119.7	3.93	2.64
Error	1066	35	30.5		
Sum	1545	39			

SS——sum of square DF——degree of freedom

MS——mean square F ——value of F

F crit —— criteria value of F

Because F= 3.93 > $F_{0.95}$ (4, 35) = 2.64, reject hypothesis H_0:τ_1=τ_2=τ_3=τ_4=τ_5=0, have position factor avail, namely position factor is obvious.

From the result, it can be show that data of heat meters reflect the heat consumption character of different position households. So we consider the data is reliability and can be used for next step research.

4 EFFECT OF ADJACENT ROOMS' HEAT TRANSFER

Adjacent rooms' heat transfer is one problem of rejecting heat metering put into practice. In China, residential buildings' partial wall is not insulated. If one room stops heat supply, it still can gain heat through heat transfer from adjacent rooms. The temperature of room can be hold at about 10□. If paying as heat meters' data, this part heat is reordered by adjacent households' heat meter and used by the non-heating room. It departs from the substance that "who uses who pays." For those adjacent heating households, it is not fair.

4.1 Calculated Principle of Adjacent Rooms' Heat Transfer

Mean annual heat consumption through exterior-protected construction of heating room: [2]

$$Q_0 = \frac{A_1}{R_1}(t_L - t_w) \qquad (1)$$

Mean annual heat consumption through exterior-protected construction of non-heating room:

$$Q_1 = \frac{A_1}{R_1}(t_n - t_w) \qquad (2)$$

Heat gain of non-heating room from adjacent rooms:

$$Q_2 = \frac{A_2}{R_2}(t_L - t_n) \qquad (3)$$

A_1——Exterior-protected construction area of calculation room, m²

R_1——Mean heat resistance of exterior-protected construction of calculation room, m2·□/W

A_2——Total area of partition wall and floor slab between calculation room and adjacent rooms, m2

R_2——Mean heat resistance of partition wall and floor slab between calculation room and adjacent rooms, m^2·□/W

t_n——Room-temperature of non-heating room, □

t_L ——Room-temperature of adjacent room, as heating room, t_L=20□

t_w ——Main heating exterior dry-bulb temperature of Baotou, □ ,t_w =-6.5□

For simplifying calculation, cold air infiltrate heat consumption is ignored.

According to heat balance principle, the heat gain of calculation room Q_1 equals the heat loss of calculation room Q_2. By formula (1) (2) (3), we can work out: [3]

$$Q_1 = Q_2 = \frac{A_1 A_2 (t_L - t_w)}{A_1 R_2 + A_2 R_1} \qquad (4)$$

$$\frac{Q_1}{Q_0} = \frac{1}{1 + \frac{A_1 R_2}{A_2 R_1}} \qquad (5)$$

Form formula (4), it can be show that the adjacent rooms' heat transfer relate with area and heat resistance of exterior-protected construction, partition wall and floor slab of calculation room. For one room, the A_1 and A_2 are constant. If holding the temperature difference, increasing the value of R_1 and R_2 can decrease quantity of heat transfer between adjacent rooms. But it doesn't indicate that increasing the heat preservation capability can decrease the effect of adjacent rooms' heat transfer for heat metering. Now the existing residential buildings energy efficiency reconstruction is putting up. The reconstruction improves the heat resistance of exterior-protected construction. Namely the value of R_1 is increased. But the partition wall and floor slab of room don't construct. Namely the value of R_2 is fixed. According to formula (5), it is shown that Q_1/Q_0 is inverse ratio with R_2/R_1. After reconstruction, value of R2/R1 falls, so value of Q_1/Q_0 increases. The proportion of adjacent rooms' heat transfer with normal heat consumption increases. The problem of adjacent rooms' heat transfer become obviously.

4.2 Calculation of Adjacent Rooms' Heat Transfer

For straighter analyzing the effect degreed of adjacent rooms' heat transfer, we work out the quantity of heat transfer between adjacent rooms before reconstruction and after reconstruction. The NO.7 building is calculation object. Fig 1 is plain view drawing of calculation rooms. Position relative of every rooms is shown in Fig 2. Table 3 shows Coefficient of heat transmission of protected construction. Protected construction areas of three calculating rooms are shown in table 4.

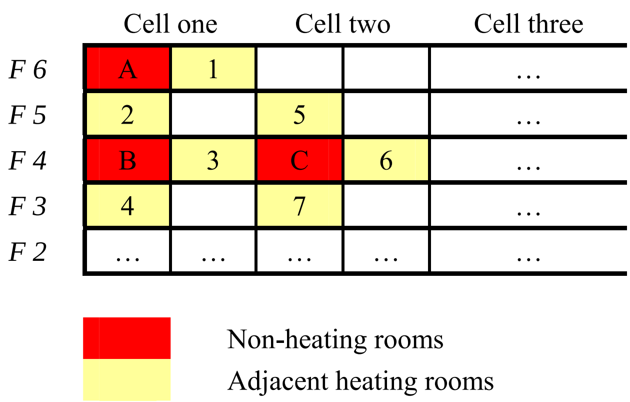

Fig 2 Illustration of NO.7 building west side rooms

In calculating process, we select three different position households as analysis object of non-heating rooms, quantity of adjacent rooms' heat transfer Q_2 and room temperature t_n are work out. The calculating result shows as table 4.

Tab 3 Coefficient of heat transmission of exterior-protected construction [4]

	Before reconstruction (W/ m^2·□)	After reconstruction (W/ m^2·□)
	Value of test	*65% standard*
Exterior wall	1.49	0.60
roof	1.08	0.50
windows	4.00	2.70
doors	2.00	1.50
floor slab	1.00	1.00
Partition wall	2.03	2.03

Tab 4 Protected construction area of three calculating rooms

Protected construction		Area of calculating rooms		
		A(m2)	B(m2)	C(m2)
exterior	North wall	13.9	13.9	13.9
	North win	6.3	6.3	6.3
	West wall	32.8	32.8	——
	South wall	14.8	14.8	14.8
	South win	8.7	8.7	8.7
	Roof	98.3	——	——
	Staircase	16.0	16.0	16.0
Interior	Partition Wall	16.8	16.8	16.8×3
	Floor Slab	98.3	98.3×2	98.3×2

Tab 5 Quantity of adjacent rooms' heat transfer of non-heating rooms

Position	Before reconstruction		After reconstruction	
	t_n	Q_1	t_n	Q_1
	□	W	□	W
a	2.4	2330.0	6.4	1797.6
b	9.3	2463.0	12.6	1715.4
c	12.8	2147.8	14.8	1540.9

Tab 6 Quantity of adjacent rooms' heat transfer of heating rooms

Room num	Before reconstruction			After reconstruction		
	Q_1	Q_0	Q_1/Q_0	Q_1	Q_0	Q_1/Q_0
	w	w	%	w	w	%
1	600	5766	10.4%	463	3218	14.4%
2	2779	4125	67.4%	2065	2385	86.6%
3	845	2953	28.6%	599	1916	31.2%
4	1049	4125	25.4%	731	2385	30.7%
5	710	2953	24.1%	510	1916	26.6%
6	247	2953	8.3%	177	1916	9.2%
7	710	2953	24.1%	510	1916	26.6%

Through table 5, it is shown when buildings' heat preservation capability of protected construction increase, absolute value of adjacent rooms' heat transfer is greatly decrease. But by table 6, it is shown that relative value of adjacent rooms' heat transfer is increase obviously. So after save-energy reconstruction, the problem of adjacent rooms' heat transfer becomes more seriously (Fig 3). Households adjacent with non-heating rooms should get relevant compensation. Or dispute maybe comes into being.

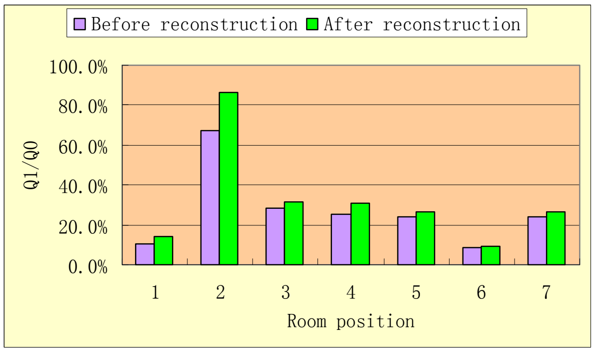

Fig 3 Ratio change of quantity of adjacent rooms' heat transfer of heating rooms

5 RECOMMENDATION TOLLING MODE OF HEAT FEE

Kouan residential area has condition of heat metering. But if tolling heat fee by heat metering data, there are many unreasonable things. By the integrated analyzing to heat metering data of recent three years and product log of heating corporation, we draw a recommendation of two parts heat price system. Calculate formula as followed.(detailed deduction process is shown in project report)

$$F_w = 7.8 \times A_m + 0.05 \times Q_w \quad (6)$$

F_w——heat fee (Yuan)

A_m——area of rooms（m^2）

Q_w——quantity of heat using（KWh）

According to formula (6), the heat fee make up of two parts. The one part is capability heat fee which is paid as room area. The price is 7.8Yuan/m^2 which is half of former heat fee. User must pay this part heat fee whether heat is used. The other part is quantity heat fee, which is paid as quantity of heat. The price is 0.05Yuan/Kwh.

5.1 The Virtue of Two Parts Heat Price System

(1) Two parts heat price system doesn't bring much fluctuation for heat fee. It can be accepted easily by both heat users and Heat Corporation. The value of exterior-protected construction thermal resistance of Kouan residential area is better-than-average level of Baotou. So value of heat consumption is about 30w/m^2 which is small than average value of Baotou about 40w/m^2. The heat fee of Kouan reduces. By calculating, heat fee of 82% households is reduces. Fig 4 is the illustration of heat

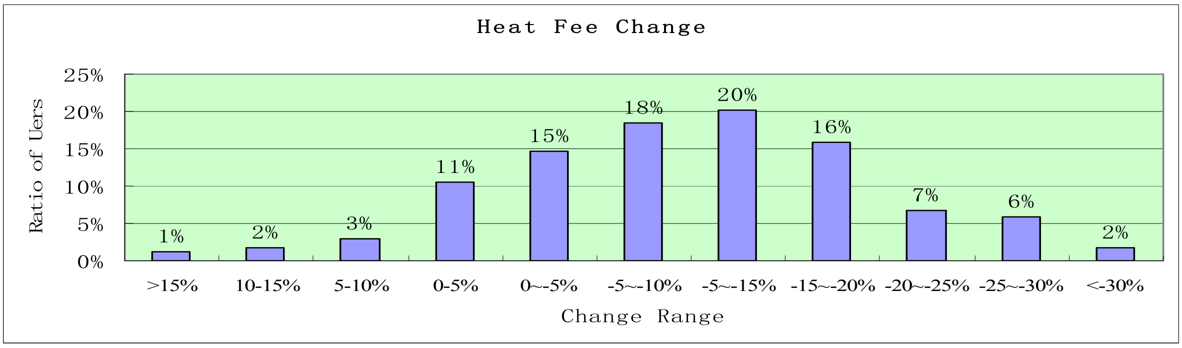

Fig 4 Heat fee change of users after new system running

fee change. The income of Heat Corporation decrease 9%. But the loss can make up for cost falling and heat supply area expanding.

(2) Two parts heat price system shrinks the effect degree of adjacent rooms' heat transfer, room position and orientation. In new heat fee system, capability heat fee is fixed and is 50% of former heat fee. The remainder part is quantity heat fee which is change with data of heat meter. So the new system controls heat fee change in 50% of former heat fee. The problem of heat metering paying is released. The test can proceed more successfully.

(3) New heat fee system imports the concept of paying as quantity of heat. Although heat users have not paid by heat entirely, the object of "more using, more pay; less using, less pay" is realized. The consciousness of save energy is wakening up.

5.2 Problem Waiting for Solving

(1) In the processing of reliability analyzing of heat meters' data, we can find that factor of rooms position effect the heat consumption obviously. According to calculation, the main heat consumption different of angle and middle is close to 10w/m2. The value is largish. If the heat metering system runs, the position correct is necessary. Different position rooms have different correction coefficient.

(2) The problem of adjacent rooms' heat transfer is main factor which effecting justice of heat metering paying. Some unfortunate households maybe contribute more heat to adjacent households than using themselves. After building reconstruction the problem is more important. One of ways is increasing the thermal resistance of partition wall and floor slab. But for new buildings it enhances construction cost; for existing buildings it is difficult. The other way is compensating those households which are adjacent with non-heating rooms or less heating rooms. The capacity heating fee can use as compensation fund. But there are many works waiting to determine compensation value of different households with different position, different orientation and different temperature.

6 BRIEF SUMMARY

Now, pilot projects of two part heat price system have been trying out at many cities in China. Many problems have been found. But at the same time much experience has been got. Baotou locates in cold zone. It is very important for heating reform of cold zone that heat metering testing running in Baotou as fast as impossible. Heat reform needs time. With the developing of social economic and professional skill, the heating reform will succeed at last.

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