

Analysis of Heating Systems and Scale of Natural Gas-Condensing Water Boilers in Northern Zones

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Abstract: In this paper, various heating systems and scale of the natural gas-condensing water boiler in northern zones are discussed, based on a technical-economic analysis of the heating systems of natural gas condensing water boilers in northern zones. The analysis shows that the low-temperature radiant floor heating system is more suitable for natural gas-condensing water boilers. It is more comfortable, more economical, and can save more energy than other heating systems.

Key words: natural gas; condensing water boiler; heating system; technical-economic analysis

1 .INTRODUCTION

With the operation of sustainable development strategy in the world, the adjustment of energy structure, the reform of the heat charging system and the implement of household metering system in China, the heating system of the natural gas water boiler becomes the one of main residential heating systems in the current. At present, the “medium and long term energy saving program ” was issued, and the main energy use equipments was required to save energy ,especially, the heat efficiency of household gas-fired boiler must be above 90%. At the same time, consumers of natural gas water boilers are interested in energy saving-type natural gas water boilers, so heating systems of natural gas condensing water boiler become a focus in engineering and firms, and will be more and more popular. In this paper, various heating systems of the natural gas condensing water boiler in north zones were analyzed, and technical-economic analysis was also presented. Furthermore, the best heating scale in north zones was discussed

2 .THE CHARACTERISTIC OF HEAT SOURCE FOR THE NATURAL GAS CONDENSING WATER BOILER

Heating is required in north zones including freezing and cold zones. Various natural gas-fired heating and domestic hot water-supply systems consist of central heating system of gas-fired boiler room in neighborhood, heating system of gas-fired boiler in buildings and heating system of household natural gas water boiler. However, comparing with other heating systems, the heating system of household natural gas water boiler is the most

energy-saving and the most economical.

Comparing with central heating system of gas-fired boiler room in neighborhood, the cost of pipe network can be saved about 30~50yuan /m², heat loss and transfer energy consumption of pipe network can be also reduced, for lack of neighborhood pipe network ; the cost can still be saved about 30~50yuan /m², for lack of metering device. Because additional water heater isn't needed in the house, the cost can be saved about 30~40yuan/m², and it is also regulated ,according to the need of users^[1,2].Therefore, it is the most energy-saving system.

Comparing with heating system of gas-fired boiler in buildings, heat loss and charge of insulation layer of pipe network can be reduced, and fuel can be also saved, for lack of public pipeline and heating tube well^[1].

Household natural gas condensing water boilers appeared in Holland firstly. Subsequently, they were developed and applied in England, French, Germany and America .Presently, this heating system was applied in Europe popularly, and accounts for 18% in single heating systems, but our country is underway now^[2].

Comparing with the traditional household gas-fired water boiler, a condensing heat exchanger is installed in the boiler. If the boiler is applied to heating, the temperature of flue gas can be reduced to below the dew point temperature, thus sensible heat of flue gas and latent heat of a great deal of vapor in the flue gas can be recovered, Therefore, its efficiency is 10%~20% higher than that of the traditional gas-fired water boiler, and environmental contamination can be reduced^[2].

However, when natural gas condensing water boilers are applied to heating, indoor heating systems and heating scales can affect consumers' heating effect , the heat source efficiency , the first cost and operating charge.

3. HEATING SYSTEMS OF NATURAL GAS CONDENSING WATER BOILER

The heating system of natural gas condensing water boiler supplying domestic hot water additionally is classified to the radiator heating system and the low-temperature radiant floor heating system in terms of the difference of linked terminal

radiating equipments.

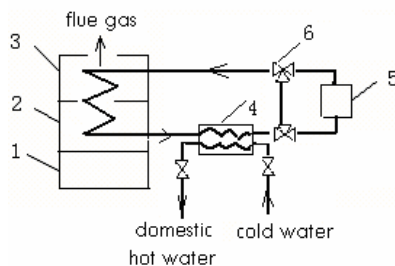
3.1 The Inherent Characteristic of both Heating Systems

Comparing with radiator heating system, the low-temperature radiant floor heating system has a lot of advantages when the traditional heat source of heating systems is same. They are as follows:

Firstly, Low-temperature radiant floor heating system occupies less valid building space in occupants' activity zone, and it is beautiful and advantaged for decoration in room. Secondly, it supplies good temperature distribution to satisfy occupants in the room, and has better heat stability, so it makes the humidity and the effective temperature high in the room, thus the indoor design temperature can be reduced, and energy can be saved about 10%. Finally, it is advantaged to household metering^[3].

3.2 The Effect on both Heating Systems for Natural Gas Condensing Water Boilers

The heating system principle of natural gas condensing water boiler is shown in Fig.1. Comparing with the volume of traditional natural gas water boiler, that of natural gas condensing water boiler is bigger. Both of heating water and domestic hot water is controlled by three-way valves. When domestic hot water is needed, water supply for heating will be stopped. When radiator heating system stops, the temperature will have a great change in the room, and the system isn't steady. However, low-temperature floor radiant heating system has better heat stability under discontinuous heating.



- 1—combustion segment 2—traditional heat exchanger
3—condensing heat exchanger
4—plate heat exchanger
5—terminal radiating equipment for heating
6—three-way valve

Fig. 1 Sketch map for heating system of natural gas condensing water boiler

When natural gas condensing water boiler is the heat source of heating, its operating efficiency is dependant on the water-return temperature of system, and will become high as water-return temperature of system reduces. When it is applied to radiator heating system of traditional water-supply and water- return temperature, the condensation of vapor in flue gas is difficult, so that the condensing heat exchanger is no

effective, due to higher water-return temperature. However, if water-supply and water- return temperature reduces, the number of radiating fins will increase, thus the first cost will also increase consequently. When natural gas condensing water boiler is applied to low-temperature radiant floor heating system, water-supply and water- return temperature of system is low (water-supply temperature is below 60 °C , the difference of water-supply and water-return temperature is not beyond 10°C), so the condensation is efficient ,and sensible heat and latent heat of flue gas can be recovered.

4. ECONOMIC ANALYSIS ON DIFFERENT HEATING SYSTEMS

Take example for a “A” door type of standard floor in a certain neighborhood of Beijing here .When the heat source is natural gas condensing water boiler, the first cost and operating charge of radiator heating system during a heating period are compared with the one of low-temperature radiant floor heating system respectively. The thermo-technical performance of building envelopes complies with the regulations in “Design Standard of Civil Building Saving Energy (JGJ26-95)” .Because the index of heat loss of building q_H is 20.6 W/m² (when the outdoor mean air temperature during heating period is -1.6°C), the index of design load for heating building is 34.7 W/m² (when the outdoor design air temperature during heating period is -9°C) . But it is 41.64 W/m², 20% is addition, due to the heat loss of system and the radiating efficiency of terminal radiating equipment. The area of structure is 157.56 m², the heating area is 120 m².

4.1 The First Cost

The first cost consists of the cost of natural gas condensing water boilers, terminal radiating equipments, pipelines and valves and the construction charge and so on.

Indoor design temperature for heating is set at 16 in terms of the requirement in “Design standard of Civil Building Saving Energy (JGJ26-95)”. In low-temperature radiant floor heating system ,the design heat load is 92% of heat load for radiator heating system , water-supply and water-return temperature is 45 and 35 respectively , PE-X pipe is chosen ,the structure layer of floor includes heat insulating layer of polystyrene board(20mm) , mortar layer (40mm) , screed-coat (20mm) and skin plate (wood floor) from the bottom up. The system plan is shown in Fig.2. In radiator heating system, radial tow-pipe system is chosen, and water-supply and water-return temperature is 60 and 35 respectively, due to the restriction of water-return temperature in condensing

boiler. Steel radiator and cast-iron radiator are used apart. The plan of system is shown in Fig.3. By calculation, the first cost of both heating systems is shown in tab.1^[4,5,6].

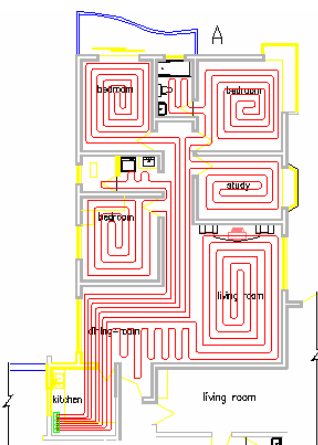


Fig.2 Low temperature radiant floor heating system

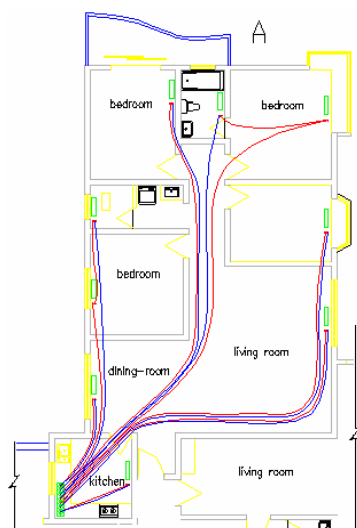


Fig.3 Radiator heating system

From the tab.1, it can be seen that the first cost of low-temperature radiant floor heating system is the lowest, the one of cast-iron radiator heating system is secondary, and the one of steel radiator heating system is the highest. Though the first cost of

common cast-iron radiator heating system is lower than the one of steel radiator heating system, common cast-iron radiator is prone to dropping scruff and stopping plate heat exchanger. Moreover, it isn't better than steel radiator in terms of aesthetics and elimination of heat, so it isn't chosen generally.

4.2 The Operating Charge

The operating charge of natural gas condensing water boiler consists of electricity charge for operating pump and fan and charge of natural gas. The system can be opened and closed, according to Consumers' own custom of living and need, due to flexible adjustment for heating systems of natural gas condensing water boiler. Domestic hot water can be also supplied. Therefore, the operating charge depends on many random factors, including outdoor temperature, structure of building envelope, living level and consumers' custom and so on^[7]. When heating for both heating systems, boilers operate for 12h for heating to meet heating need, for 3h for supplying domestic hot water to meet three persons' needs every day on average, the amount of hot water need is 75L/d per person^[6]. The price of natural gas is 1.7yuan per 1 Nm³dry natural gas, the price of electricity is 0.44yuan /kwh. Meanwhile, because the natural gas condensing water boiler can recover talent heat of vapor in wet flue gas, the high heat value of natural gas in Beijing ($H_h=38358KJ/Nm^3$ dry natural gas)is used to calculate the amount and charge of natural gas during a heating period(125days).The operating charge is shown in tab.2.

From tab.2, it can be seen that the operating charge of low-temperature radiant floor heating system is a little lower than that of radiator heating system. The charge of natural gas for low-temperature radiant floor heating system is chiefly lower, because its indoor design heating load is less under the same thermal comfort condition supplied by both heating systems, so that the amount of natural gas is less. However, its resistance of system is larger

Tab.1 The comparison of first cost between different heating systems

Door type	Heating system		First cost (Yuan)				Overall first cost (Yuan)	First cost per square meter (Yuan/m ²)
			Natural gas condensing water boiler (JLG20)	Terminal_radiating equipments	Pipe, valve and accessorial equipments	Construction expense		
A	Radiator system	Steel columnar radiator	7000~8000	12000~14500	3000	3000	25000~28500	208~238
		cast-iron columnar radiator	7000~8000	4700~8000	3000	2740	17440~21740	145~181
	Low-temperature radiant floor heating system		7000~8000	5600~7300	1600	1411	15611~18311	130~153

Tab.2 The comparison of operating charge between different heating systems

Heating systems	Operating charge (Yuan)		Overall operating charge during a heating period (Yuan)	operating charge per square meter during heating period (Yuan/m ²)
	Charge for burning natural gas (Yuan)	Electricity charge (Yuan)		
radiator	1370	165	1535	12.8
radiant floor heating	1318	206	1524	12.7

than that of radiator heating system, and is equipped with secondary circulating pump in order to get the operation mode of big water flow and low temperature, so its electricity charge for pump operation is higher.

The above discussion shows that low-temperature radiant floor heating system is more economic than radiator heating system, whether on the first cost or on the operating charge, when the heat source is the natural gas condensing water boiler.

5 .THE BEST HEATING SCALE

Presently, household gas-fired condensing water boiler which is on sell are foreign products mostly in China, their power are mainly 20kw、26kw、32kw. When index of design load for heating of building q is 41.64W/m, the heat efficiency is 103%, correct coefficient is 0.8, due to heat loss of system. The top heating capacity of natural gas condensing water boiler for different powers is shown in tab.3.

Tab.3 The top heating capacity of natural gas condensing water boiler

Type	JLG20	JLG26	JLG32
Input power (kW)	6.6~20.0 kW	8.7~26.3 kW	10.6~32.0 kW
output power(condensation)	6.8~20.6 kW	9.0~27.0 kW	10.9~33.0 kW
Heating area(m ²)	130~396	172~520	210~633

The tab.3 shows that JLG20 type natural gas condensing water boiler can supply heat for 200 m²、250 m²、300 m²、350 m² area. Heating powers of water boiler for different heating areas are shown in

Tab.6 The choice of boiler types to meet the need of domestic hot water and heating

Heating area (m ²)	The number of person using domestic hot water at the same time	Boiler types under different times			
		10 (min)	12 (min)	15 (min)	20 (min)
100	1	JLG26	JLG20	JLG20	JLG20
150	1	JLG26	JLG20	JLG20	JLG20
200	1	JLG26	JLG20	JLG20	JLG20
	2	—	—	JLG32	JLG26
250	1	JLG26	JLG20	JLG20	JLG20
	2	—	—	JLG32	JLG26
300	1	JLG26	JLG20	JLG20	JLG20
	2	—	—	JLG32	JLG26
350	1	JLG26	JLG20	JLG20	JLG20
	2	—	—	JLG32	JLG26

Note: — is no choice.

tab.4. However, water-supply powers for domestic hot water depend on the number of occupants, custom of living and the time of obtaining the amount of water which occupants require (75L/d per person). The relationship between the time and the water-supply power is shown in tab.5.

Combining tab.4 and tab.5, the water boiler, which must meet needs of domestic hot water and heating, is chosen for different heating areas. The results are shown in tab.6.

Tab.4 The operating power of natural gas condensing water boiler under design heat loads for different heating areas

Heating area (m ²)	100	150	200	250	300	350
Design heating load (w)	4164	6246	8328	10410	12492	14574
The largest operating power	5.05	7.58	10.1	12.6	15.2	17.7

Tab.5 The relationship between the time of obtaining the amount of water which occupants require(75L/d per person) and the water-supply power for domestic hot water

Time(min)	10	12	15	20
water-supply power(kW)	23.52	19.60	15.68	11.76

It is obvious that the choice of water boiler types is mainly dependant on water-supply powers of condensing water boiler for domestic hot water, so it depends on the time of obtaining the amount of water which occupants require (75L/d per person) and the number of person using domestic hot water at the same time. Therefore, the time of heating domestic hot water should be long properly, so that little boiler can be chosen to reduce the first cost .When the water-supply power of domestic hot water is guaranteed , the bigger heating area is ,the bigger heating power is ,so that the difference between the heating power and the water-supply power of domestic hot water is little ,thus the condensing water boiler can operate efficiently under the full load, whereas, its operation is inefficient .

6. CONCLUSIONS

1. Comparing with radiator heating system ,Low-temperature radiant floor heating system is most suitable for natural gas condensing water boiler ,and its cost can be saved 78~85yuan /m²,but their operating charge is equivalent.
2. The heating capacity of condensing water boiler is great, but the difference between heating load and domestic hot water load is large. Therefore, little types of condensing water boilers should be chosen when enough domestic hot water is supplied.
3. Condensing water boilers with large adjustment range should be developed to satisfy different heating areas. At the same time, a series of types for condensing water boilers should be also

developed to make heating powers and water-supply powers of domestic hot water equivalent, so that the operating efficiency can be improved.

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