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Design and Research of the Digital VRV Multi-connected Units With Three Pipes Type Heat Recovery System

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ABSTRACT

A digital multiple variable refrigerant volume air conditioning system with three pipes type heat recovery has been designed and researched in this paper. Design and research were conducted on a nominal 30KW new type multi-connected unit. The system can meet the load of each room by using new type digital scroll compressor with the variable capacity and electronic expansion valves that can automatically control the refrigerant flow for each indoor unit, can achieve the demand of concurrent heating and cooling through the switch of the solenoid valves, and can regulate the heat capacity of the outdoor heat exchanger by using the AC inverter fan in the outdoor unit. The system can run in the heat pump model, refrigeration model or heat recovery model throughout the year and can run in the working temperature range from -18℃ to 48℃.

1. INTRODUCTION

It was shown that many multi-system air-conditioners have been applied to satisfy the need of several rooms in Chinese buildings (Masuda et al., 1991). However, the operation is limited to a single mode (heating or cooling) at one time. With the development of national economy and the air conditioning technology, air conditioner is developed from the viewpoint of decreasing the energy consumption and increasing the human comfort. Thus Quieshi and Tassou (1996) pointed that variable frequency compressor and electronic expansion valves are more and more widely used. In modern buildings, some rooms in a building should be cooled in winter because of computers and other electronic machinery, and concurrent heating and cooling is necessary which can not be achieved with a conventional multi-system air conditioner which can only satisfy all the room to be cooled or to be heated at the same time.

So a digital multiple variable refrigerant volume air conditioning system with three pipes type heat recovery (high pressure liquid pipe, high pressure gas pipe, low pressure gas pipe) has been designed and researched in this paper. Design and research were conducted on a nominal 30KW new type Multi-connected unit. The system can meet the load of each room by using new type digital scroll compressor with the variable capacity and electronic expansion valves that can automatically control the refrigerant flow for each indoor unit, can achieve the demand of concurrent heating and cooling through the switch of the solenoid valves, and can regulate the heat capacity of the outdoor heat exchanger by using the AC inverter fan in the outdoor unit. The indoor unit in the heating room acts as condenser and the indoor unit in the cooling room acts as evaporator while the outdoor unit may act as evaporator or condenser. Because both the condensing heat and evaporating heat are valuable in use, while the traditional systems only the condensing heat and evaporating heat can be used, the energy efficiency ratio of the system is increased greatly. The system can run in the heat pump model, refrigeration model or heat recovery model throughout the year and can run in the working temperature range from -18℃ to 48℃. The system, which provides higher comfort with lower energy consumption, can be used in the residential buildings or commercial buildings. It is shown that the digital VRV multi-connected units with three pipes type heat recovery system Multi-connected can attain demanded performance and run stably.

2. SYSTEM CONFIGURATION AND OPERATING MODES

2.1 System Introduction

The designed and researched new type nominal 30KW Multi-connected system consist of one outdoor unit and several indoor units. The outdoor unit adopts a digital scroll compressor and a constant speed scroll compressor, the indoor unit adopts ducted type indoor unit including 25P, 50P, 70P and 120P. As shown in Fig.1, the system consists of two scroll compressors, a oil separator, a liquid-gas separator, a high pressure liquid accumulator and high pressure and low pressure transducer, and the connection pipes use three pipes (high pressure liquid pipe, high pressure gas pipe, low pressure liquid pipe), refrigerant type is R22. Unit consists of some electronic expansion valves that can automatically control the refrigerant flow for each indoor unit, and can achieve the demand of concurrent heating and cooling through the switch of some solenoid valves, also can regulate the heat capacity of the outdoor heat exchanger by using the AC inverter fan in the outdoor unit.

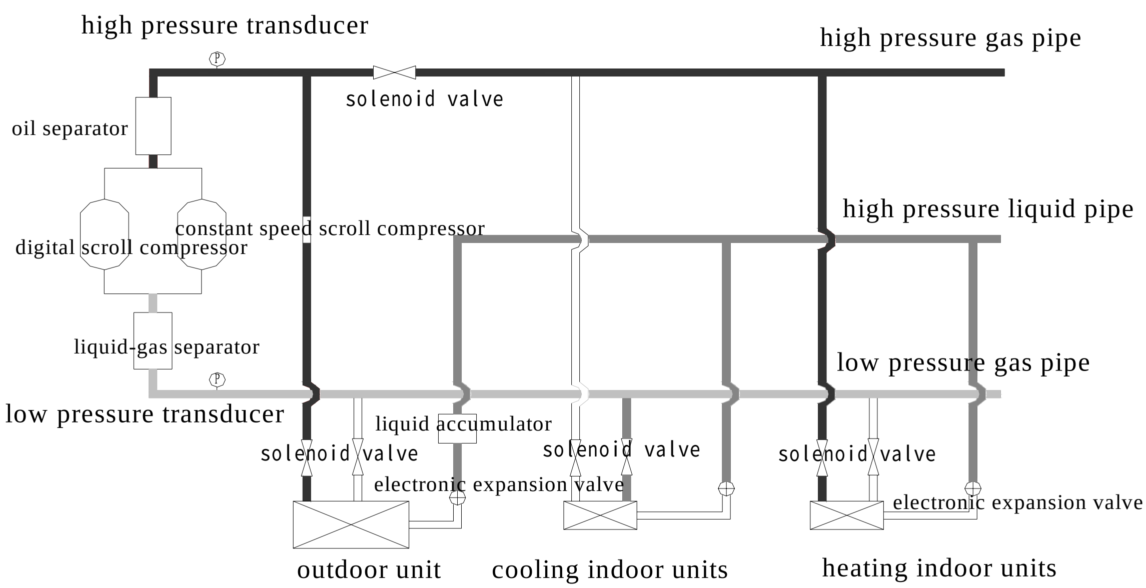

Figure 1: Schematic diagram for the new type three pipes heat recovery GMV-R300W2/Rh unit

2.2 Operating modes

The designed and researched new type Multi-connected system can operate at four operating modes: cooling-only mode, heating-only mode, cooling-principal mode and heating-principal mode. In the cooling-only mode, the indoor units are in cooling operation. The gas refrigerant discharged from the compressor flows into the outdoor heat exchanger through high pressure gas connecting pipe and is condensed there. The liquefied refrigerant flows into the indoor units through high pressure liquid pipe and is depressurized by the indoor electronic expansion valve. The depressurized refrigerant is evaporated in the indoor heat exchangers and returns to the compressors through low pressure gas pipe. The indoor heat exchangers work as evaporators, and the outdoor heat exchanger works as a condenser in this mode. In the heating-only mode, the indoor units are in heating operation. The gas refrigerant discharged from the compressor flows into the indoor heat exchangers through high pressure gas pipe and is condensed there. The liquefied refrigerant from each indoor heat exchanger flows into the outdoor unit through high pressure liquid pipe and is depressurized by the indoor and outdoor electronic expansion valve. The depressurized refrigerant is evaporated in the outdoor heat exchanger and returns to the compressors through low pressure gas connecting pipe. The indoor heat exchangers work as condensers, and the outdoor heat exchanger works as a evaporator in this mode. In the cooling-principal mode, the gas refrigerant discharged from the compressors flows into the outdoor heat exchanger and the heat exchangers of the heating indoor units through high pressure gas connecting pipe and is condensed there. The liquefied refrigerant flows into the cooling indoor units through high pressure liquid pipe and is depressurized by the indoor electronic expansion valves. The depressurized refrigerant is evaporated in the cooling indoor units and return to the compressors through low pressure gas connecting pipe. The outdoor heat exchanger and the heating indoor units work as condensers, and the cooling indoor units work as evaporators. And in the heating-principal mode, the gas refrigerant discharged from the compressors flows into the heating indoor units through high pressure gas connecting pipe and is condensed there. The liquefied refrigerant from the heating indoor units flows into the cooling indoor units and the outdoor unit through high pressure liquid connecting pipe and is depressurized by the indoor and outdoor electronic expansion valves. The depressurized refrigerant is evaporated in the cooling units and the outdoor units and returns to the compressors through low pressure connecting pipe. The outdoor heat exchanger and the cooling indoor units work as evaporators, and the heating indoor units work as a condenser.

2.3 Unit figures and system cop analysis

The outdoor unit picture is shown in Figure.2, the outline dimension of the outdoor unit is about 990×840×1715 mm (Length×Width× Height), the refrigerant charge volume is about 20kg. Three connecting pipes are shown in Figure.3, the out diameter of the high pressure gas pipe, high pressure liquid pipe and low pressure gas pipe is 22, 12 and 28mm respectively.

Figure 2: Outdoor unit picture

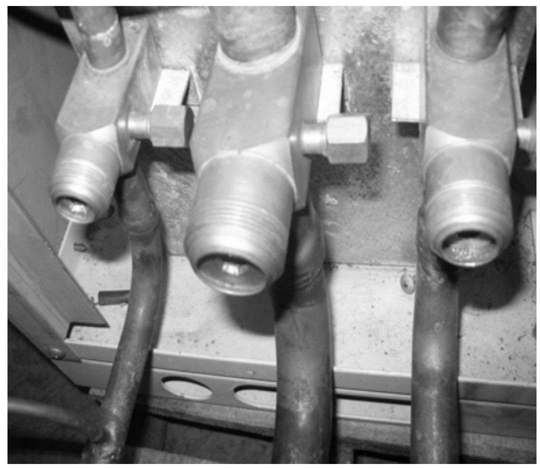

Figure 3: Three connection pipes photo

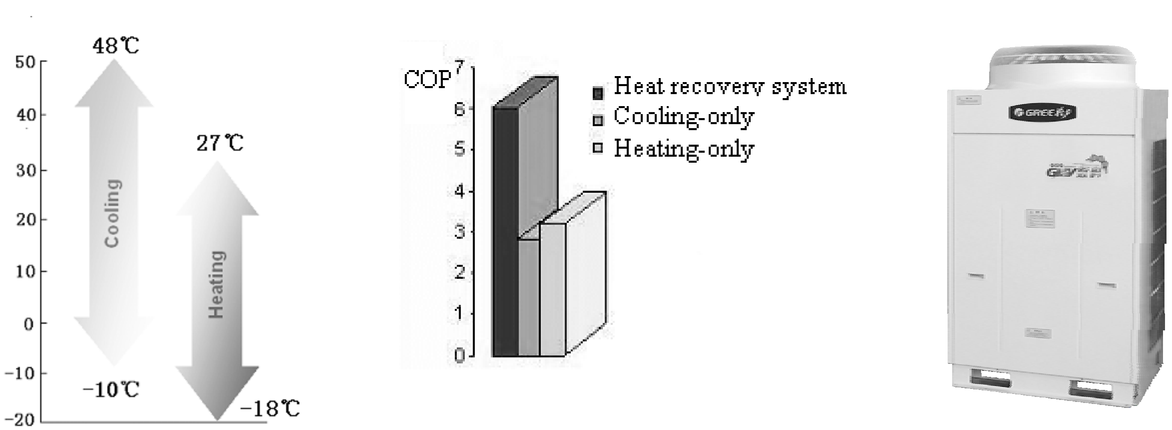

Figure 4: Schematic diagram of the system work temperature range and COP analysis

From the illumination of the operating modes it is found that both the condensing heat and evaporating heat are valuable in use in the cooling-principal and heating-principal mode, so the coefficient of performance (COP) of the heat recovery system increases markedly. On the other hand, for the heat transferred from indoor environment to outdoor environment is decreased largely; the pollution to the environment is reduced accordingly. It is shown that the COP of the heat recovery system is about two times of the COP in cooling-only or heating-only mode from Figure.4, more it can be seen that the work temperature range of the heat recovery system is from -18℃ to 48℃ from Figure.4.

3. EXPERIMENTS AND RESULTS

3.1 Experiment Apparatus

When the design of the nominal 30KW new type Multi-connected unit was complete, the experimental research was conducted in two standard psychrometrics. The test apparatus consisted of an outdoor psychrometric, a Multi-connected unit, two indoor psychrometric and the data acquisition system. The psychrometric allows dry-bulb temperature to be ranged from -20℃ to 60℃ and the relative humidity to be ranged from 5%Rh to 95%Rh. The indoor units adopt five ducted type indoor units including 25P, 50P, 70P and 120P, with nominal capacity of 2500W, 5000W, 7000W and 12000W respectively. The indoor units were placed in two psychrometrics. Airflow is measured by standard nozzles, the pressure difference between nozzles is measured by the differential manometer which has a tolerance of ±0.5%. The temperature and humidity of air is measured with the dry-bulb/wet-bulb psychrometer. The data acquisition system includes temperature probes, pressure transducers, thermocouples and the watt transducers that measure the power consumption of the outdoor fan, indoor fan and compressors. The data acquisition system monitors all temperatures, pressures, and power and can access and dispose under complete program control. The experimental data presented in the thesis are the arithmetic average values generated from seven steady repetitive results under the same and steady conditions to obtain the reliable and accurate experimental results.

3.2 Results And Analysis

From the experiments it can be seen that the designed system can achieve the demand of concurrent heating and cooling through the switch of the solenoid valves, and the indoor units can run in the cooling and heating mode concurrently. Figures.5~8 figure out the attained percent of nominal capacity in different indoor units combination when the unit ran in the cooling-principal mode and the heating-principal mode. The different indoor units combination includes that combination 1: 120P and 70P were cooling and 70P, 50P and 25P were heating, combination 2: 120P and 70P were cooling and 25P were heating, combination 3: 120P and 70P were heating and 70P, 50P and 25P were cooling, and combination 4: 120P and 70P were heating and 25P were cooling. The y-axis shows that the recorded cooling and heating capacity attained the percent of the nominal capacity respectively.

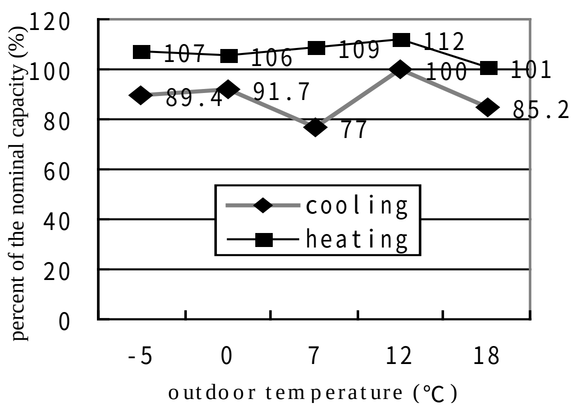

Figure 5: Curves of the percent of nominal capacity in the cooling-principal mode at combination 1

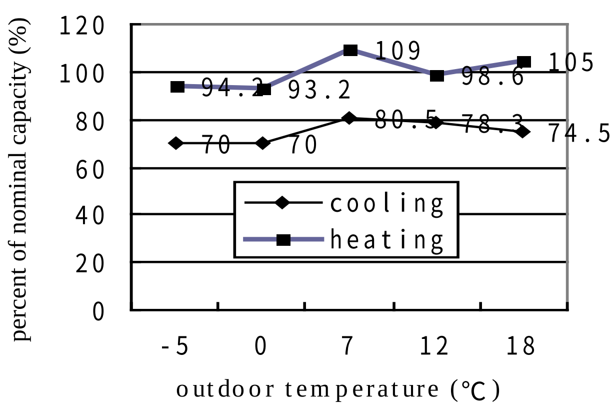

Figure 6: Curves of the percent of nominal capacity in the cooling-principal mode at combination 2

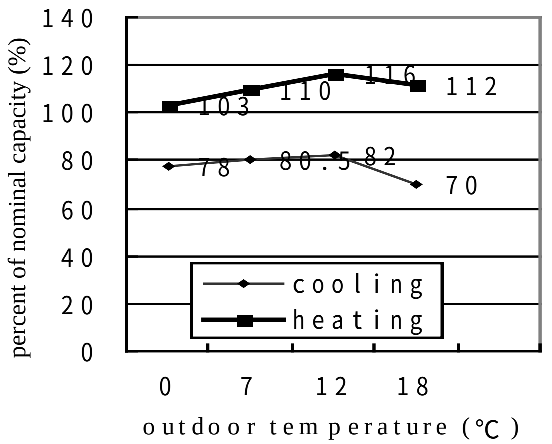

Figure 7: Curves of the percent of nominal capacity in the heating-principal mode at combination 3

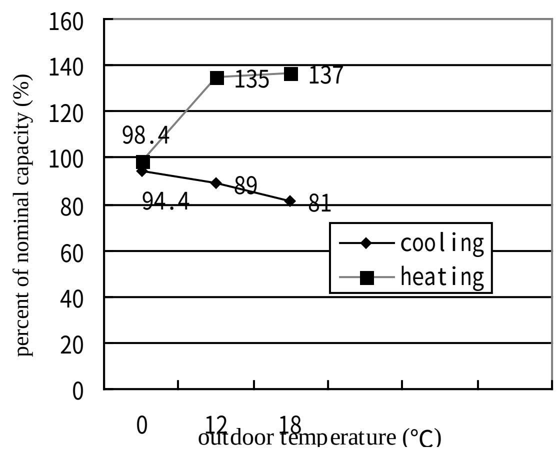

Figure 8: Curves of the percent of nominal capacity in the heating-principal mode at combination 4

Table 1: System performance in the cooling-principal mode

Indoor units combination	**Outdoor condition(℃)**	**Indoor condition(℃)**	**Capacity (W)**	**Power consumption(W)**	**COP**
Cooling: (120+70)P Heating: (70+50+25)P	7/6	Cooling: 27/19 Heating: 20/15	Cooling: 14750 Heating: 15854	6763	4.53
Cooling: (120+70)P Heating: (70+50+25)P	0	Cooling: 27/19 Heating: 20/15	Cooling: 17419 Heating: 15357	7435	4.41
Cooling: (120+70)P Heating: (70+50+25)P	-5/-6	Cooling: 27/19 Heating: 20/15	Cooling: 15455 Heating: 16994	7740	4.19
Cooling: (120+70)P Heating: 25P	7/6	Cooling: 27/19 Heating: 20/15	Cooling: 15295 Heating: 2631	6136	2.92
Cooling: (120+70)P Heating: 25P	0	Cooling: 27/19 Heating: 20/15	Cooling: 13236 Heating: 2329	5801	2.68
Cooling: (120+70)P Heating: 25P	18/12	Cooling: 27/19 Heating: 20/15	Cooling: 14158 Heating: 2612	6689	2.51

Note: 7/6, -5/-6, and 18/12 *etc*. mean dry-bulb/ wet-bulb

Table 2: System performance in the heating-principal mode

Indoor units combination	**Outdoor condition(℃)**	**Indoor condition(℃)**	**Capacity (W)**	**Power consumption(W)**	**COP**
Heating: (120+70)P Cooling: (70+50+25)P	7/6	Heating: 20/15 Cooling: 27/19	Heating: 21120 Cooling: 11657	7476	4.38
Heating: (120+70)P Cooling: (70+50+25)P	0	Heating: 20/15 Cooling: 27/19	Heating: 19551 Cooling: 11301	7716	4.0
Heating: (120+70)P Cooling: (70+50+25)P	18/12	Heating: 20/15 Cooling: 27/19	Heating: 21332 Cooling: 10148	6874	4.58
Heating: 120P Cooling: (70+50)P	7/6	Heating: 20/15 Cooling: 27/19	Heating: 14673 Cooling: 9745	6727	3.63
Heating: 120P Cooling: (70+50)P	0	Heating: 20/15 Cooling: 27/19	Heating: 14185 Cooling: 10530	6555	3.77
Heating: 120P Cooling: (70+50)P	-5/-6	Heating: 20/15 Cooling: 27/19	Heating: 12767 Cooling: 9989	7315	3.11

Note: 7/6, -5/-6, and 18/12 *etc*. mean dry-bulb/ wet-bulb

The heating capacity, the cooling capacity, and the power consumption were recorded and listed in Table.1 and Table.2. It is shown that the COP of the designed new test system increased markedly in the cooling-principal and the heating-principal mode from Table.1 and Table.2, and the cooling and heating capacity can attain about 70%~110% of the nominal capacity, though sometimes the percent was only 70%.

4. CONCLUSIONS

A digital multiple variable refrigerant volume air conditioning system with three pipes type heat recovery has been designed and researched in this paper. The three pipes were high pressure liquid pipe, high pressure gas pipe and low pressure gas pipe. The new unit was named nominal 30KW new type multi-connected unit. The system can meet the load of each room by using new type digital scroll compressor with the variable capacity and electronic expansion valves that can automatically control the refrigerant flow for each indoor unit, can achieve the demand of concurrent heating and cooling through the switch of the solenoid valves, and can regulate the heat capacity of the outdoor heat exchanger by using the AC inverter fan in the outdoor unit. It can be seen that the COP of the designed new Multi-connected system increased markedly in the cooling-principal and the heating-principal mode because both the condensing heat and evaporating heat are valuable in use, while the traditional systems only the condensing heat and evaporating heat can be used. The system can run in the heat pump model, refrigeration model or heat recovery model throughout the year and can run in the working temperature range from -18℃ to 48℃. It is shown that the digital VRV multi-connected units with three pipes type heat recovery system can attain demanded performance and run stably, and the cooling and heating capacity can attain about 70%~110% of the nominal capacity, though sometimes the percent was only 70%.
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