Summary of Chinese Patents Regarding to Heat Pump

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Abstract. The heat pump is an efficient energy-saving device that makes full use of low-grade heat energy. Heat can be transferred spontaneously from a high-temperature object to a low-temperature object, but it cannot spontaneously proceed in the opposite direction. The working principle of the heat pump is a mechanical device that forces heat to flow from a low-temperature object to a high-temperature object in a reverse cycle. It consumes only a small amount of reverse cycle energy and can obtain a large amount of heat supply, which can effectively use low-grade products that are difficult to apply. Finally, the purposes of saving energy are achieved. This article mainly relates to the patents of high-power heat pumps, compact heat pumps, and split heat pumps, this article discusses from three aspects: high power, split and compact heat pumps. In the hope that reflect the novelty, it mainly discusses the relevant patent documents in the past five years.

1. Introduction
The heat pump is an efficient energy-saving device that makes full use of low-grade heat energy. Heat can be transferred spontaneously from a high-temperature object to a low-temperature object, but it cannot spontaneously proceed in the opposite direction. The working principle of the heat pump is a mechanical device that forces heat to flow from a low-temperature object to a high-temperature object in a reverse cycle. It consumes only a small amount of reverse cycle energy and can obtain a large amount of heat supply, which can effectively reduce the difficulty of low-grade applications. In recent years, the heat pump technology has been continuously developed, and the development direction is also different. This article focuses on the three development directions of high power, compact, and split, based on the patent field to discuss the development overview of high-power heat pump, compact heat pump and split heat pump.

2. Development status of heat pump patents in China
This article lists the number of applications for heat pump related patents from 2000 to 2019 by analysing the application status of heat pump related patents on Google patents, as shown in Figure 1. It can be seen from Figure 1 that the total number of Chinese patent applications in the heat pump field is increasing year by year, and its growth trend can be roughly divided into the following four stages: The first stage, 2000 to 2003, the heat pump showed slow development during this time The average annual number of applications is about 300, indicating that China’s heat pump research is in its infancy; the second phase, 2004 to 2012, the total number of applications has shown a rapid growth trend, the number of applications in 8 years from 539 The increase to 4397 cases indicates that the research on heat pumps in China has entered a stage of rapid development; the third stage, from 2012 to 2015, the number of applications per year remained at around 4,700. I think this is a technical bottleneck that will inevitably occur in the development of technology in the fourth stage, a new round of sudden...
growth occurred in 2016 to 2018. The total number of applications in this stage increased from 5927 to 9780, indicating that the economic recovery at home and abroad affected the number of patent applications during this period. The obvious rise is a period of sharp rise. At this stage, to seize the market share of domestic heat pumps, domestic and foreign applicants are competing to apply for patents in China and carry out industrial strategic layout to obtain the largest cake. The reason is mainly due to the progress made by China in the industrialization of patented technology in recent years. While Chinese companies are exploring the market, they are paying more and more attention to the organic combination of technology R&D and patent protection awareness to grasp the intellectual property rights. The intellectual property is core competitiveness.

![Figure 1. Table of the quantity change of heat pump patent application in 2000-2019.](image)

3. Patent investigation of high-power heat pump

For some traditional heat pumps, due to the large amount of heat transferred, the length of the heat exchange tube of the condenser must be extended, but the increase in the length of the heat exchange tube will increase the resistance of the refrigerant to flow in the heat exchange tube, which will affect use effect of heat pump.

In order to solve the above problems, for example, You etc [1] invented a condenser, which is composed of two or more rows of coils and is wrapped around the surface of the refrigerator in a "D" shape, which is equivalent to increasing the length of the heat exchange tube in disguise and almost did not increase the flow resistance of the condensate, thereby achieving an increase in power.

Of course, the most intuitive way to increase the power of the heat pump is to directly increase the power of the compressor. This is also the method used in many large places in the early days, but the start-up current of the high-power compressor is large every time when it is turned on, and in some places where the voltage is unstable it often fails to start, and each time the device starts, it will generate a huge voltage drop, and even cause an impact on the entire power grid, which directly affects the stability of the grid voltage. Long-term use may damage some electrical equipment. In order to reduce the danger while increasing the power of the heat pump, Jin [2] invented a way of combining the electronic control system with the heat pump system to reduce the current instability when the equipment is turned on by the electronic control system, thereby reducing the power grid shock, reduce potential safety hazards, and in the hope that ensure the smooth operation of the heat pump, voltage stabilization devices and lightning protection devices are added to ensure that the
current and voltage are stable when the high-power compressor is turned on and operated, thereby ensuring the safety of the working environment.

In recent years, under the condition of ensuring the safety of the working environment, the method of increasing the overall power of the heat pump by increasing the power of the heat pump compressor has been mature, so a compound (hybrid) power heat pump device came into being. The main solution of the hybrid heat pump device is: in cold-heat-electricity cogeneration energy stations in many regions, the summer cooling load is much greater than the heat load, and the heat pump unit must be driven by power generation. This gas heat energy is converted into mechanical energy and then into electrical energy. The method of conversion into mechanical energy of the compressor is extremely inefficient and the problem of great energy loss. When heating in winter, the gas boiler is directly burned, and a large amount of heat is discharged with the flue gas, which is a big problem of waste. For example, Patent No. CN107957149A [3] reference to one hybrid heat pump apparatus combined with a thermal power of the main power generator and the heat pump unit composition and comprising electronic control system.

4. Patent Investigation of Compact Heat Pump

Early patents generally made some changes to the appearance of heat pump water heaters for the purpose of compactness. For example, Song etc [4] invented a patent that transform the original cylindrical upright water tank into a flat square structure to achieve a compact effect. Obviously, the above-mentioned transformation alone cannot adapt the needs of production and life.

The invention about the compact heat pump is not only reflected in the heat pump water heater, but also in the heat pump air conditioner. As the patent invented by Xie etc [5], a compact marine heat pump air conditioner is designed, which is characterized by the design of a common chassis, which connects the air conditioning unit to the common chassis in an integrated manner, which can reduce the general air conditioner's fully enclosed The frame structure reduces manufacturing costs and floor space, and at the same time improves the energy efficiency ratio due to the use of heat pump technology. However, the patent of compact heat pump air conditioners not only that, and there have been developments in recent years. For example, Zhang etc [6] designed a single-channel compact heat pump driven solution dehumidification fresh air treatment unit, which is characterized by the use of liquid hygroscopic agent to achieve the functions of cooling and dehumidification, and is driven by the existing heat pump The biggest feature of the solution dehumidification new fan unit is the use of a single air duct. The fresh air to be treated can be used as regeneration air at the same time. No additional regeneration air source and air duct are required, which makes the unit compact.

In addition to the above-mentioned compact inventions for heat pump water heaters and heat pump air conditioners, there have also been inventions that have achieved compactness in other heat pump fields in recent years. Xiao etc [7] invented a patent to overcome the shortcomings of the known air-conditioning heat pump equipment not suitable for installation in residential rooms such as kitchens, living rooms, bedrooms, bathrooms, a heat pump equipment including a closing / opening valve is proposed This device allows one to advantageously close the passage of the working fluid at the inlet of the compressor until a pressure difference of at least 2.5 bar is reached between the discharge and return of the compressor. Operating in this way, a small compressor can be used, to achieve the purpose of compactness, it is installed in various scenarios with the device. There are also related applications in the field of mine ventilation systems. For example, Sui etc [8] invented a separate heat pipe. Compared with the conventional heat pipe heat exchanger, the steam of the separate heat pipe is in the condensing section. Flowing up and down with the liquid film in the same direction can avoid the carrying limit of the single tube long heat pipe heat exchanger that is easy to appear. Therefore, in the case of the same heat exchange, a smaller diameter tube can be selected as the heat transfer tube to ensure the compactness of the device.

Inventions related to compact heat pumps can also be seen in the field of water-source heat pumps. You etc [9] invented a patent that a gas cooler for trans critical carbon dioxide heat pump refrigeration and heating system adopts a two-stage heat exchange structure, that is, designing two heat exchange
shells connected in series. The inlets of carbon dioxide and low temperature water are set on different shells to reverse heat exchange between high temperature gaseous carbon dioxide and low temperature water, and the single heat exchange shell is designed as a fixed tube sheet structure, which can improve the overall heat exchange efficiency and make the structure simple. It is compact and can withstand higher pressure, reducing the flow resistance of water and carbon dioxide.

5. Patent investigation of split heat pump

Split heat pumps are commonly used in our lives. For example, the wall-mounted air conditioners that are available in almost every household are a common split heat pump.

As mentioned above, the heat pump air conditioners play an important role in people's daily life and production. However, when the heat pump air conditioner is used in an environment with a very low outdoor temperature in winter, the working fluid evaporation temperature is low, the moisture in the air is very easy to condense into frost on the surface of the evaporator, and frost will increase the wind resistance of the external machine. Leading to a decrease in the heat transfer coefficient and a decrease in the heating performance coefficient, which leads to a reduction in the utilization rate of heat, which will lead to a decrease in the utilization rate of heat energy. For solving the above problems, Su etc [10] invented a split-type heat pump air conditioner, including a compressor with a refrigerant line connected at one time, a four-way reversing valve, an outdoor heat exchanger, a throttling device, and an indoor heat exchanger. Besides, it also includes a heat exchange tube located on the outdoor side and connected between the throttle device and the indoor heat exchanger. Taking heating as an example, its main function is to use the heat exchange tubes to recover the residual heat of the refrigerant at the indoor outlet during heating, improve the heat exchange process of the low-temperature and low-pressure refrigerant on the outdoor side, and improve the frost state on the outdoor side, thereby improving heat exchange efficiency.

The problem of split air conditioner is not limited to this. Due to the long use time, or the disassembly of the machine, damage to the pipeline, etc, the split air conditioner's cooling effect needs to be repaired, and the refrigerant such as freon is added. In the existing split-type air conditioner, freon can be added only when the refrigerant flowing at the shut-off valve is in a low-pressure state, but when operating in the heating mode, the refrigerant flowing at the shut-off valve is a high-temperature and high-pressure refrigerant, so when it is in the heating mode in winter it must be forced to switch to the cooling mode, which is a lot of tedious operations, and some maintenance unions choose to forcibly unplug the four-way reversing valve to cut off the power to quickly switch to the cooling mode, which will inevitably bring hidden safety risks.

For the purposes of solving the above problem, Zhao etc [11] invented a split heat pump air conditioner. Its main feature is the design of the first refrigerant filling port and the second refrigerant filling port, so that no matter in heating mode or cooling mode, the refrigerant can be filled from the corresponding refrigerant filling port, which is convenient for maintenance personnel to maintain and avoid high-altitude operations and difficult operations.

The split heat pump is not only widely used in air conditioners, but also has many inventions in heat pump water heaters. For example, in order to solve the problem that the "energy efficiency ratio" of the heat pump water heater continues to decrease when the water temperature in the water tank of the heat pump water heater continues to rise under heating. Kuang etc [12] invented a split heating scheme, that is, condensation. The heating coil of the heater is designed in a split type, that is, the original integrated heating coil is divided into an upper heating coil and a lower heating coil, which are respectively arranged at the upper and lower parts of the heating water tank. At the beginning, the upper and lower temperatures are relatively low, and the heating energy efficiency ratio is relatively high, but as the heating progresses, the upper temperature will be higher than the lower temperature. At this time, the refrigerant inlet of the upper heating coil is closed, so that the refrigerant enters the lower heating plate tube to maintain a higher heating energy efficiency ratio.

The invention of improving energy efficiency is not only that. Zhang etc [13] invented a split heat pump water heater. In order to solve the problem that the overall heat exchange efficiency of the L-
shaped tube sheet heat exchanger is low and the heat transfer performance of the heat pump water heater is poor, a first heat exchanger for heating is added to the hot water tank, and the outdoor unit a fan and a second heat exchanger are installed, and a throttling device is provided between the first heat exchanger and the second heat exchanger, and respectively connected to the compressor. The distribution of the second heat exchanger along the side wall of the shell can maximize the use of the area of the side wall of the shell for uniform circulation heat exchange, increasing the heat exchange area and heat exchange efficiency of the second heat exchanger to obtain higher heat exchange efficiency and the compressor and other components are wrapped by the second heat exchanger, which can effectively reduce the thickness of the outdoor unit, make the structure more compact, and effectively reduce the overall volume of the outdoor unit.

6. Conclusions
It can be seen from the above patent investigation that the number of compact heat pump patents is much smaller than that of split heat pumps. The main reason is that the current split heat pump structure has been widely used in life, whether it is air conditioners, water heaters or dehumidification drying system; there are a considerable number of patents in the field of improving energy efficiency ratio or reducing maintenance cost and difficulty. However, in recent years, patents have gradually developed toward compactness. For example, patents that originally belonged to the field of split heat pumps have realized the content of the invention while making the structure more compact and reducing the size of the outdoor unit. But at present, one of the problems is that there are few patents for compact heat pumps.

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