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ZHONG et al.(10) **Pub. No.: US 2016/0177954 A1**(43) **Pub. Date: Jun. 23, 2016**(54) **MULTI-STAGE CENTRIFUGAL
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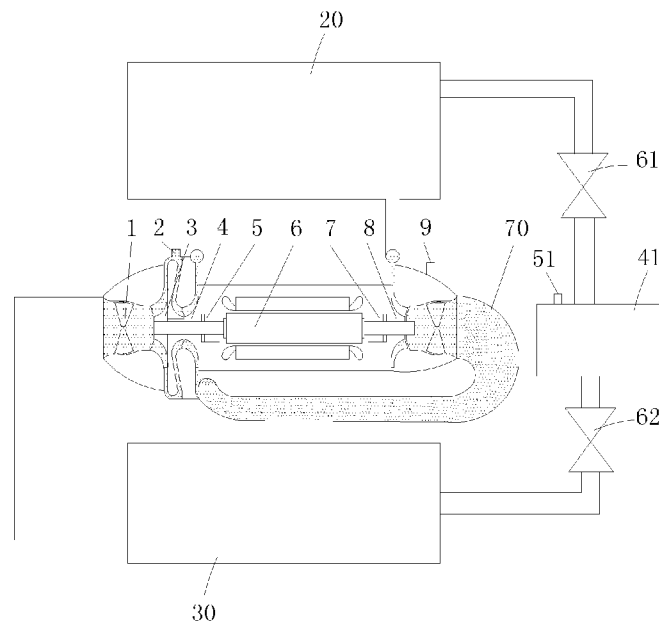
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(57)

ABSTRACT

A multi-stage centrifugal compressor and an air conditioning unit are disclosed. The multi-stage centrifugal compressor comprises a power portion and an impeller portion. The power portion comprises a motor (6), a shaft of the motor comprises a first end and a second end. The impeller portion comprises N impellers, wherein N is equal to or more than 2 and less than 10. When N is an even, the number of the impellers on the first end of the shaft is equal to that of the impellers on the second end of the shaft. When N is an odd, the number of the impellers on the first end of the shaft is one more than that of the impellers on the second end of the shaft. The first stage impeller farthest away from the motor (6) is arranged at the first end of the shaft; other impellers at the first end of the shaft are arranged in an ascending order. The Nth stage impeller nearest to the motor (6) is arranged at the second end of the shaft; other impellers at the second end of the shaft are arranged in a descending order. A gas outlet of the impellers arranged at the first end of the shaft communicates with a gas inlet of the impellers arranged at the second end of the shaft through a connection pipeline, so that the pressure ratio and the energy efficiency are improved.



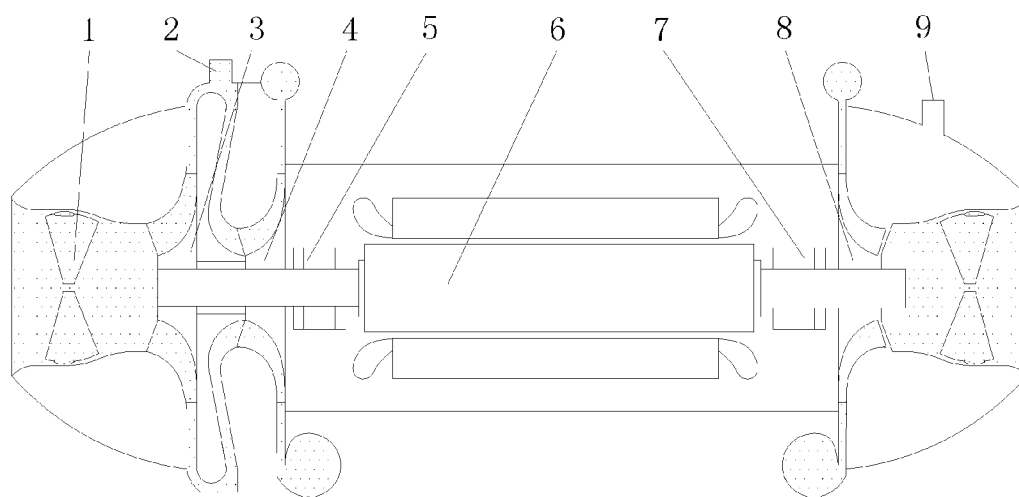


Fig. 1

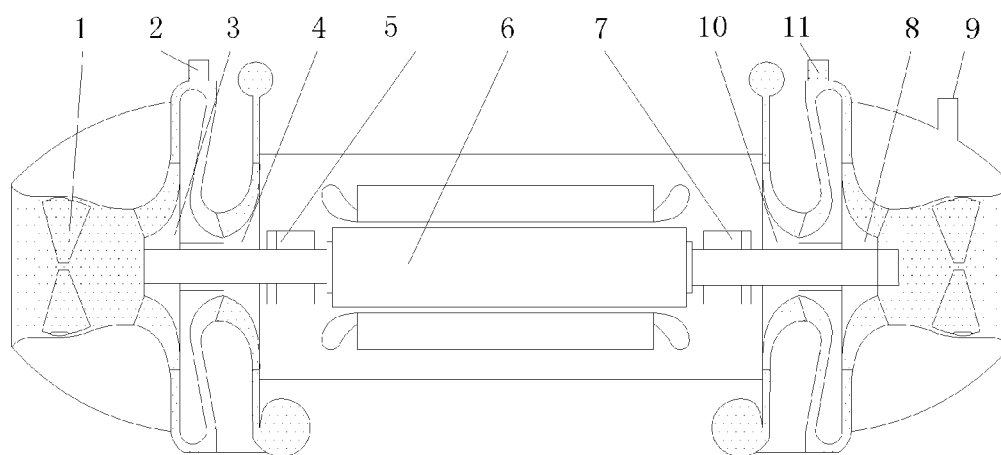


Fig. 2

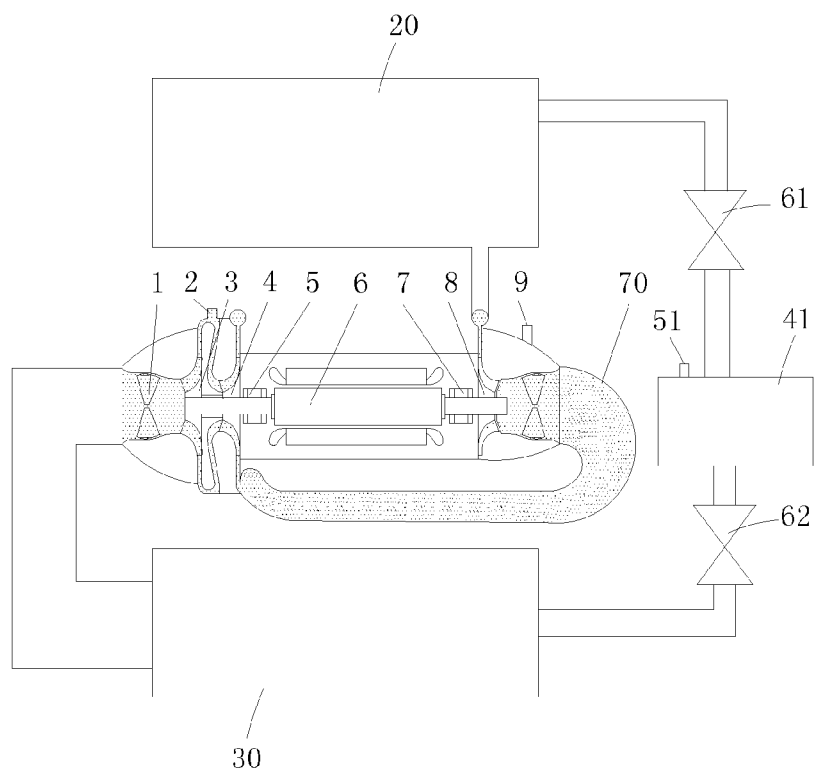


Fig. 3

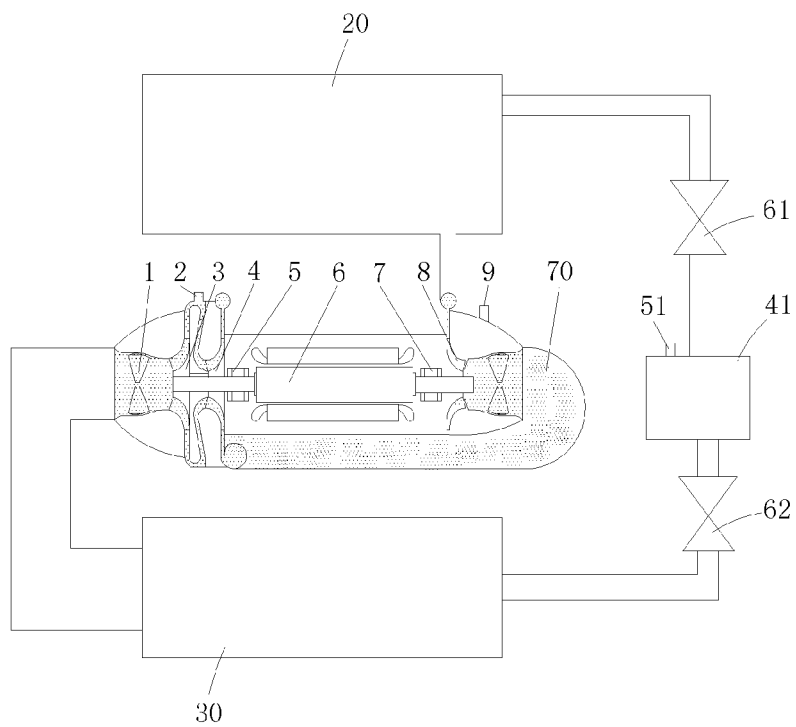


Fig. 4

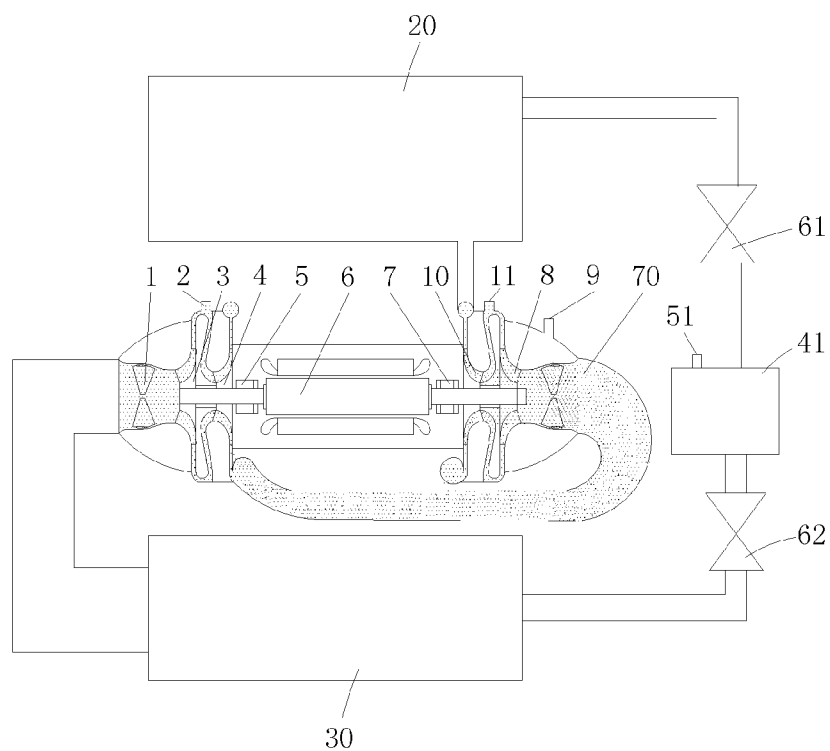


Fig. 5

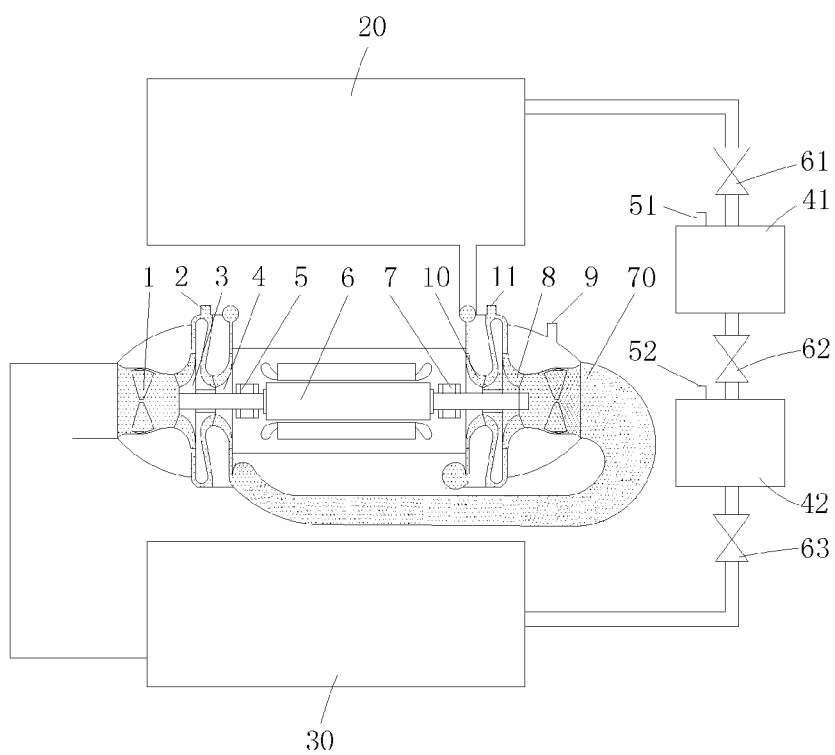


Fig. 6

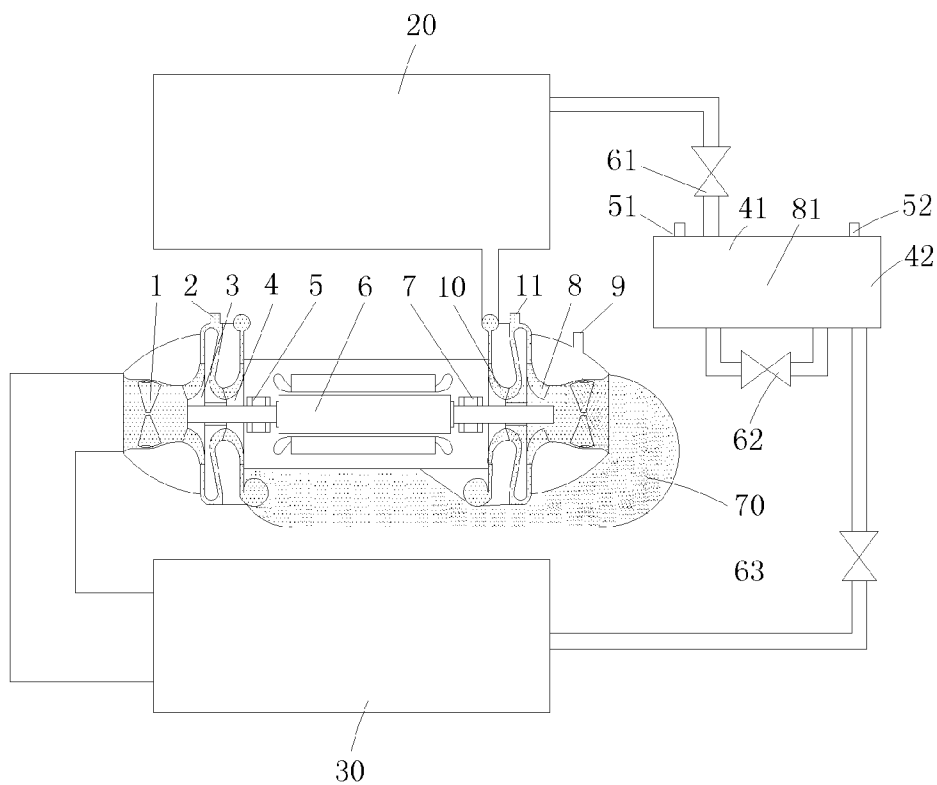


Fig. 7

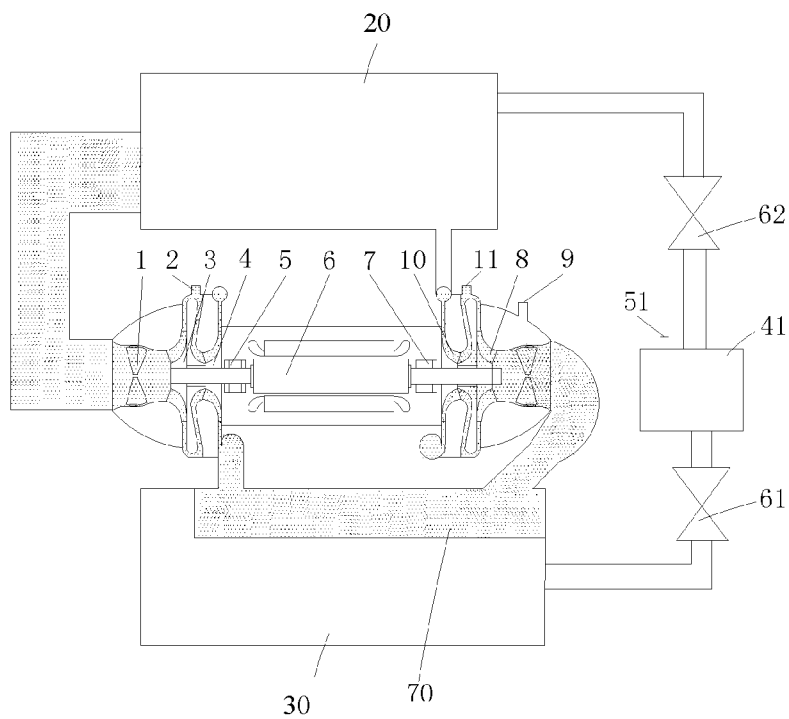


Fig. 8

MULTI-STAGE CENTRIFUGAL COMPRESSOR AND AIR CONDITIONING UNIT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation application of PCT Patent Application No. PCT/CN2014/084414, entitled “Multi-stage Centrifugal Compressor and Air Conditioning Unit”, filed on Aug. 14, 2014, which claims priority to Chinese Patent Application No. 201310377356.2, entitled “Multi-stage Centrifugal Compressor and Air Conditioning Unit”, filed on Aug. 26, 2013, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to the technical field of compressors and air conditioners, more especially, to a multi-stage centrifugal compressor and an air conditioning unit.

BACKGROUND

[0003] In the prior art, the centrifugal compressor for refrigeration use is a one-stage or two-stage compressor. In the common refrigeration range, such as the temperatures 12/7° C. of the inflow and outflow freezing water, and the temperatures 30/35° C. of the inflow and outflow cooling water, as the pressure ratio under such water temperatures is not high, the air conditioning unit is mostly provided with a one-stage or two-stage compressor. If the temperatures 12/7° C. of the inflow and outflow freezing water remain unchanged, and the temperature of the outflow cooling water is relatively higher, such as 70° C., then the required pressure ratio of the unit will be very high, even up to 6.5, while this is just the operating condition required by most industrial production facilities and required in the field of heating and heat-exchanging.

[0004] In order to increase the pressure ratio of the centrifugal compressor, as for a single compressor, the common scheme is to enlarge the dimensions of the impeller or increase the rotating speed of the impeller, thereby enabling the impeller to gain more power so as to increase the pressure ratio. But this scheme of increasing the pressure ratio is limited by factors as follows: 1. the material strength of the impeller; 2. the first order critical speed of the rotation part.

[0005] Generally, in order to ensure that the impeller operates safely and reliably, the peripheral speed of the impeller outlet is no greater than 300 m/s. However, in order to realize a higher pressure ratio, the outer diameter or the rotating speed of the impeller has to be increased, which conflicts with the requirement of the material strength of the impeller. If the increase of the pressure ratio is realized only by increasing the rotating speed but keeping the dimensions of the impeller unchanged, it is likely that the speed of the rotating part approaches or reaches the inherent critical rotating speed and thus causes resonances, thereby affecting the reliable operation of the compressor and the air conditioning unit.

[0006] In view of the low pressure ratio of a single compressor, there are solutions proposed that multiple stages of compressors or multiple air conditioning units are connected in series so as to solve the problem. But, with no doubt, these solutions have the following defects: the overall production cost and maintenance cost of the unit are too high, the overall

dimensions are oversized, and the area occupied by the relative equipment room is too large, and thus it is difficult to meet the practical application requirements of customers.

[0007] In view of the defects above, after a long period of research and practice, the inventors finally obtained the present invention.

SUMMARY OF THE INVENTION

[0008] In view of the situations, it is necessary to provide a multi-stage compressor with a higher pressure ratio, and to provide an air conditioning unit, which has a compact structure and operates stably.

[0009] The present disclosure provides a multi-stage centrifugal compressor, comprising a power portion and an impeller portion;

[0010] the power portion comprises a motor having a shaft; the shaft of the motor comprises a first end and a second end;

[0011] the impeller portion comprises N impellers, wherein N is equal to or more than 2 and less than 10;

[0012] when N is an even, number of the impellers on the first end of the shaft is equal to number of the impellers on the second end of the shaft;

[0013] when N is an odd, the number of the impellers on the first end of the shaft is one more than the number of the impellers on the second end of the shaft;

[0014] a first stage impeller farthest away from the motor is arranged at the first end of the shaft; other impellers at the first end of the shaft are arranged in an ascending order;

[0015] an Nth stage impeller nearest to the motor is arranged at the second end of the shaft; other impellers at the second end of the shaft are arranged in a descending order;

[0016] a gas outlet of the impellers arranged at the first end of the shaft communicates with a gas inlet of the impellers arranged at the second end of the shaft through a connection pipeline; wherein, the gas outlet of the impellers arranged at the first end of the shaft is same gas outlet of the impeller nearest to the motor and arranged at the first end of the shaft; the gas outlet of the impellers arranged at the second end of the shaft is same gas outlet of the impeller farthest to the motor and arranged at the second end of the shaft.

[0017] In one of the embodiments, a connection pipeline is disposed outside the multi-stage centrifugal compressor or inside a casting of the multi-stage centrifugal compressor.

[0018] In one of the embodiments, except the first stage impeller, gas-injection inlets are provided at inlets of other impellers, including a first gas-injection inlet provided at the inlet of the second stage impeller, . . . , and an (N-1)th gas-injection inlet provided at the Nth stage impeller.

[0019] In one of the embodiments, the centrifugal compressor further comprises at least two bearings; at least one bearing is sleeved on the first end of the shaft and at least one bearing is sleeved on the second end of the shaft.

[0020] In one of the embodiments, the bearings are embodied as a roll bearing, slide bearing or magnetic floating bearing.

[0021] The present disclosure provides an air conditioning unit, comprising an evaporator and a condenser and said multi-stage centrifugal compressor.

[0022] In one of the embodiments, the connection pipeline, which is disposed between the gas outlet of the impellers arranged at the first end of the shaft and the gas inlet of the impellers arranged at the second end of the shaft, is arranged inside the evaporator or inside the condenser.

[0023] In one of the embodiments, the air conditioning unit further comprises an economizer; other impellers except the first stage impeller are each provided with a gas-injection inlet; gas flash evaporated from the economizer is guided into the gas-injection inlet of the multi-stage centrifugal compressor.

[0024] In one of the embodiments, the gas flash evaporated from the economizer is guided into an (N-1)th gas-injection inlet preferably.

[0025] In one of the embodiments, the air conditioning unit comprises N-1 economizers corresponding to N-1 gas-injection inlets;

[0026] each economizer comprises an economizer inlet and an economizer outlet, and further comprises an economizer gas outlet in communication with the corresponding gas-injection inlet.

[0027] In one of the embodiments, the air conditioning unit comprises only one economizer; the economizer is partitioned into several independent economizer parts, number of the economizer parts is the same as the number of the gas-injection inlets;

[0028] each economizer part comprises an economizer inlet and an economizer outlet, and further comprises an economizer gas outlet in communication with the corresponding gas-injection inlet.

[0029] In one of the embodiments, throttling devices are arranged on the refrigerant connection pipeline of an economizer inlet and arranged at an economizer outlet respectively.

[0030] As compared with the prior art, the present disclosure has following beneficial effects: as the pressure ratio of the multi-stage centrifugal compressor is higher, the multi-stage centrifugal compressor and the air conditioning unit operate efficiently and stably; the connections between the components and parts of the unit are optimized, which makes the production cost lower and the area occupied smaller; the intermediate gas injection can save energy, and enhance the efficiency; the gas flow state of other impellers except the first stage impeller are improved, thereby lowering the gas temperature and reducing the compression work; flexible connection pipeline arrangements are allowed, and thus the pipelines are easy to fix, to operate and to maintain; the overall unit is compact in structure, which reduces noises effectively, and it is easy to meet the customers' requirements for the overall dimensions of the overall air conditioning unit; the axial forces are smaller, and the service life is longer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. 1 is a structural schematic diagram of the three-stage centrifugal compressor according to the present disclosure;

[0032] FIG. 2 is a structural schematic diagram of the four-stage centrifugal compressor according to the present disclosure;

[0033] FIG. 3 is a schematic diagram illustrating the air conditioning unit having the three-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the external connection pipeline;

[0034] FIG. 4 is a schematic diagram illustrating the air conditioning unit having the three-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the intra-casting connection pipeline;

[0035] FIG. 5 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the external connection pipeline;

[0036] FIG. 6 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with double gas-injection inlets connected with the external connection pipeline and is provided with double economizers;

[0037] FIG. 7 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with double gas-injection inlets connected with the intra-casting connection pipeline and is provided with a partitioned economizer;

[0038] FIG. 8 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the internal connection pipeline of the evaporator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0039] In order to solve the problem of too low pressure ratio, a multi-stage centrifugal compressor and an air conditioning unit are provided.

[0040] The present disclosure provides a multi-stage centrifugal compressor, comprising a power portion and an impeller portion. The power portion comprises a motor having a shaft. The shaft of the motor comprises a first end and a second end;

[0041] The impeller portion comprises N impellers, wherein N is equal to or more than 2 and less than 10;

[0042] When N is an even, the number of the impellers on the first end of the shaft is equal to that of the impellers on the second end of the shaft;

[0043] When N is an odd, the number of the impellers on the first end of the shaft is one more than that of the impellers on the second end of the shaft;

[0044] The first stage impeller farthest away from the motor is arranged at the first end of the shaft; other impellers at the first end of the shaft are arranged in an ascending order;

[0045] The Nth stage impeller nearest to the motor is arranged at the second end of the shaft; other impellers at the second end of the shaft are arranged in a descending order;

[0046] A gas outlet of the impellers arranged at the first end of the shaft communicates with a gas inlet of the impellers arranged at the second end of the shaft through a connection pipeline; wherein, the gas outlet of the impellers arranged at the first end of the shaft is the same gas outlet of the impeller nearest to the motor and arranged at the first end of the shaft; the gas outlet of the impellers arranged at the second end of the shaft is the same gas outlet of the impeller farthest to the motor and arranged at the second end of the shaft.

[0047] As compared with the prior art, the present disclosure has the following beneficial effects: the multi-stage centrifugal compressor has a higher pressure ratio, operates reliably and stably.

[0048] The technical features above, other additional technical features and the advantages of the present disclosure will be further described in more details with reference to the accompanying figures.

[0049] FIG. 1 is a structural schematic diagram of the three-stage centrifugal compressor according to the present disclosure. As shown in FIG. 1, the three-stage centrifugal compressor comprises a power portion and an impeller portion;

[0050] The power portion comprises a motor 6 having a shaft. The shaft of the motor 6 comprises a first end and a second end; the first end and the second end of the shaft are respectively and symmetrically arranged at the left end and the right end of the motor 6, so as to reduce the forces on the shaft in the axial direction.

[0051] The impeller portion comprises a directing vane 1, the first stage impeller 3, the second stage impeller 4 and the third stage impeller 8. The first stage impeller 3 is arranged on the first end of the shaft, and is farthest away from the motor.

[0052] The first stage impeller 3 and the second stage impeller 4, and the third stage impeller 8 are respectively disposed at two ends of the motor 6. The first end of the shaft drives the first stage impeller 3 and the second stage impeller 4 to rotate, and the second end of the shaft drives the third stage impeller 8 to rotate.

[0053] The multi-stage centrifugal compressor further comprises a supporting portion, the supporting portion comprises a first bearing 5 and a second bearing 7 which are respectively sleeved on the first end of the shaft and the second end of the shaft.

[0054] FIG. 2 is a structural schematic diagram of the four-stage centrifugal compressor according to the present disclosure. As shown in FIG. 2, the four-stage centrifugal compressor comprises a power portion and an impeller portion.

[0055] The power portion comprises a motor 6. The motor 6 has a shaft with a first end and a second end, the first end and the second end are respectively disposed at the left end and the right end of the motor.

[0056] The impeller portion comprises a directing vane 1, the first stage impeller 3, the second stage impeller 4, the third stage impeller 8 and the fourth stage impeller 10. The first stage impeller 3 is arranged on the first end of the shaft, and is farthest away from the motor.

[0057] The first stage impeller 3 and the second stage impeller 4, and the third stage impeller 8 and the fourth stage impeller 10, are respectively disposed at two ends of the motor 6. Respectively, the first end of the shaft drive two impellers to rotate, and the second end of the shaft drive two impellers to rotate.

[0058] The multi-stage centrifugal compressor further comprises a supporting portion, the supporting portion comprises a first bearing 5 and a second bearing 7, which are respectively sleeved on the first end of the shaft and the second end of the shaft. Generally, the four-stage centrifugal compressor is provided with at least one first bearing 5 and at least one second bearing 7. According to requirements, two or more first bearings 5 or second bearings 7 may be provided, so as to realize better supporting effects.

[0059] The multi-stage centrifugal compressor may be in the form of a three-stage or four-stage centrifugal compressor, and at most, a nine-stage centrifugal compressor. The motor 6 directly drives the multiple stages of impellers to perform work on the gas.

[0060] As shown in FIGS. 1 and 2, all impellers are assembled on the output shaft of the motor 6 through interference-fit joints, maintaining a high coaxiality between the impellers and the rotor, further ensuring the whole rotating portion to run stably at high speeds. Except the first stage impeller 3 of the multi-stage centrifugal compressor, accord-

ing to the requirements of the system structure, the second stage impeller or the third stage impeller may be provided with a gas-injection inlet, or both the second stage impeller and the third stage impeller are provided with gas-injection inlets so as to realize the power saving mode with an intermediate gas injection.

[0061] As shown in FIG. 1, the gas-injection inlet disposed at the second stage compression inlet is the first gas-injection inlet 2; the gas-injection inlet disposed at the third stage compression inlet is the second gas-injection inlet 9. As shown in FIG. 2, the gas-injection inlet disposed at the second stage compression inlet is the first gas-injection inlet 2; the gas-injection inlet disposed at the third stage compression inlet is the second gas-injection inlet 9; the gas-injection inlet disposed at the fourth stage compression inlet is the third gas-injection inlet 11.

[0062] The gas-injection inlet of the second stage impeller is connected with the casting body, and communicates with the gas-injection channel disposed in front of the inlet of the second stage impeller, thus it is convenient to produce and connect the gas-injection channel. The gas-injection channel of the third stage impeller may be connected with the casting at the inlet, or may be provided with a connection pipeline, which can be selected according to the system structural configuration. The gas-injection inlet of the fourth stage compressor is connected with the casting body, which is similar to the arrangement for the gas-injection inlet of the first stage impeller and that for the gas-injection inlet of the second stage impeller.

[0063] The motor 6 shown in FIGS. 1 and 2 is a variable frequency permanent magnetic synchronous motor, whose power is greater than 140 kW, and whose rotating speed is greater than 6000 r/min. The first bearing 5 and the second bearing 7, which may be embodied as a roll bearing, slide bearing or magnetic floating bearing, perform the supporting function.

[0064] For the case that the bearings are roll bearings, one of the bearings is an angular contact bearing, so as to balance the axial forces generated by the impeller when it rotates at a high speed. For the case that the bearings are slide bearings, at least one bearing has a thrust surface, or two bearings are provided with thrust surfaces, so as to balance big axial forces.

[0065] In order to make the bearings more compact, the bearing which bears radial forces and the bearing which bears axial forces are integrated into one bearing part, so that the bearing part has a radial-axial compound-function, and it is convenient to assemble and repair.

[0066] The three-stage centrifugal compressor shown in FIG. 1 has the following flow direction of the main gas flow: the gas inlet→the directing vane 1→the first stage impeller 3→the second stage impeller 4→the third stage impeller 8→the gas outlet. The four-stage centrifugal compressor shown in FIG. 2 has the following flow direction of the main gas flow: the gas inlet→the first stage impeller 3→the second stage impeller 4→the third stage impeller 8→the fourth stage impeller 10→the gas outlet.

[0067] As shown in FIGS. 3, 4, 5, 6, 7 and 8, FIG. 3 is a schematic diagram illustrating the air conditioning unit having the three-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the external connection pipeline; FIG. 4 is a schematic diagram illustrating the air conditioning unit having the three-stage centrifugal

compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the intra-casting connection pipeline; FIG. 5 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the external connection pipeline; FIG. 6 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with double gas-injection inlets connected with the external connection pipeline and is provided with double economizers; FIG. 7 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with double gas-injection inlets connected with the intra-casting connection pipeline and is provided with a partitioned economizer; FIG. 8 is a schematic diagram illustrating the air conditioning unit having the four-stage centrifugal compressor according to the present disclosure, the air conditioning unit is provided with a single gas-injection inlet connected with the internal connection pipeline of the evaporator.

[0068] The gas outlet of the impellers arranged at the first end of the shaft communicates with the gas inlet of the impellers arranged at the second end of the shaft through a connection pipeline 70. The connection pipeline 70 can be realized in the following manners:

[0069] 1. An external connection pipeline: as shown in FIGS. 3, 5 and 6, the external connection pipeline may be formed by seamless steel pipes, said seamless steel pipes are welded with flanges and then connected together through the flanges; or the external connection pipeline may be formed by casting channels, said casting channels are connected through cast flanges thereof; wherein, the seal between the flanges may be embodied as a gasket seal, O-shaped ring seal or spherical seal.

[0070] The connection pipeline in the form of the external connection pipeline is easy to fix, and is convenient to operate and maintain.

[0071] 2. The gas compressed by the first stage impeller and the second stage impeller is guided into the gas inlet through an inner connection pipeline in the casting of the multi-stage centrifugal compressor, as shown in FIGS. 4 and 7. Inner connection pipelines may be cast in respective castings of the multi-stage centrifugal compressor, then the castings are connected and the overall gas flow passage is formed.

[0072] With the gas flow passage formed by the intra-casting connection pipelines, the structure of the overall unit is compact. As the wall thickness of the casting is greater than that of the steel pipe, the noises between the second stage impeller and the third stage impeller is lowered effectively.

[0073] 3. The gas compressed by the first stage impeller and the second stage impeller is discharged into an additional built-in cavity of the condenser, then the gas is guided into the gas inlet through an inner connection pipeline in the cavity. The built-in cavity can be constructed by steel pipes or steel plates welded in the barrel of the condenser, and the welding airtightness is ensured through leakage detection under pressure.

[0074] 4. The gas compressed by the first stage impeller and the second stage impeller is discharged into an additional built-in cavity of the evaporator, then the gas is guided into the gas inlet through an inner connection pipeline of the cavity, as

shown in FIG. 8. The built-in cavity can be constructed in the same way as the built-in cavity of the condenser.

[0075] With the gas flow passage formed by the inner connection pipeline inside the condenser or inside the evaporator, the structure of the overall unit is compact; and the external connection pipeline is simple to connect, which is easy to meet the customers' requirements for the overall dimensions of the unit.

[0076] As shown in FIG. 3, the air conditioning unit having the three-stage centrifugal compressor, which is provided with a single gas-injection inlet connected with the external connection pipeline, comprises the multi-stage centrifugal compressor, the condenser 20, the evaporator 30, a first economizer 41, a first throttling device 61, a second throttling device 62 and the connection pipeline 70.

[0077] A first economizer gas outlet 51 is disposed at the top of the first economizer 41. FIG. 4 and FIG. 3 differ in the connecting manner of the connection pipeline 70. FIG. 5 and FIG. 3 differ in the number of the stages of the multi-stage centrifugal compressor. The number of the stages in FIG. 3 is three, and the number of the stages in FIG. 4 is four.

[0078] FIG. 6 and FIG. 5 differ in the number of the gas-injection inlets. Double gas-injection inlets are provided in FIG. 6, and a single gas-injection inlet is provided in FIG. 5.

[0079] As shown in FIG. 6, the air conditioning unit having the four-stage centrifugal compressor, which is provided with double gas-injection inlets connected with the external connection pipeline and is provided with double economizers, comprises the multi-stage centrifugal compressor, the condenser 20, the evaporator 30, the first economizer 41, the second economizer 42, the first throttling device 61, the second throttling device 62, the third throttling device 63 and the connection pipeline 70.

[0080] The first economizer gas outlet 51 is disposed at the top of the first economizer 41. A second economizer gas outlet 52 is disposed at the top of the second economizer 42.

[0081] FIG. 7 is distinguished from FIG. 6 by the following features:

[0082] 1. the connecting manner of the connection pipeline 70;

[0083] 2. the economizer is not embodied as two independent economizers, instead, one economizer is partitioned into two economizer parts by a baffle 81.

[0084] As shown in FIG. 7, the air conditioning unit having the four-stage centrifugal compressor, which is provided with double gas-injection inlets connected with the intra-casting connection pipeline and is provided with a partitioned economizer, comprises the multi-stage centrifugal compressor, the condenser 20, the evaporator 30, the first economizer part 41, the second economizer part 42, the first throttling device 61, the second throttling device 62, the third throttling device 63 and the connection pipeline 70.

[0085] The first economizer gas outlet 51 is disposed at the top of the first economizer part 41. The second economizer gas outlet 52 is disposed at the top of the second economizer part 42.

[0086] FIG. 8 is distinguished from FIG. 3 in the connecting manner of the connection pipeline 70, namely, the gas outlet of the multi-stage centrifugal compressor is in communication with the gas inlet of the multi-stage centrifugal compressor through the additional built-in cavity in the evaporator.

[0087] Preferably, the air conditioning unit having the multi-stage centrifugal compressor adopts an intermediate

gas injection, so as to improve the gas flow state of other impellers except the first stage impeller, for example, to lower the gas temperature, reduce the compression work, so as to realize the objectives of saving power and improving the efficiency.

[0088] If the multi-stage centrifugal compressor is a three-stage compressor, and only one gas-injection inlet is required, as shown in FIGS. 3 and 4, then either one of the first gas-injection inlet 2 and the second gas-injection inlet 9 can be selected as the gas-injection inlet, and preferably, the second gas-injection inlet 9 is selected as the gas-injection inlet.

[0089] Accordingly, only one economizer is provided in the air conditioning unit. Through the first throttling device 61, the liquid refrigerant from the condenser 20 flows into the first economizer 41; then through the second throttling device 62, the liquid refrigerant from the first economizer 41 flows into the evaporator 30.

[0090] Through the first throttling device 61, the gas flash evaporated from the first economizer gas outlet 51 is guided into the first gas-injection inlet 2 or into the second gas-injection inlet 9 as required.

[0091] If the multi-stage centrifugal compressor is a four-stage compressor, and only one gas-injection inlet is required, as shown in FIGS. 5 and 8, then any one of the first gas-injection inlet 2, the second gas-injection inlet 9 and the third gas-injection inlet 11 corresponding to said multi-stage centrifugal compressor can be selected as the gas-injection inlet, and preferably, the third gas-injection inlet 11 is selected as the gas-injection inlet.

[0092] Accordingly, only one economizer is provided in the air conditioning unit. Through the first throttling device 61, the liquid refrigerant from the condenser 20 flows into the first economizer 41; then through the second throttling device 62, the liquid refrigerant from the first economizer 41 flows into the evaporator 30.

[0093] Through the first throttling device 61, the gas flash evaporated from the first economizer gas outlet 51 is guided into any one of the first gas-injection inlet 2, the second gas-injection inlet 9 and the third gas-injection inlet 11 as required.

[0094] If the multi-stage centrifugal compressor is a four-stage compressor, and two gas-injection inlets are required, as shown in FIGS. 6 and 7, then any two of the first gas-injection inlet 2, the second gas-injection inlet 9 and the third gas-injection inlet 11 corresponding to said multi-stage centrifugal compressor can be selected as the gas-injection inlets, and preferably, the second gas-injection inlet 9 and the third gas-injection inlet 11 are selected as the gas-injection inlets.

[0095] Accordingly, two economizers need to be provided in the air conditioning unit. The economizers may be two independent vessels, as shown in FIG. 6; alternatively, the economizers may be embodied as the two economizer parts of one independent economizer partitioned by the baffle 81, as shown in FIG. 7. Through the first throttling device 61, the liquid refrigerant from the condenser 20 flows into the first economizer part 41; then through the second throttling device 62, the liquid refrigerant from the first economizer part 41 flows into the second economizer part 42; at last through the third throttling device 63, the liquid refrigerant flows into the evaporator 30.

[0096] Through the first throttling device 61, the gas flash evaporated from the first economizer gas outlet 51 is guided into the first gas-injection inlet 2 as required; through the second throttling device 62, the gas flash evaporated from the

second economizer gas outlet 52 is guided into the second gas-injection inlet 9 as required.

[0097] By varying the embodiments above, some other combinations of the number of stages of the multi-stage centrifugal compressor and the number of gas-injection inlets can be concluded as follows:

[0098] If the multi-stage centrifugal compressor is a three-stage compressor and two gas-injection inlets are required, the first gas-injection inlet 2 and the second gas-injection inlet 9 corresponding to said multi-stage centrifugal compressor are selected as the gas-injection inlets.

[0099] Accordingly, two economizers need to be provided in the air conditioning unit. The economizers may be two independent vessels, as shown in FIG. 6; alternatively, the economizer may be embodied as the two economizer parts of one independent economizer partitioned by the baffle 81, as shown in FIG. 7. Through the first throttling device 61, the liquid refrigerant from the condenser 20 flows into the first economizer part 41; then through the second throttling device 62, the liquid refrigerant flows into the second economizer part 42; at last, through the third throttling device 63, the liquid refrigerant flows into the evaporator 30.

[0100] Through the first throttling device 61, the gas flash evaporated from the first economizer gas outlet 51 is guided into the first gas-injection inlet 2; through the second throttling device 62, the gas flash evaporated from the second economizer gas outlet 52 is guided into the second gas-injection inlet 9.

[0101] If the multi-stage centrifugal compressor is a four-stage compressor and three gas-injection inlets are required, the first gas-injection inlet 2, the second gas-injection inlet 9 and the third gas-injection inlet 11 corresponding to said multi-stage centrifugal compressor are selected as the gas-injection inlets.

[0102] Accordingly, three economizers need to be provided in the air conditioning unit. The economizers may be three independent vessels; alternatively, the economizer may be embodied as the three economizer parts of one independent economizer partitioned by the baffles 81. Firstly, through the first throttling device 61, the liquid refrigerant from the condenser 20 flows into the first economizer part 41; secondly, through the second throttling device 62, the liquid refrigerant flows into the second economizer part 42; thirdly, through the third throttling device 63, the liquid refrigerant flows into the third economizer part; finally, through the fourth throttling device, the liquid refrigerant flows into the evaporator 30.

[0103] Through the first throttling device 61, the gas flash evaporated from the first economizer gas outlet 51 is guided into the first gas-injection inlet 2; through the second throttling device 62, the gas flash evaporated from the second economizer gas outlet 52 is guided into the second gas-injection inlet 9; and through the third throttling device 63, the gas flash evaporated from the third economizer gas outlet is guided into the third gas-injection inlet 11.

[0104] In conclusion, if the number of the stages of the multi-stage centrifugal compressor is larger than four, an intermediate gas injection may be provided according to the method of arranging the gas-injection inlets above, so as to realize the objectives of energy saving and improving the efficiency. The method of arranging the gas-injection inlets above is applicable to the multi-stage centrifugal compressor with nine stages at most; even if only two stages of impellers are applied in the multi-stage centrifugal compressor, the intermediate gas injection may also be provided according to

the method of arranging the gas-injection inlets above, which will not be described repeatedly here.

[0105] What described above are several embodiments of the present invention, and they are specific and in details, but not intended to limit the scope of the present invention. It will be understood by those skilled in the art that various modifications and improvements can be made without departing from the conception of the present invention, and all these modifications and improvements are within the scope of the present invention.

What is claimed is:

1. A multi-stage centrifugal compressor, comprising a power portion and an impeller portion, wherein,

the power portion comprises a motor having a shaft; the shaft of the motor comprises a first end and a second end; the impeller portion comprises N impellers, wherein N is equal to or more than 2 and less than 10;

when N is an even, number of the impellers on the first end of the shaft is equal to number of the impellers on the second end of the shaft;

when N is an odd, the number of the impellers on the first end of the shaft is one more than the number of the impellers on the second end of the shaft;

a first stage impeller farthest away from the motor is arranged at the first end of the shaft;

other impellers at the first end of the shaft are arranged in an ascending order;

an Nth stage impeller nearest to the motor is arranged at the second end of the shaft; other impellers at the second end of the shaft are arranged in a descending order;

a gas outlet of the impellers arranged at the first end of the shaft communicates with a gas inlet of the impellers arranged at the second end of the shaft through a connection pipeline;

wherein, the gas outlet of the impellers arranged at the first end of the shaft is same gas outlet of the impeller nearest to the motor and arranged at the first end of the shaft; the gas outlet of the impellers arranged at the second end of the shaft is same gas outlet of the impeller farthest to the motor and arranged at the second end of the shaft.

2. The multi-stage centrifugal compressor according to claim 1, wherein, a connection pipeline is disposed outside the multi-stage centrifugal compressor or inside a casting of the multi-stage centrifugal compressor.

3. The multi-stage centrifugal compressor according to claim 1, wherein, except the first stage impeller, gas-injection inlets are provided at inlets of other impellers, including a first gas-injection inlet provided at the inlet of the second stage impeller, . . . , and an (N-1)th gas-injection inlet provided at the Nth stage impeller.

4. The multi-stage centrifugal compressor according to claim 1, wherein, the centrifugal compressor further comprises at least two bearings; at least one bearing is sleeved on the first end of the shaft and at least one bearing is sleeved on the second end of the shaft.

5. The multi-stage centrifugal compressor according to claim 4, wherein, the bearings are embodied as a roll bearing, slide bearing or magnetic floating bearing.

6. An air conditioning unit, comprising an evaporator and a condenser, wherein, the air conditioning unit further comprises the multi-stage centrifugal compressor as defined in claim 1.

7. The air conditioning unit according to claim 6, wherein, a connection pipeline is disposed outside the multi-stage centrifugal compressor or inside a casting of the multi-stage centrifugal compressor.

8. The air conditioning unit according to claim 6, wherein, the centrifugal compressor further comprises at least two bearings; at least one bearing is sleeved on the first end of the shaft and at least one bearing is sleeved on the second end of the shaft.

9. The air conditioning unit according to claim 6, wherein, the connection pipeline, which is disposed between the gas outlet of the impellers arranged at the first end of the shaft and the gas inlet of the impellers arranged at the second end of the shaft, is arranged inside the evaporator or inside the condenser.

10. The air conditioning unit according to claim 7, wherein, the connection pipeline, which is disposed between the gas outlet of the impellers arranged at the first end of the shaft and the gas inlet of the impellers arranged at the second end of the shaft, is arranged inside the evaporator or inside the condenser.

11. The air conditioning unit according to claim 8, wherein, the connection pipeline, which is disposed between the gas outlet of the impellers arranged at the first end of the shaft and the gas inlet of the impellers arranged at the second end of the shaft, is arranged inside the evaporator or inside the condenser.

12. The air conditioning unit according to claim 9, further comprising an economizer;

other impellers except the first stage impeller are each provided with a gas-injection inlet;

gas flash evaporated from the economizer is guided into the gas-injection inlet of the multi-stage centrifugal compressor.

13. The air conditioning unit according to claim 10, further comprising an economizer;

other impellers except the first stage impeller are each provided with a gas-injection inlet;

gas flash evaporated from the economizer is guided into the gas-injection inlet of the multi-stage centrifugal compressor.

14. The air conditioning unit according to claim 11, further comprising an economizer;

other impellers except the first stage impeller are each provided with a gas-injection inlet;

gas flash evaporated from the economizer is guided into the gas-injection inlet of the multi-stage centrifugal compressor.

15. The air conditioning unit according to claim 12, wherein, the gas flash evaporated from the economizer is guided into an (N-1)th gas-injection inlet preferably.

16. The air conditioning unit according to claim 12, wherein, the air conditioning unit comprises N-1 economizers corresponding to N-1 gas-injection inlets;

each economizer comprises an economizer inlet and an economizer outlet, and further comprises an economizer gas outlet in communication with the corresponding gas-injection inlet.

17. The air conditioning unit according to claim 12, wherein, the air conditioning unit comprises only one economizer; the economizer is partitioned into several independent economizer parts, number of the economizer parts is the same as the number of the gas-injection inlets;

each economizer part comprises an economizer inlet and an economizer outlet, and further comprises an economizer gas outlet in communication with the corresponding gas-injection inlet.

18. The air conditioning unit according to claim **13**, wherein, the air conditioning unit comprises only one economizer; the economizer is partitioned into several independent economizer parts, number of the economizer parts is the same as the number of the gas-injection inlets;

each economizer part comprises an economizer inlet and an economizer outlet, and further comprises an economizer gas outlet in communication with the corresponding gas-injection inlet.

19. The air conditioning unit according to claim **14**, wherein, the air conditioning unit comprises only one economizer; the economizer is partitioned into several independent economizer parts, number of the economizer parts is the same as the number of the gas-injection inlets;

each economizer part comprises an economizer inlet and an economizer outlet, and further comprises an economizer gas outlet in communication with the corresponding gas-injection inlet.

20. The air conditioning unit according to claim **8**, wherein, throttling devices are arranged on the refrigerant connection pipeline of an economizer inlet and arranged at an economizer outlet respectively.

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