The invention sets out a system of interconnected non-reversing heater-chiller modules having a virtual moveable endcap separating select units. The system facilitates the variable operation of heater/chiller modules in a combination of heating/chilling/simultaneous operation modes, or rest modes, in order to adjust to variable building load, mechanical, and environmental conditions.
VIRTUAL MOVEABLE ENDCAP NON-REVERSING HEATER CHILLER SYSTEM

BACKGROUND OF THE INVENTION

0001 1. Field of the Invention

0002 The invention relates to improvements in heating and cooling systems. Particularly, the invention relates to a plurality of modular heater/chiller units which are arranged to provide greater flexibility in meeting heating and cooling demands while at the same time reducing energy consumption.

0003 The present invention utilizes a plurality of heater/chillers which are interconnected and controlled in a manner which allows for optimal utilization of condenser-heat and evaporator cooling during full time heating, full time cooling, and variable simultaneous heating/cooling load applications.

0004 2. Description of the Related Art

0005 In the past, there has been a need to provide coordinated multiple unit chiller/heater structures and systems to provide flexibility in meeting heating/cooling requirements while at the same time reducing energy consumption.


0007 However, although these systems provide a substantial advantage over the prior art, they still suffer from certain shortcomings. For example, the previous virtual moveable endcap systems involved the use of reversing heat pump chillers, with the inherent individual efficiency compromises, drawbacks and reversing problems. Also in some arrangements, the units on each end of the arrangement tended to experience more wear and tear than the center units with a resultant imbalance in the reliability and maintenance of the system as a whole.

0008 It is therefore desirable to provide a virtual moveable endcap heating/cooling system which avoids the efficiency shortcomings of reversing heat pump/chiller systems.

0009 It is desirable to provide a virtual moveable endcap heating/cooling system which allows for even distribution of wear and tear on the individual units.

0010 It is desirable to provide a virtual moveable endcap heating/cooling system which utilizes a ground or water source heat sink for storage and exchange of heat.

0011 It is also desirable to provide a virtual moveable endcap heating/cooling system which allows for full flexibility in utilizing all or one of the individual units, or any combination of units, to variably provide heating, cooling, or a combination of simultaneous heating and cooling, variable depending on changing building load requirements, ambient conditions, mechanical considerations and electrical energy costs.

BRIEF SUMMARY OF THE INVENTION

0012 According to the present invention, there is provided a heating/cooling system comprising a plurality of modular non-reversing heater/chiller units. Each module unit may comprise one or more compressors, a working fluid loop, an evaporator, a condenser, cooling load fluid connections, heating load fluid connections, and virtual moveable endcap connections at each side or alternatively one side of both the cooling load and heating load fluid connections. The connections may most preferably be easily separable and reconnectable, such as compression fittings, or may be more conventional connections such as flanged, screwed, or even welded connections. The virtual moveable endcap connections may each include a valve to isolate flow.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS

0013 FIG. 1 shows modular units with 1 through n heating side and 1 through n cooling side applied to building load, where n=6

0014 FIG. 2 shows modular units with 1 through n cooling side applied to building load and 1 through n heating side sending heat to sink

0015 FIG. 3 shows modular units with 1 through n heating side and 1 through (n-1) cooling side applied to building load, and n cooling side receiving heat from sink

0016 FIG. 4 shows modular unit 1 heating side and 1 through n cooling side applied to building load, and (n-4) through n heating side sending heat to sink

0017 FIG. 5 shows modular units with 1 through n heating side and 1 through n cooling side applied to building load, where unit n+5 is rested

0018 FIG. 6 shows modular units with 1 through n heating side and 1 through n cooling side applied to building load, where unit n+2 is rested

DETAILED DESCRIPTION OF THE INVENTION

0019 Following is a list setting out various elements of the invention as described in the foregoing drawing Figures.

0020 1. Building

0021 2. Building Cooling Heat Exchanger

0022 3. Building Heating Heat Exchanger

0023 4. Modular Non-reversing Chiller Heater

0024 5. Condenser

0025 6. Evaporator

0026 7. Working Fluid Loop

0027 8. Heat Sink/Source

0028 9. Heat Sink/Source Comingled Heat Exchanger


0030 11. Heat Sink/Source Cold Side Heat Exchanger

0031 12. Evaporator Control/Isolation Valve

0032 13. Condenser Control/Isolation Valve

0033 14. Building Conditioning Fluid Conduit

0034 15. Virtual Moveable Endcap Valve

0035 16. Comingled Heat Sink/Source Hot Side Isolation Valve

0036 17. Comingled Heat Sink/Source Cold Side Isolation Valve

0037 18. Heat Sink/Source Local Hot Side Heat Exchanger Valve

0038 19. Heat Sink/Source Local Cold Side Heat Exchanger Valve

0039 There are four main states or modes for each of the individual modular units, as set out below:

<table>
<thead>
<tr>
<th>Evaporator Operation</th>
<th>Condenser Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>State 1 cool building space</td>
<td>reject heat to sink/source</td>
</tr>
<tr>
<td>State 2 cool building space</td>
<td>utilize heat in building space</td>
</tr>
<tr>
<td>State 3 receiving heat from sink/source</td>
<td>utilize heat in building space</td>
</tr>
<tr>
<td>State 4 off (rest or repair)</td>
<td>off (rest or repair)</td>
</tr>
</tbody>
</table>
The number of permutations and combinations of these four useful states of each modular unit, when combined into a system of modular units can be mathematically determined.

Where \( n \) = number of individual modules in a system, each module being numbered 1 through \( n \). Then the total number of possible permutations and combinations of the various arrangements of cooling/heating/heat sink source/off operation modes for the entire system is given by the relation:

Number of possible modes = \( n^4 \).

There may be practical considerations which would tend to reduce the maximum number of possible mathematical modes.

The possibility of utilizing the condensers and evaporators of each modular unit selectively in different modes, provides for flexibility heretofore not seen in heating/cooling systems.

This flexibility allows the operator to continually select the most efficient operating mode for even rapidly changing building load/ambient/electricity cost conditions.

Another major advantage of the present invention is that any or all of the individual units may be rested as necessary. The operating load factor on the mechanical equipment of each unit can be precisely monitored and balanced. End units, middle units, or any combination can be selectively rested. This will result statistically in the longest life span possible for the entire system without the need for shutdown due to failure of an overworked unit. Meanwhile, should a failure occur in any of the units, that unit may be removed from service while still maintaining a remarkable level of performance and flexibility in the system as a whole utilizing the remaining units.

Another advantage of the present invention is that all modular units are non-reversing, with the resultant inherent efficiencies available in non-reversing chillers. In contrast, prior art reversing heat pumps suffer from inherent operating efficiency drawbacks, owing in part to the fact that elements of the equipment must be compromised, due to the reversing nature of the machine.

Referring now to the drawings:

In FIG. 1 it is shown where units 1-n (a being 6 in this embodiment) are utilized where all heat for all condensers 5 is being utilized in the building to be conditioned, while all cooling capacity from all evaporators 6 is simultaneously being utilized in the building. No heat is exchanged in the heat sink/source.

It is to be noted that modular element 1 in the drawings shows details including the evaporator/condenser isolation valves, and flow arrows, which point at the counter flow nature of the heat exchangers in one embodiment. It is to be noted that these details are included in 2-n modular elements, but are omitted from the drawing figures for the sake of clarity in the figures.

In FIG. 2, it is shown where all heat from all condensers 1-n is being rejected to the heat sink/source, while all cooling capacity from all evaporators 1-n is being utilized in the building.

In FIG. 3, it is shown where all heat from all condensers 1-n is being utilized in the buildings, all cooling capacity from all evaporators 1, 2, 3, 4, and 5 is being utilized in the building, while heat is exchanged between evaporator number 6 and the heat sink/source.

In FIG. 4, it is shown where heat from condenser number 1 is being utilized in the building, heat from condenser numbers 2-6 is being rejected to the heat sink/source, and all cooling capacity from evaporators numbers 1-6 is being utilized in the building.

In FIG. 5, it is shown where modular unit 6 is taken out of service, while meanwhile all heat from condensers numbers 1-5 is utilized in the buildings, and all cooling capacity from evaporators number 1-5 is utilized in the building. It must be noted that even with the unit 6 out of service a particular number of remaining condensers numbers 1-5 may be selected to either provide heat to the building or reject heat to the sink/source, and a particular number of remaining evaporator numbers 1-5 may be selected, independent from the utilization of the condensers, to either provide cooling to the building or exchange heat with the sink/source.

In FIG. 6 it is shown where modular unit 3 is taken out of service while meanwhile all heat from condenser numbers 1, 2, 4, 5, and 6 is utilized in the building, and all cooling capacity from evaporators numbered 1, 2, 4, 5, and 6 is utilized in the building.

In FIG. 7 it is shown where modular units 2 and 5 are taken out of service. Meanwhile all heat from condensers 1, 3, 4, is utilized in the building, all heat from condenser number 6 is rejected to the heat sink/source, all cooling capacity from evaporator numbers 1 and 3 are utilized in the building, and heat is exchanged between evaporator numbers 4 and 6 with the heat sink/source.

The building/heat sink/source conditions which would prompt such an operating arrangement such as set out in FIG. 7 is not described for this embodiment. This combination is set out merely to illustrate the flexibility in the present system.

In the foregoing examples, it may be that cominged heat sink/source hot side isolations valves 16 are open, cominged heat sink/source cold side isolation valves 17 are open, heat sink/source local hot side heat exchange valves 18 are closed, and heat sink/source local cold side heat exchange valves 19 are closed. This valving arrangement could cause cominged of building conditioning fluid, and eventual heat exchange at heat sink/source cominged heat exchanger 9.

In one embodiment, heat sink/source hot side heat exchanger 10 and associated valves 18 and heat sink/source cold side heat exchanger 11 and associated valves 19 are provided at different locations in the heat sink/source. In this manner, the heat added and/or removed from the heat sink/source can be concentrated and adjusted locally depending on the requirements and capacities of the entire heat sink/source. In this embodiment the building conditioning fluid can be kept separate, hot side and cold side, as it is sent into the heat sink/source.

It is contemplated that frequently, however, the building conditioning fluid will be cominged and sent to/from the heat sink/source in a cominged manner.

In this invention, in the preferred embodiment, there is only a single “refrigerant lift,” which allows for increased efficiencies of up to 30% and more over systems which do not operate with a single lift.

The virtual moveable endcap valves may be omitted between constant simultaneous load modules, in certain embodiments, in the event equipment cost savings are desired.

In certain embodiments, the modular elements have a single point electrical connection for valves and controllers, and may have a disconnecting circuit breaker for each module.
Modulating valves may be included for built-in head control and for precisely controlling water temperatures.

Built-in heat recovery may result in simultaneous efficiency.

The compressors in the modular system can be run and rested where desired in a manner which results in equalization of their run times.

1. A building space heating and cooling system, comprising:
   a building space to be conditioned,
   a heat sink/source,
   at least two modular non-reversing heater chillers connected in parallel,
   each of said non-reversing heater chillers having a condenser, an evaporator, a condenser control/isolation valve, and an evaporator control/isolation valve,
   a building conditioning fluid conduct containing building conditioning fluid,
   said building conditioning fluid conduct being in heat transfer connection with the evaporators, the condensers, said heat sink/source, a building space cooling side heat exchanger, and a building space heating side heat exchanger,
   virtual moveable endcap valves disposed in said building conditioning fluid conduct to variously isolate or communicate heat transferred out of said condensers and heat transferred into said evaporators with said building conditioning fluid,
   wherein each of said modular non-reversing heater chillers can be selectively operated to send heat transferred from its respective condenser to said building conditioning fluid either to said building space heating side heat exchanger or to said heat sink/source, and to send building conditioning fluid having heat removed from it by said respective evaporator either to said building space cooling side heat exchanger or to said heat sink/source.

2. A building space heating and cooling system, according to claim 1,
   comprising a plurality of modular non-reversing heater chillers numbered 1-n connected in parallel, said modular non-reversing heater chillers having said respective condensers numbered 1-n and said respective evaporators numbered 1-n,
   said respective condensers and evaporators being selectively separable via said virtual moveable endcap valves such that any or all of said condensers 1-n and any or all of said evaporators 1-n may be selectively isolated from said building space heating side heat exchanger and said building space cooling side heat exchanger respectively, and said heat sink/source.

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