A coil system for an outdoor heat exchanger in a HVAC system. The coil system comprises an integrated subcooler coil section positioned between the primary coil section and the expansion valve. A distributor combines the individual refrigerant streams from the coils of the primary coil section into a single refrigerant stream before separating the stream among the different coils of the subcooler section. The subcooler coil section is positioned such that the incoming air stream is directed directly at the subcooler coil section to maximize the difference in temperature between the air stream and the refrigerant within the subcooler section.
OUTDOOR HEAT EXCHANGER COIL

RELATED APPLICATION

FIELD OF THE DISCLOSURE
[0002] The present invention is generally directed to a heat exchanger coil system for a heat exchanger in a HVAC system. Specifically, the present invention is directed to a heat exchanger coil system for facilitating the exchange of heat between a refrigerant stream and an outdoor air stream.

BACKGROUND OF THE DISCLOSURE
[0003] A conventional HVAC system generally comprises a compressor, an expansion valve and at least two heat exchangers. A refrigerant is sent from the compressor through the first heat exchanger to the expansion valve and sent back to the compressor after passing through the second heat exchanger. One of the heat exchangers is typically positioned to exchange heat with an interior air stream, while the other heat exchanger is positioned to exchange heat with an outdoor air stream. Depending on whether the HVAC system is functioning as a cooling system or a heating system, the exterior heat exchanger can function as either a condenser or an evaporator while the interior heat exchanger operates in the opposite capacity.

[0004] The efficiency of the heat exchangers is typically gauged by determining the “temperature approach” of the heat exchanger. The temperature approach is the difference between the inlet temperature of one stream and the outlet temperature of the second stream and is commonly used as an efficiency measurement of the heat exchanger. An efficient heat exchanger has a low temperature approach while an inefficient heat exchanger has a high temperature approach. In a HVAC system, a low temperature approach occurs when the refrigerant output temperature from the heat exchanger is nearly identical to the temperature of the air stream entering the heat exchanger.

[0005] A typical heat exchanger configuration for HVAC systems is a “fin and tube” configuration in which the refrigerant is fed through an elongated tube and the air stream is passed across the tube to cool or heat the refrigerant. The arrangement is effective at providing maximum contact between the refrigerant and the air stream. A challenge for exterior heat exchangers is that adverse weather conditions, such as extremely low temperatures, can cause frost to form on pipes, rob heat from the refrigerant instead of supplying heat and otherwise reduce the efficiency of the heat exchanger and HVAC system as a whole. As such, HVAC systems having exterior fin and tube heat exchangers installed in less temperate climates are often less efficient when the exterior weather conditions are less than ideal.

[0006] A common feature of fin and tube heat exchangers used in HVAC systems is having a plurality of individual tube coils instead of a single elongated tube coil. The refrigerant input is typically split evenly by a distributor into amongst the coils. The refrigerant must be evenly distributed and constantly supplied to each coil to maximize the heat transfer and efficiency of the heat exchanger. However, in cooler temperatures, unevenly distributing the refrigerant between the different coils is often difficult as the increased viscosity of the refrigerant and other factors cause the refrigerant to be unevenly distributed through the heat exchanger.

[0007] The reduced efficiency of exterior heat exchangers in less temperate climates reduces the overall efficiency of HVAC systems installed in those climates. As energy efficiency is a primary concern with HVAC systems, the increased energy required by the HVAC system to overcome the inefficiencies caused by poor performance of the exterior heat exchanger is a significant concern. As such a need exists to improve the efficiency of exterior shell and tube heat exchangers in less temperate climates.

SUMMARY OF THE DISCLOSURE
[0008] The present invention is directed to a coil system for an outdoor heat exchanger in a HVAC system. The coil system comprises an integrated subcooler coil section positioned between the primary coil section and the expansion valve. A distributor can be positioned between the primary coil section and the subcooler coil section to combine the individual refrigerant streams from the coils of the primary coil section into a single refrigerant stream before separating the stream among the different coils of the subcooler section. The subcooler coil section can be positioned such that the incoming air stream is directed directly at the subcooler coil section to maximize the difference in temperature between the air stream and the refrigerant within the subcooler section.

[0009] In a cooling mode where the coil system acts a condenser, the condensed liquid refrigerant is drawn from the primary coil section as the refrigerant condenses and is fed into the subcooler. Continually removing the condensed liquid refrigerant improves the efficiency of the heat exchanger and overall HVAC system by dropping the condensing temperature in the primary section and lowering the amount of energy required by the compressor supplying the high pressure, gaseous refrigerant to the coil system. Similarly, positioning the subcooler such that the incoming air stream is directed at the subcooler maximizes the temperature difference between the air stream and the refrigerant stream, which facilitates further lowering of the refrigerant stream temperature to nearly the temperature of the incoming air stream. The lower refrigerant temperature leaving the coil system boosts the evaporative capacity of the refrigerant stream thereby improving the efficiency of the evaporator and the overall HVAC system.

[0010] In a heating mode where the coil system acts an evaporator, the subcooler section is operated at an intermediate pressure and an intermediate temperature between the evaporator temperature and the condenser temperature. The operating conditions allow the subcooler section to still draw heat from the air stream. The smaller temperature difference between the subcooler and the air stream can also prevent the subcooler coils from frosting too quickly. This feature is particularly advantageous in wet and cold weather conditions.

[0011] According to an embodiment of the present invention, the coil system can further comprise at least one Venturi distributor for distributing the fluid among coils of the primary section. Each Venturi distributor is oriented in a vertical-up or vertical-down orientation rather than at a non-vertical angle. Surprisingly, orienting the Venturi distributor in a vertical orientation avoids disruptions in the flow of refrigerant to and from the various coils of the primary coil section that can occur when the Venturi distributor is oriented in a non-vertical
orientation. Similarly, orienting the Venturi distributor in a vertical orientation prevents uneven distribution of the refrigerant amongst the coils that can occur when the Venturi distributor is orientated in a non-vertical orientation.

[0012] A method for exchanging heat between a liquid refrigerant and an outdoor air stream, according to the present invention, can comprise supplying a refrigerant stream to an outdoor heat exchanger having a primary coil section and subcooler coil section, each having a plurality of coils. The method can further comprise dividing the high temperature stream into a plurality of sub-streams that are each fed into a primary coil of the primary coil section. An outdoor air stream is passed across each of the primary coil sections to exchange a first quantity of heat with the subdivided refrigerant stream. The plurality of sub-streams can then be recombined into a single refrigerant before being redistributed among the plurality of subcooler coils of the subcooler coil section. The outdoor air stream is passed across each of the subcooler coil sections to exchange a second quantity of heat with the subdivided refrigerant stream. The subdivided refrigerant stream is then recombined into a single refrigerant stream.

[0013] The above summary of the various representative embodiments of the invention are not intended to describe each illustrated embodiment or every implementation of the invention. Rather, the embodiments are chosen to enable one skilled in the art to appreciate and understand the principles and practices of the invention. The figures in the detailed description that follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a representative process flow diagram of a prior art HVAC system.

[0015] FIG. 2 is a schematic side view of a heat exchanger coil according to an embodiment of the present invention.

[0016] FIG. 3 is a partial schematic side view of a heat exchanger coil of FIG. 1.

[0017] FIG. 4 is a perspective view of a heat exchanger coil according to an embodiment of the present invention.

[0018] FIG. 5 is a side view of a heat exchanger utilizing a heat exchanger coil according to a representative embodiment of the present invention.

[0019] FIG. 6 is a partially hidden side view of the heat exchanger of FIG. 5 having exterior fins removed.

[0020] FIG. 7 is a partial, perspective side view of the heat exchanger of FIG. 5.

[0021] FIG. 8 is a partially hidden side view of the heat exchanger of FIG. 5 having distributor assemblies and piping removed.

[0022] FIG. 9 is a side view of the heat exchanger of FIG. 5.

[0023] While the invention is amenable to various modifications and alternative forms, specific thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the invention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0024] As shown in FIG. 1, a HVAC system 2 for use with the present invention generally comprises a compressor 4, a first heat exchanger 6, an expansion valve 8 and a second heat exchanger 10. A refrigerant stream is fed through the compressor 4 to the first heat exchanger 6, where a first air stream is passed across the refrigerant stream to exchange a first quantity of heat with the refrigerant stream. The refrigerant stream is then fed through the expansion valve 8 and into the second heat exchanger 10 where a second air stream is passed across the refrigerant stream to exchange a second quantity of heat with the refrigerant stream. In a cooling mode for cooling the interior of the building, the first air stream is typically an outdoor air stream used to cool the refrigerant stream, while the second air stream is an indoor air stream cooled by the refrigerant stream. In a heating mode, the outdoor air stream is effectively the second air stream that supplies heat to refrigerant stream, while the indoor air stream is effectively the first air stream drawing heat from the refrigerant stream. For the purposes of this disclosure, an outdoor air stream is an air stream originating from and supplied back to the exterior of the building while an indoor air stream is an air stream from and supplied back to the interior of the building.

[0025] As shown in FIG. 2-4, a heat exchanger 20 for exchanging a quantity of heat with an outdoor air stream, according to an embodiment of the present invention, “in cooling mode,” comprises an inlet 22, an outlet 25, a primary coil section 24 having a plurality of primary coils 26 and a subcooler coil section 28 having a plurality of subcooler coils 30. The heat exchanger 20 further comprises a first header assembly 32 positioned between the inlet 22 and the primary coil section 24, a second header assembly 34 positioned between the primary coil section 24 and the subcooler coil section 28; a third header assembly 36 positioned between the subcooler coil section 28 and the outlet 25.

[0026] As shown in FIGS. 2-3, according to an embodiment of the present invention, the plurality of primary coils 26 can be subdivided into a top section 38 and a bottom section 40. The bottom section 40 can be positioned relative to the subcooler coil section 28 such that an air stream fed through the heat exchanger 20 will pass across the subcooler coils 30 before intersecting the primary coils 26 of the bottom section 40. In sizing the subcooler coil section 28, the mode of operation of heat exchanger 20 will determine the relative size of the subcooler coil section 28 relative to the primary coils section 24. For example, in a cooling mode, subcooler coil section 28 is sized based upon pressure drop and flow rate with the desired goal of having as close an approach temperature as possible relative to the refrigerant stream and outdoor air stream. Generally, an approach temperature of at least 5°F is desired, more preferably about 3-4°F and even more preferably, about 2.5°F. In a heating mode, physical size of the subcooler coil section 28 can be a design factor based upon potential condensation on the exterior of the subcooler coils 30. According to one representative embodiment of the present invention, the primary coil section 24 can comprise twenty three parallel primary coils 26 with eleven primary coils 26 in the top section 38 and twelve primary coils 26 in the bottom section 40. In this configuration, the primary coils 26 of the top section 38 comprise 4-row coils while the primary coils 26 of the bottom section 40 comprise 3-row coils. According to one representative embodiment of the present invention, four subcooler coils 30 can make up the subcooler coil section 28.

[0027] In cooling operation, a refrigerant stream is fed into the inlet 22 and divided into a plurality of sub-streams by the first header assembly 32. Each refrigerant sub-stream is fed
into one of the primary coils 26 and an outdoor air stream is passed across the primary coils 26. In a cooling configuration, the refrigerant stream is supplied from the compressor 4 as a high pressure, high temperature gaseous stream that is cooled by the outdoor air stream. As the outdoor air stream intersects the primary coils 26 a portion of each refrigerant sub-stream condenses and exits the primary coils 26 into the second distributor assembly 34 where the sub-streams are recombined into a single refrigerant stream. In a heating configuration, the refrigerant stream is supplied from the expansion valve 8 as a cooled refrigerant stream that is heated by the outdoor air stream. The heated refrigerant sub-streams are similarly recovered in the second distributor assembly 34. In either operating mode, the recombined refrigerant stream is then separated again amongst the subcooler coils 30 for additional heat transfer. The outdoor air stream is passed across the subcooler coils 30 to either further cool the condensed refrigerant or supply additional heat in a heating configuration. In cooling, the subdivided refrigerant stream exiting the subcooler 28 is recombined into a single refrigerant stream in the third distributor assembly 36 before exiting the heat exchanger 20 through the outlet 25.

According to an embodiment of the present invention, at least one of the distributor assemblies 32, 34, 36 can comprise at least one Venturi distributor 42. In this configuration, the Venturi distributor 42 is oriented in a vertical orientation to avoid uneven distribution of the refrigerant stream that occurs when the Venturi distributor 42 is oriented in a non-vertical orientation.

Referring specifically to FIGS. 5-9, a heat exchanger 50 according to the present invention can comprise a frame 52 to which individual fins 53 and heat exchanger coil 54 is mounted. As seen in FIG. 5, fins 52 can be so closely spaced so as to provide a face side 56 with a substantially solid looking appearance. With fins 52 removed, heat exchanger coil 54 is readily visible including subcooler coil section 28 and top section 38.

While the invention is amenable to various modifications and alternative forms, specific examples thereof have been shown by way of example in the drawings and described in detail. It is understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A heat exchanger for transferring heat between a refrigerant stream and an outdoor air stream in an HVAC system, comprising:
   a plurality of primary coils defining a first primary coil section and a second primary coil section, each primary coil receiving a portion of a primary refrigerant stream, the primary coils arranged in an outdoor airstream path such that the portions of the primary refrigerant stream exchange a first quantity of heat with the outdoor airstream path;
   a plurality of subcooler coils defining a subcooler coil section having a front face mount orientation with respect to the plurality of primary coils, each subcooler coil receiving a portion of a subcooler refrigerant stream, the subcooler coils arranged such that the portions of subcooler refrigerant stream exchange a second quantity of heat with the outdoor airstream path; and
   a subcooler distributor assembly fluidly coupled between the primary coil section and the subcooler coil section, wherein the subcooler distributor assembly receives the portions of primary refrigerant stream from each of the plurality of primary coils and combines the plurality of primary refrigerant streams into a subcooler refrigerant stream, wherein the subcooler refrigerant stream is separated into the portions of subcooler refrigerant stream, each subcooler refrigerant stream being directed into one of the subcooler coils.

2. The heat exchanger of claim 1, wherein the first primary coil section defines a bottom primary coil section and the second primary coil section defines a top primary coil section.

3. The heat exchanger of claim 1, wherein the front face mount orientation of the subcooler coil section positions the subcooler coil section in front of the bottom primary coil section, such that an outdoor air stream passes over the subcooler coils before contacting the primary coils of the bottom primary coil section.

4. The heat exchanger of claim 1, wherein the subcooler distributor assembly comprises at least one Venturi distributor in a vertical orientation, said vertical orientation promoting even distribution of the portions of subcooler refrigerant steam into each subcooler coil.

5. The heat exchanger of claim 1, wherein the first primary coil section includes at least as many primary coils as the second primary coil section, and wherein the subcooler coil section has a front face mount orientation with respect to the first primary coil section.

6. The heat exchanger of claim 1, wherein the second primary coil section includes at least as many primary coils as the first primary coil section, and wherein the subcooler coil section has a front face mount orientation with respect to the first primary coil section.

7. The heat exchanger of claim 1, further comprising a first distributor assembly positioned between a refrigerant inlet and the plurality of primary coils, the first distributor assembly receiving a refrigerant inlet stream, the first distributor separating the refrigerant stream into the portions of primary refrigerant stream and directing each portion of primary refrigerant stream into the corresponding primary coil.

8. The heat exchanger of claim 7, further comprising a second distributor assembly positioned between the subcooler coil section and a refrigerant outlet, the second distributor assembly receiving the portions of subcooler refrigerant stream and combining the portions of subcooler refrigerant stream into a refrigerant outlet stream.

9. The heat exchanger of claim 8, wherein the first distributor assembly, the second distributor assembly and the subcooler distributor assembly each comprise at least one venturi distributor in a vertical orientation.

10. A method for transferring heat between a refrigerant stream and an outdoor air stream in an HVAC system, comprising:
   separating a refrigerant stream into a plurality of primary coil streams, each primary coil stream being directed through a corresponding one of a plurality of primary coils positioned so as expose each primary coil to an outdoor air stream, wherein a first quantity of heat is transferred between each primary coil stream and the outdoor air stream;
   collecting a portion of the plurality of primary coil streams exiting from the primary coils,
combining the portion of the plurality of primary coils stream into a subcooler coil stream;
separating the subcooler coil stream into a plurality of portions of subcooler coil stream; and
feeding each portion of subcooler coil stream through a corresponding one of a plurality of subcooler coils, each subcooler coil positioned to expose each subcooler coil to the outdoor air stream, wherein a second quantity of heat is transferred between each portion of subcooler coil stream and the outdoor air stream.

11. The method of claim 10, further comprising:
arranging the plurality of primary coils into a first primary coil section and a second primary coil section, wherein the portion of the plurality of primary coils streams is collected from the first primary coil section.

12. The method of claim 11, further comprising:
arranging the plurality of subcooler coil sections into a subcooler coil section; and
mounting the subcooler coil section to the first primary coil section such that the subcooler coil section has a front face mount orientation with respect to the outdoor air stream.

13. The method of claim 12, wherein arranging the plurality of primary coils into the first primary coil section and the second primary coil section, further comprises:
including at least as many primary coils in the first primary coil section as are included in the second primary coil section.

14. The method of claim 12, wherein arranging the plurality of primary coils into the first primary coil section and the second primary coil section, further comprises:
including at least as many primary coils in the second primary coil section as are included in the first primary coil section.

15. The method of claim 10, wherein collecting a portion of the plurality of primary coil streams exiting from the primary coils, further comprises:
collecting a condensed portion of the plurality of primary coil streams exiting from the primary coils.

16. The method of claim 10, wherein combining the portion of the plurality of primary coils stream into a subcooler coil stream, further comprises:
using a vertically oriented venturi distributor to combine the portions of the plurality of primary coils stream into the subcooler coil stream.

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