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Bussjager et al.

[11] **3,866,439**

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[54] **EVAPORATOR WITH INTERTWINED CIRCUITS**

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[52] **U.S. Cl.** **62/504,** 62/524

[51] **Int. Cl.** **F25b 39/02**

[58] **Field of Search** 62/199, 200, 504, 524, 62/525, 160, 324

[56] **References Cited**

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2,669,099	2/1954	Mallcoff	62/525
2,806,674	9/1957	Biehn	62/160
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Primary Examiner—Meyer Perlin

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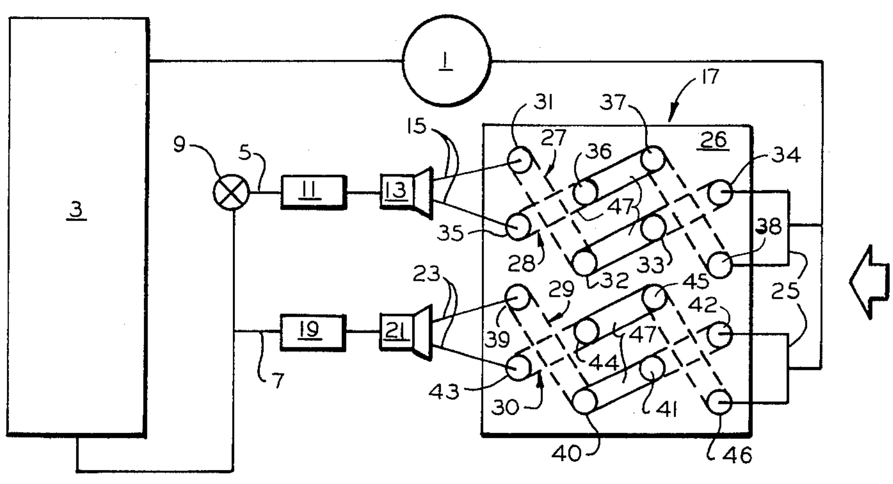
[57] **ABSTRACT**

A refrigerant evaporator having a plurality of intertwined refrigerant circuits which are connectable in alternative groups to refrigerant distributors of a refrigeration system. Under low load conditions, flow through one or more distributors is stopped to remove from service the circuits connected to those distributors and to present to the external heat exchange medium passing over the evaporator refrigerant-carrying circuits selected according to the nature of the circuit-distributor connections.

5 Claims, 2 Drawing Figures



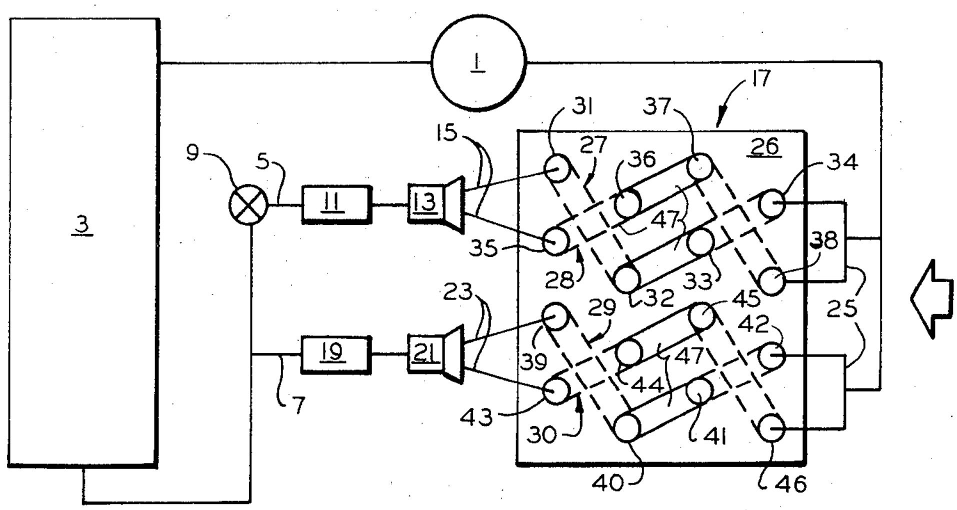

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FIG. 1

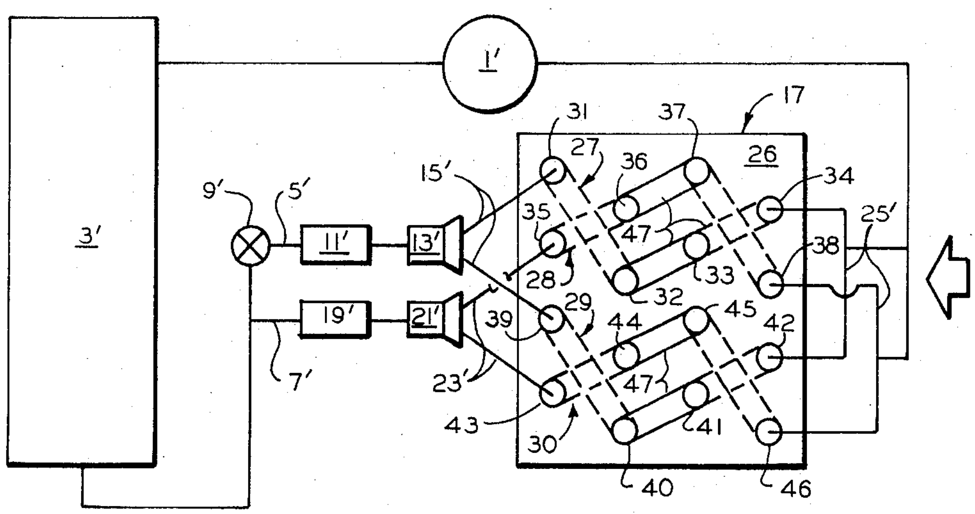
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FIG. 2

EVAPORATOR WITH INTERTWINED CIRCUITS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to refrigeration systems generally, and in particular to evaporators used in such systems. More specifically, the present invention relates to variable capacity, multi-circuit refrigerant evaporators adapted for use in refrigeration systems having a plurality of distributors for distributing refrigerant to the various circuits.

2. Description of the Prior Art

Compression refrigeration systems generally comprise a compressor, a condenser, an expansion device and an evaporator connected by appropriate refrigerant lines to form a refrigeration circuit. Refrigerant vapor is compressed by the compressor and fed to the condenser where it releases heat, condenses, and flows through a liquid line to an expansion device. The pressure of the refrigerant is reduced as it passes through the expansion device, and it enters the evaporator. The refrigerant in the evaporator absorbs ambient heat and vaporizes, and is discharged into the suction line leading to the compressor.

In order to improve the flow characteristics of refrigerant passing through the evaporator, and in order to make fuller use of the heat exchange surfaces (such as parallel, planar heat exchange fins) of the evaporator, it is a common expedient to direct refrigerant through the evaporator via a plurality of refrigerant circuits or coils. Each circuit generally comprises a plurality of refrigerant tubes which run transverse to the fin structure of the heat exchanger, with the ends of appropriate tubes in each circuit being connected by curved tubes or return bends. Refrigerant flowing through a circuit makes several passes through the evaporator, enabling it to absorb a significant amount of heat.

Refrigeration evaporators are frequently used to cool an ambient heat exchange medium such as air, and it is common to force the air or other heat exchange medium across the evaporator coils to enhance the heat transfer at the heat exchange surfaces. It is conventional to run each circuit across the full dimensions of the evaporator transverse to the direction of flow of the external heat exchange medium to increase the effect of the medium. In order to equalize the air flow, and hence the air load, on each of the circuits, it has been found advantageous to intertwine such circuits in the evaporator. By this expedient, corresponding portions of each circuit are exposed to the flow of the external heat exchange medium at points of common temperature. The foregoing is taught in U.S. Pat. Nos. 2,806,674 and 3,142,970.

Refrigerant evaporators of the foregoing types are frequently used in situations where the loads upon the system may vary, such as in air conditioning systems for commercial and industrial building space. It is common to design the compressors and evaporators used in these air conditioning systems according to the maximum load to which they may be subjected, and it is known in the art to reduce compressor capacity under low load conditions and to make a corresponding reduction in the evaporator surface in service. The effects of reducing the evaporator surface under the latter conditions are to reduce the evaporator temperature to a useful level for air conditioning and to maintain a sufficient rate of refrigerant flow for proper oil return to the compressor. By reducing the evaporator surface under low load conditions, the compressor output can be reduced accordingly to prevent excessive pressure in the evaporator. In U.S. Pat. No. 2,332,981, there is disclosed an evaporator having ten rows of finned tubes. Five of the rows are connected to a first distributor and a second group of five rows are connected to a second distributor. Three tubes from each of the two groups of five rows are additionally connected to third and fourth distributors respectively. Valves in the liquid refrigerant lines leading to each of the distributors can selectively be closed to remove portions of the evaporator tube surfaces from service during low load conditions.

One type of air conditioning system used in certain commercial applications comprises a compression refrigeration system having a large capacity commensurate with the space being conditioned, and includes as one component a fan-coil unit. The fan-coil unit includes an evaporator which absorbs heat from air passing therethrough, and a fan moving the air through the evaporator. The fan-coil unit is frequently used in systems having variable capacities as described above, and the evaporator of these units is sometimes provided with a plurality of refrigerant circuits, groups of which are supplied with refrigerant from distributors connected in turn to expansion devices. The refrigerant lines leading to the distributors include valves which can be adjusted to close groups of circuits passing through the unit to thereby reduce the capacity of the evaporator. (Alternatively, each line can be supplied with refrigerant by a separate compressor, in which case selected circuits can be closed by shutting down the compressors supplying those circuits.) There are two commonly known types of evaporators adapted to have designated refrigerant circuits removed from service under reduced load conditions. They are known in the art as "face split evaporators," and as "row split evaporators." The structure of evaporators incorporating these two forms of "splitting" are different, so that it is necessary to design and manufacture different evaporators for each type of split.

Evaporators designed to be face split include a plurality of refrigerant circuits running back and forth across the length of the unit. Each circuit includes a set of parallel tubes which are often disposed at different positions in the depth of the unit, tubes at each end of the evaporator being connected by return bends to form the circuit. The circuits are arranged one over the other along the height of the unit. (For this discussion, evaporators are considered as having a horizontal length, a height which is perpendicular to the flow of air over the unit and to the length, and a depth which is parallel to the direction of air flow. The flow of the external heat exchange medium is transverse to the area defined by the length and height. It is understood that other shapes and configurations are within the scope of the discussion.) Adjacent groups of the circuits are connected to each of the distributors. Thus for example, the circuits in the upper half of the evaporator can be connected to one distributor and the circuits in the lower half of the evaporator can be connected to a second distributor. Refrigerant from the condenser passes through parallel refrigerant lines and through expansion devices in those lines, and thereafter through the distributors and into the various circuits in the evaporator. Under low load conditions, the compressor of the system operates at partial capacity, and flow through the line to one of the distributors is closed, so that only the upper or lower half of the evaporator coil receives refrigerant. Thus, only about half of the air or other heat exchange medium passing through the evaporator is cooled thereby.

In an evaporator adapted to be row split, the circuits do not run throughout the depth of the evaporator, but rather are confined to forward or rearward portions of the evaporator (the external heat exchange medium passing first through the forward portions and then through the rearward portions of the evaporator). An evaporator of this type could thus comprise a plurality of refrigerant circuits arranged in vertically oriented groups in the forward and rearward halves of the evaporator. Each circuit has an inlet for receiving refrigerant from a distributor and an outlet for discharging refrigerant to a refrigerant vapor header leading to the suction line of the compressor of the system. Air or other external heat exchange medium passes first through the circuits in the forward half of the unit and then through the circuits in the rearward half of the unit, whereby the greatest amount of heat exchange frequently occurs as the medium passes through the first group of circuits. Each group of circuits is supplied with refrigerant by a distributor associated with that group, and means are provided for preventing refrigerant flow to at least one of the distributors under low load conditions, whereby the circuit supplied with refrigerant by that distributor can selectively be put out of service. Unlike a face split evaporator, active circuits are presented to the flow of external heat exchange medium across the full evaporator area transverse to the flow even when a distributor or compressor is not in service. Although more effective heat transfer is achieved at partial load conditions with a conventional row split evaporator than with a comparable face split evaporator, the face split evaporator is more effective under full load. It is desirable to superheat all refrigerant leaving the evaporator to prevent liquid from passing to the compressor, and this can effectively be done by having the relatively hot external heat exchange medium (e.g., air) pass first over the exit tubes of the evaporator since the temperature differential between the medium and the evaporator tubes decreases as the medium proceeds through the evaporator. It is feasible with the face split evaporator to place the refrigerant discharge tubes of the evaporator at the air-entering side of the evaporator to achieve the desired superheat. However, all of the refrigerant discharge tubes cannot be so arranged with the row split evaporator so that the superheat capability is severely hampered.

A serious drawback of multi-circuit evaporators currently used in face split and row split applications is that different evaporators must be provided for each arrangement. This involves different designs, and different manufacturing processes.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an improved variable capacity evaporator.

Another object of the invention is to provide a variable capacity refrigerant evaporator having a plurality of circuits which can be connected to a plurality of refrigerant distribution means in alternative ways without altering the structure of the various circuits, to effect alternative refrigerant flow paths through the evaporator when the evaporator is operating at partial capacity.

Still another object of the invention is to provide a refrigerant evaporator having a plurality of substantially balanced refrigerant circuits which can be connected to a plurality of refrigerant distributors and which are selectively removable from service under low load conditions.

A further object of the invention is the provision of a variable capacity evaporator wherein the refrigerant discharge tubes are all disposed at the entering side of the external heat exchange medium.

Still another object of the invention is the provision of a refrigeration system incorporating an evaporator having the foregoing features, and refrigerant flow control apparatus for cooperation with such evaporator.

Other objects will be apparent from the description to follow and from the appended claims.

The foregoing objects are achieved by the provision of a refrigerant evaporator which comprises a plurality of intertwined refrigerant circuits which are so arranged that the evaporator can be incorporated in a refrigeration system having a plurality of refrigerant distributors, the distributors being connectable to the circuits in alternative ways to effect alternative refrigerant flow paths through the evaporator. Means are provided for withdrawing selected circuits from service to reduce the capacity of the evaporator under low heat load conditions. Depending on the nature of the connection between the circuits and the distributors, and between the circuits and refrigerant vapor headers, alternative refrigerant-carrying circuits are presented to the external heat exchange medium under low load

Each circuit includes a set of parallel refrigerant tubes running transversely of the parallel planes of heat exchange fins included in the evaporator. These fins advantageously comprise a plurality of heat conductive metal sheets which substantially define the length, height and depth of the evaporator. Curved connecting tubes or return bends join the ends of the parallel tubes at the ends of the evaporator to form the circuits. These circuits run across the length of the evaporator and extend throughout the depth thereof. Each circuit has an inlet which is connectable with a line leading from a refrigerant distributor which receives refrigerant from an expansion device. The inlets of groups of adjacent circuits can be connected to a common distributor of a refrigeration system, there being a distributor provided for supplying refrigerant to each group of circuits. When a refrigerant flow leading to any of the distributors is stopped, the group of circuits receiving refrigerant from that distributor is removed from service. Alternatively, the inlets of each of a group of circuits spaced across the area of the evaporator normal to the flow of the external heat exchange medium can be connected to a common distributor. When the refrigerant flow to any of the distributors is stopped, the capacity of the evaporator is reduced, but refrigerant-carrying circuits remain across the full flow path of the external heat exchange medium. The circuits are connected at their outlet ends to refrigerant vapor headers which are in turn connected to the compressor suction line, the nature of the latter connection depending on the manner in which the distributors are connected to the circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 show in schematic form compression refrigeration system employing an evaporator according to the present invention which is connected to pairs of refrigerant distributors in the systems in alternative manners.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The description to follow relates to an evaporator having a plurality of refrigerant circuits running therethrough and to a refrigeration system incorporating such an evaporator. The evaporator circuits are intertwined, and selected groups of the circuits can be withdrawn from service depending on the manner in which the circuits are connected to distributors supplying refrigerant thereto. For the sake of this description, the evaporator is presumed to have a conventional fin-tube construction in that it comprises a large number of parallel, planar, heat exchange fins through which tubes or other refrigerant conduits extend transverse to the planes of the fins. In the drawings, end views of an evaporator according to the invention are shown. Thus, the portions of the tubes which are visible in the drawings are the ends thereof and the curved connecting tubes or return bends which connect the various parallel tubes together to form the refrigerant circuits. The "depth" of the evaporator, as that term is used herein, refers to the right to left dimension of the evaporator as viewed in the drawings. The "height" of the evaporator is the top to bottom dimension of the evaporator as viewed in the drawings. Similarly, the "length" of the evaporator refers to that dimension extending into the plane of the drawings.

Referring now to the drawings, there is shown in FIG. **1**, a compression refrigeration system including a compressor **1** from which a refrigerant line leads to a condenser **3** having a liquid or discharge line which terminates in parallel refrigerant lines **5** and **7**. Refrigerant flow through line **5** can be controlled through a valve **9** disposed in the line, and an expansion device **11** and a conventional refrigerant distributor **13** are located in series in line **5**. A plurality of parallel refrigerant lines **15** lead from distributor **13** to each of a group of refrigerant circuits running through an evaporator **17**. Similarly, an expansion device **19** and a distributor **21** are disposed in series in refrigerant line **7**, and a group of parallel refrigerant lines **23** lead from distributor **21** to each of a second group of refrigerant circuits running through evaporator **17**. The various refrigerant circuits terminate in refrigerant vapor headers **25** which are in turn connected to the inlet or suction line of compressor **1**. Except for the manner in which the circuits of evaporator **17** in FIG. **2** are connected to the associated refrigerant distributors and refrigerant vapor headers, the refrigeration system of FIG. **2** is identical to that of FIG. **1**, and corresponding elements of the system are shown with like numbers having a prime designation.

With the exception of evaporator **17**, the elements of the two systems can be of any known type and can function in a normally expected manner. Accordingly, compressors **1** and **1′** discharge hot compressed refrigerant vapor to condensers **3** and **3′**. The refrigerant gives up heat to an external heat exchange medium such as air passing over the condenser and condenses to its liquid state. The liquid refrigerant proceeds to parallel lines **5** and **7**, and **5′** and **7′**, and through expansion devices **11** and **19**, and **11′** and **19′**. The expansion devices function to reduce the pressure of refrigerant passing therethrough, and can be of any appropriate type such as thermal expansion valves or capillary tubes. The expanded refrigerant proceeds through distributors **13** and **21**, and **13′** and **21′**. These distributors can be, for example, fabricated from solid materials and have a plurality of refrigerant passages defined therein for distributing the refrigerant to each of the selected refrigerant circuits in evaporator **17**. The passages in each of the distributors are joined with appropriate refrigerant lines leading to the selected refrigerant circuits. Refrigerant passes through the circuits of evaporator **17**, and heat is transferred to the refrigerant from an external heat exchange medium such as air whose direction of movement is parallel to the planes of the fins as indicated by the arrows. The refrigerant vaporizes by virtue of this absorption of heat and, depending on conditions, may be superheated. It is significant that the external heat exchange medium first crosses those evaporator tubes at the discharge side of the evaporator in both arrangements, so that the likelihood of superheating the discharging refrigerant is maximized. The refrigerant vapor is discharged from the evaporator into refrigerant vapor headers **25** and **25′**, and thence into the suction line leading back to compressor **1**.

Evaporator **17** includes a plurality of refrigerant circuits **27–30** running therethrough. Each circuit is made up of parallel tubes extending transversely through fins **26** and running across the length of evaporator **17**. Accordingly, circuit **27** includes parallel tubes **31–34**, circuit **28** includes tubes **35–38**, circuit **29** includes tubes **39–42** and circuit **30** includes parallel tubes **43–46**. The tubes of each circuit are joined by curved tubular connecting members or return bends to form the circuit. These return bends are broadly designated by the numeral **47**. Pairs of refrigerant circuits **27** and **28**, and **29** and **30**, are intertwined. It is important to note that the circuits shown have been depicted in a very simplified form for the sake of the clarity of this description. Evaporator **17** is shown as having four rows of aligned tubes (tubes **36, 32, 44** and **40** constituting one such row, for example). In practice, it could be expected that other row arrangements would be found to be more practical. Furthermore, only one horizontal tube from each circuit is shown in each row. In practice, one could expect to have a plurality of horizontal tubes from each circuit in each row, and the extent of intertwining could be much greater or less than is depicted.

When evaporator **17** is incorporated in a refrigeration system as shown in FIG. **1**, the inlets to the circuits in each of the upper and lower halves of the evaporator are connected to a common distributor. Thus, circuits **27** and **28** are supplied by distributor **13**, and circuits **29** and **30** are supplied by distributor **21**. When the conditions are such that reduced cooling is required, the capacity of compressor **1** is reduced by appropriate means such as by deactivating some of the pistons if the compressor is of the reciprocating type. In coordination with the reduction in the capacity of compressor **1**, valve **9** is closed. This diverts all of the refrigerant flow through line **7**, expansion device **19**, distributor **21** and circuits **29** and **30**. In other words, the upper portion of the evaporator is shut down and the evaporator is "face split."

When evaporator **17** is connected to distributor **13'** and **21'** as illustrated in FIG. **2**, each distributor supplies refrigerant to circuits disposed across the full area of the evaporator transverse the direction of the flow of the external heat exchange medium. Thus, the inlets to circuits **27** and **29** are connected to distributor **13'**, and the inlets to circuits **28** and **30** are connected to distributor **21'**.

When the refrigeration system shown in FIG. **2** is operated under low load conditions and the capacity of compressor **1'** has been reduced, valve **9'** is closed to divert the entire refrigerant flow from condenser **3'** into line **7'**, through expansion device **19'** and into distributor **21'**. The expanded refrigerant is directed by distributor **21'** into lines **23'** which lead to the inlets of circuits **28** and **30.** Since circuits **28** and **30** are spaced from each other, more effective use is made of fins **26** as contrasted both with the arrangement of FIG. **1** (and with conventional row split evaporators) when the systems operate under low load conditions, since there is more fin area associated with each active tube. Moreover, refrigerant-carrying circuits are presented to the external heat exchange medium across the full area of its flow. At full capacity, the arrangement in FIG. **2** provides a greater degree of superheat to refrigerant leaving the evaporator than would a conventional row split evaporator, because the external heat exchange medium crosses the tubes from which refrigerant is discharged from the evaporator when the medium is at its maximum temperature.

Evaporators according to the invention thus enjoy the benefits of intertwined refrigerant circuitry, in particular the equal distribution of loads on each of the circuits. Furthermore, variable capacity evaporators according to the present invention can be connected to refrigerant distributors in a variety of ways, and separate designs are not required for each type of connection. When the evaporator is connected to enable refrigerant-carrying circuits to be presented to the external heat exchange medium across a broad portion of the evaporator, more effective and efficient operation is obtainable than with present row splitting arrangements. Each circuit in evaporators according to the invention takes an equal proportion of the load, so that when some of the circuits are removed from service, the cooling effect of each of the remaining circuits is evenly distributed and is readily predictable.

Although the systems described above provide a set of distributors for supplying refrigerant to groups of evaporator circuits, it is within the scope of the invention to provide separate compressors for each group of circuits. In the latter case, the refrigerant valves can be dispensed with, and selected compressors can be shut down under low load conditions to reduce the evaporator capacity.

Evaporators according to the present invention find numerous applications in various refrigeration systems. They find particular use in direct expansion applications, since there is frequent resort to reducing the number of evaporator circuits in service under low load conditions.

The invention has been described in detail with particular reference to a preferred embodiment thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

We claim:

1. A compression refrigeration system including condenser means, a plurality of parallel refrigerant lines for conveying condensed refrigerant from said condenser means, refrigerant distribution means in each of said parallel refrigerant lines, closing means for selectively closing at least one of said parallel refrigerant lines to refrigerant flow, and an evaporator including a plurality of parallel heat exchange fins and a plurality of intertwined refrigerant circuits running through the evaporator generally transverse to said heat exchange fins, groups of said circuits covering contiguous areas of said evaporator transverse to the direction of flow of external heat exchange medium moving over said evaporator, and said groups of circuits being connected to different ones of said refrigerant distribution means, the group of circuits connected to the distribution means in the refrigerant line including said closing means being removable from service in response to the closing of said closing means to substantially reduce heat exchange between the external heat exchange medium passing through the area covered by said latter group of circuits and the evaporator.

2. A compression refrigeration system including condenser means, a plurality of parallel refrigerant lines for conveying condensed refrigerant from said condenser means, refrigerant distribution means in each of said parallel refrigerant lines, closing means for selectively closing at least one of said parallel refrigerant lines to refrigerant flow, and an evaporator including a plurality of parallel heat exchange fins and a plurality of refrigerant circuits extending through the depth of the evaporator and including connected parallel tubes running generally transverse to said heat exchange fins, groups of said circuits covering in overlapping fashion the area of said evaporator transverse to the flow of external heat exchange medium moving over said evaporator, and being connected to different ones of said distribution means, the group connected to the distribution means in the refrigerant line including said closing means being removable from service in response to the closing of said closing means to substantially reduce heat exchange between the external heat exchange medium and the evaporator.

3. A compression refrigeration system according to claim **2** wherein a plurality of said circuits are intertwined.

4. A compression refrigeration system according to claim **3** wherein the external heat exchange medium enters said evaporator at a particular side thereof, and said refrigerant circuits are arranged to discharge refrigerant from the evaporator at said particular side.

5. A compression refrigeration system according to claim **2** wherein said closing means comprises valve means for selectively closing said one refrigerant line to refrigerant flow.

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