July 4, 1939. T. B. R. PETERS 2,165,004

EVAPORATOR

Filed May 6, 1937 2 Sheets-Sheet 1

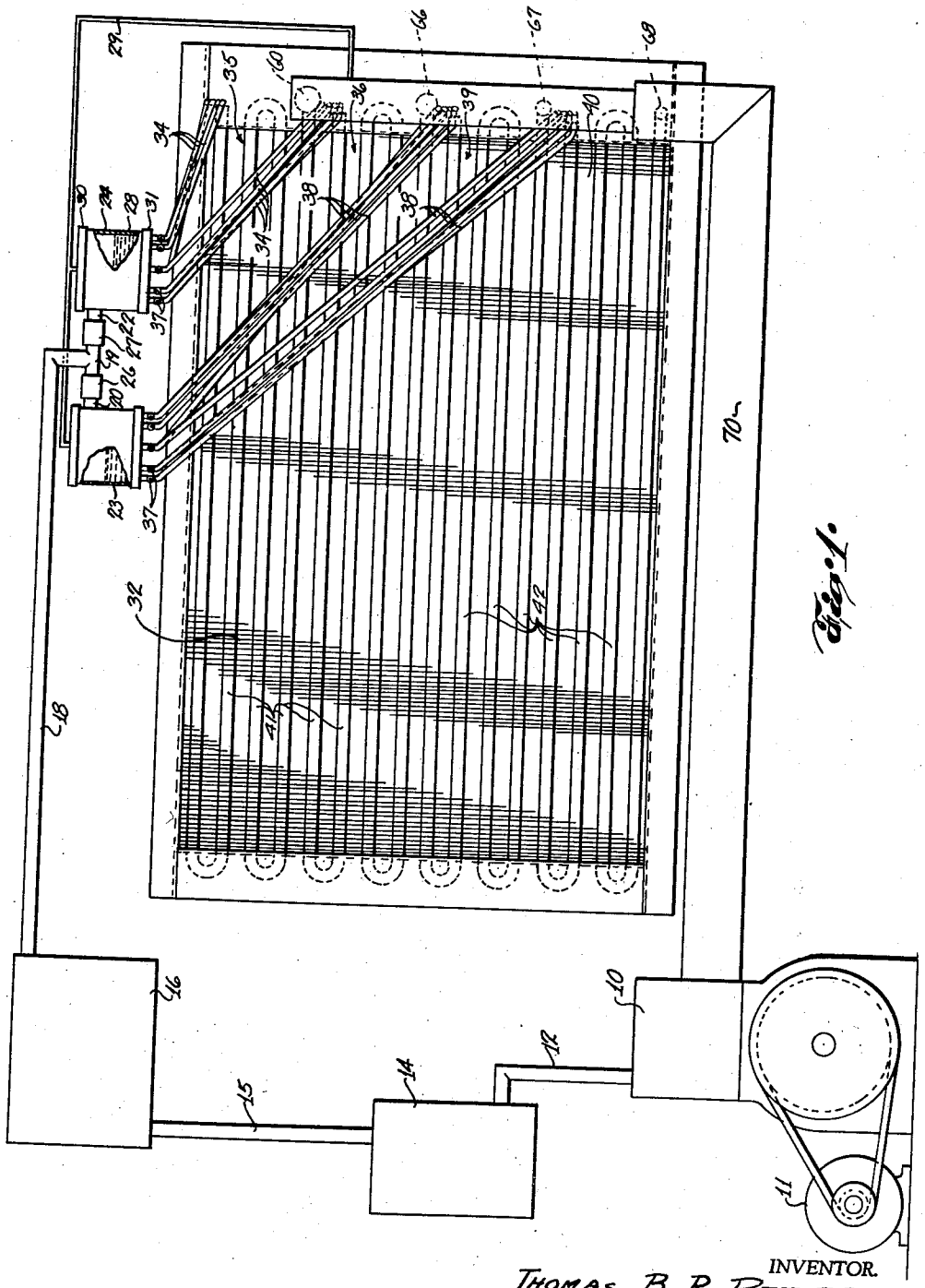


Fig. 1.

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Filed May 6, 1937 2 Sheets-Sheet 2

Fig. 2.

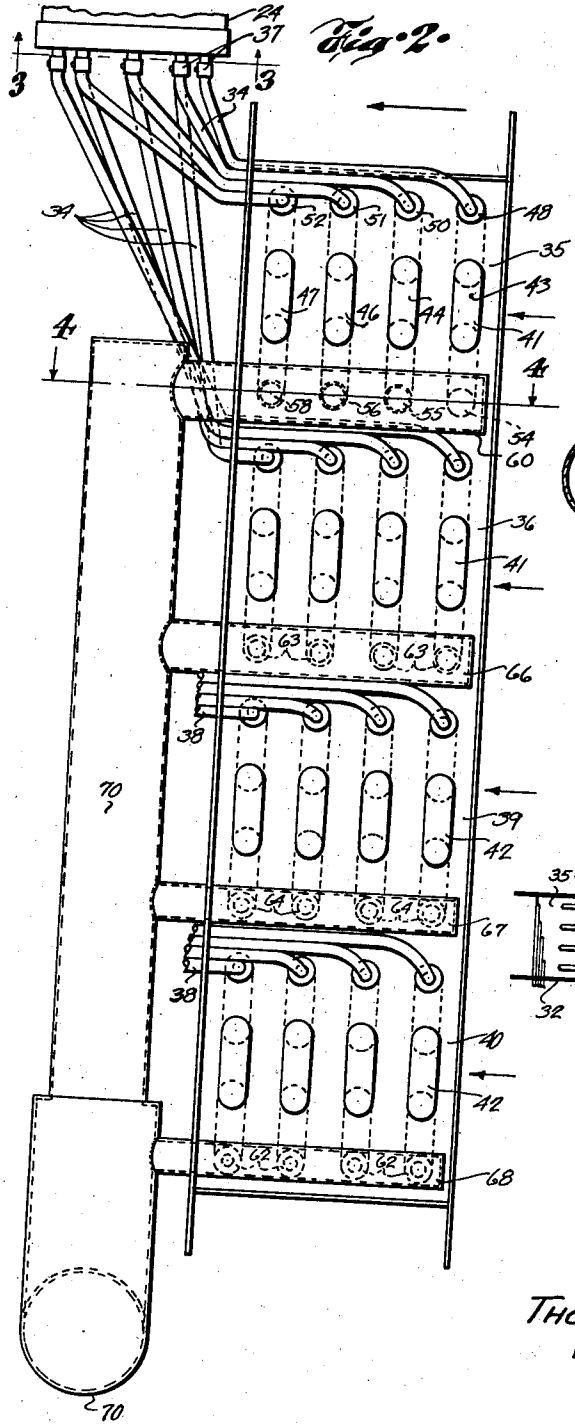
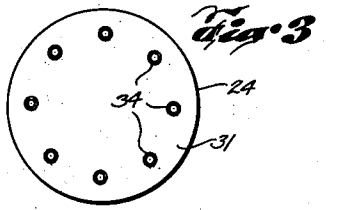


Fig. 3.



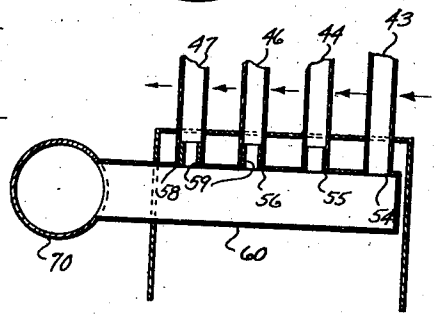


Fig. 4.

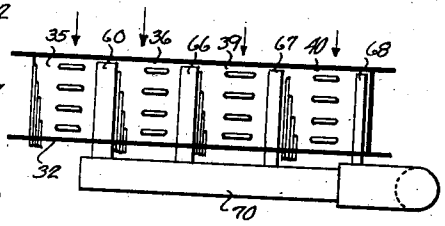


Fig. 5.

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EVAPORATOR

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Application May 6, 1937, Serial No. 141,040

5 Claims. (Cl. 62—126)

This invention relates to a refrigeration system and more particularly to an improved evaporator therefor.

The efficiency of a cooling or refrigeration installation is entirely dependent on the performance of the evaporator or direct expansion coil. Where an evaporator is comprised of a plurality of coil units, each of which consists of a set of coils placed side by side, certain difficulties are encountered in attaining a high cooling efficiency. It is well known that a refrigerant follows most readily the path of coldest flow. It is desirable therefore, to properly meter the quantity of refrigerant flowing through each coil to avoid a short circuiting, or excessive flow of the refrigerant through the colder coils, and insufficient flow through the warmer coils.

The cooling efficiency of an evaporator is also greatly reduced by the formation of oil traps in the coils. As the refrigerant is compressed, oil from the compressor suspends itself therein and is carried into the evaporator. When a refrigerant, such as freon for example, passes through the low pressure zone of the evaporator it changes into a gas, but the oil in the freon undergoes no change and remains in the liquid state. Since the liquid oil has a greater density than the gas, it tends to fall back behind the flow of the gas and lodge wherever possible. If the oil is permitted to thus accumulate within the evaporator coils, the coils in time will become oil-logged and deficient in their heat absorbing capacity.

The cooling efficiency of an evaporator is further greatly reduced by an improper distribution of the liquid refrigerant throughout the interior of the evaporator coils. A known quantity of a refrigerant in the liquid state occupies less volume than it does in the gaseous state. In the usual case, where an expansion valve forms a part of the cooling system, the liquid refrigerant in passing through the valve is changed from the liquid state to a mixture comprised in part of a liquid and in part of so-called flash gas. Since a temperature difference exists between the mixture and the air to be cooled by the evaporator, a transfer of heat between the gas of the mixture and the air will take place until the temperatures of the gas and passing air are equal. However, since the liquid in the mixture, per unit of weight, occupies a smaller volume than a corresponding weight of the gas, it will, upon the absorption of heat from the passing air, commence to boil and expand to a volume many times greater than its original volume. As a result the air is cooled not only by the sensible heat pick-up of the gas so formed but also by the latent heat necessary to effect a boiling or evaporization of the liquid. It is thus seen that the cooling efficiency of the evaporator would be increased if only the liquid refrigerant were distributed to all portions of the interior of the evaporator. It is accordingly one of the objects of the present invention to provide a refrigerant distributor which will effect a separation of the flash gas and liquid whereby the liquid may be uniformly delivered to all portions of the interior of the evaporator.

Another object of the improved evaporator is found in the provision of a means for metering the quantity of refrigerant flowing through each coil in proportion to the work to be done or heat to be absorbed by such coil. In air cooling installations employing an evaporator which is formed of a plurality of coil units each of which consists of a series or set of coils placed side by side, the coils first to contact the air to be cooled will absorb the most heat and the coils last to contact the passing air will absorb the least heat. In the improved construction herein set forth each coil is provided with a metering means for properly controlling the quantity of the refrigerant entering such coil.

Yet another object of the improved evaporator is found in the provision of a means for removing the refrigerant from the coils at a rate commensurate to its delivery therein. Each coil is provided with a different sized outlet port, the size of the port being dependent upon the heat exchange function of such coil and hence to the quantity of refrigerant delivered to such coil.

A further object of the improved evaporator is found in the provision for each coil assembly or unit of a suction header which is formed and arranged in a manner to procure a proper flow of the refrigerant through all the coils of such coil assembly. The suction header is in functional association with the coil outlet ports and is adapted to provide a positive draw or pull thereon whereby to avoid a short circuiting of the refrigerant through certain of the coils.

A still further object of the improved evaporator is found in the provision of a main suction header, which is arranged in operative association with the suction headers and formed in a manner to draw substantially the same quantity of refrigerant from each suction header during a similar unit of time.

A still further object of the improved evaporator is found in the provision of a gravity oil drain which operates to effectively drain the oil from the evaporator when the coils thereof

are mounted in either a horizontal or vertical position. A maximum flow of the refrigerant is thus attained in the coils at all times and oil logging, which materially reduces the heat absorbing capacity of the evaporator is substantially eliminated.

Other objects and advantages of the present invention will become evident from the following detailed description of parts and operation taken in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of a refrigeration system showing in part an elevational view of the distributors and evaporator; Fig. 2 is an enlarged elevational view of the evaporator showing a portion of a distributor; Fig. 3 is a bottom plan view of a distributor taken along line 3—3 in Fig. 2; Fig. 4 is a sectional plan view of a suction header and its associated coils taken along line 4—4 in Fig. 2, and Fig. 5 is a reduced elevational view of the evaporator showing a vertical mounting of the coils.

Referring to the drawings by suitable characters of reference, numeral 10 designates generally a compressor which forms a part of the refrigeration system shown in Fig. 1. The compressor 10 is operated by a motor 11 which is automatically controlled by suitable thermostatic means (not shown). The refrigerant as a vapor, is forced from the compressor under high pressure, through a pipe 12 into a condenser 14 where it is suitably cooled and liquified in a well known manner. The liquid refrigerant leaves the condenser through a pipe 15 and passes into a receiver 16 which serves to store the refrigerant and also to change the fluctuating high pressure of the refrigerant, caused by the compressor, into a high pressure of substantially constant value. The receiver is provided with a refrigerant outlet pipe 18 which joins and forms substantially a T joint with a pipe 19. The pipe 19 has its branches 20 and 22 respectively, in communication with similar distributors 23 and 24, to be hereinafter more fully described, through expansion valves 26 and 27 respectively; the valves being disposed in the branches 20 and 22 whereby the refrigerant from the pipe 18 is divided to flow substantially equally through each valve 26 and 27. It is to be noted, however, that the equal division of flow through the expansion valves into similar distributors is one of preference, since the distributors may vary in size.

The liquid refrigerant after passing through the expansion valves 26 and 27 is at a relatively low pressure and consists of a mixture of liquid and flash gas. In the use of a refrigerant, such as freon for example, if the flash gas were permitted to enter and fill the evaporator coils, a transfer of heat between the gas and the air to be cooled would only continue until the temperatures of the gas and passing air became equal. However this sensible heat pick-up by the flash gas is very small as compared to the heat transfer effected by the liquid refrigerant. When the liquid refrigerant enters the evaporator coils, a transfer of heat is necessary to change the liquid into a gas, and the gas so formed continues to take on heat until it reaches a temperature equal to the temperature of the passing air. Thus it is seen that the liquid refrigerant in the coils effects both a sensible heat pick-up and a latent heat extraction from the air passing about the evaporator; the effective work of the evaporator being accomplished when the liquid changes to gas. The presence of substantially an all liquid refrigerant in the coils provides in effect an increase in the surface area of the coil, for the heat absorbing capacity per unit of volume of the liquid refrigerant is many times greater than that of a corresponding unit of volume of the flash gas. In the present invention a substantially all liquid refrigerant is attained in the evaporator coils by means of the distributors 23 and 24 hereinabove noted and now to be fully described. Since the distributors are substantially similar in structure only one of them, say 24, will now be referred to.

The distributor 24 is, by preference, mounted above the evaporator, denoted generally as 32, and is comprised of a cylinder portion 28 having a top cover 30 and a bottom plate 31 suitably attached thereto. The pipe 19 connecting the valve 27 with the distributor 24 has its end 22 secured near the upper portion of the cylinder 28 whereby the heavier liquid particles of the refrigerant mixture entering the distributor from the valve may fall to the bottom of the distributor out of the way of the incoming mixture. The gas thus separated from the mixture rises to the top of the distributor and is carried to the suction line 70, through a bleeder pipe 29. The liquid refrigerant which has dropped to the bottom of the distributor flows into tubes 34 under the combined effects of the compressor draw in the expansion coils and the gravitational force acting on the liquid. The tubes 34, which are circumferentially arranged in the bottom of plate 31 (Fig. 3) and suitably secured thereto are adapted to supply the liquid to the coil units 35 and 36 and hence to the coils 41; while similar tubes 38 from the distributor 23 supply the liquid to the coil units 39 and 40, and hence to the coils 42. Each tube 34 is provided with a valve 37, which is graduated in a manner to meter a definite quantity of liquid into the tube with which it is associated. The quantity of liquid thus metered into each tube is dependent upon the heat exchange requirement of the particular coil in communication with such tube, as will be hereinafter more fully described. It is seen therefore that each coil assembly 35, 36, 39 and 40 is provided with a substantially liquid refrigerant which is properly metered through all the coils 41 and 42 whereby the cooling efficiency of the evaporator is greatly increased.

The liquid refrigerant in the coils 41 and 42, upon the extraction of heat from the air to be cooled and consequent evaporation process, tends to expand to a volume many times greater than its original volume. The gas formed in this manner is removed from the coils at a rate corresponding to the various metered quantities of liquid entering the coils from the distributors 23 and 24. It is thus apparent that a positive circulation of the refrigerant in all of the coils 41 and 42 is necessary for the efficient operation of the evaporator. Where a single coil of serpentine construction is employed, a positive circulation is readily attained since the coil has a single suction outlet upon which the compressor may draw. However in air cooling installations a series of at least three coils is usually provided to obtain the proper dew point for effectively extracting heat from the air. It is thus seen that the compressor draw or pull may be satisfied from one or a plurality of coil suction outlets, which are at varying distances from the compressor. If the rate of flow of the liquid in the coils is improperly controlled, the compressor will tend to draw the liquid through the coils of cold-

est flow, thus negativing the function of the metering valves 37 and causing the expansion valve in circuit with the coils to be actuated to a closed position before the coils of warmer flow have received their proportion of the liquid. It is apparent therefore that the quantity of liquid delivered to each coil by the metering valves 37 and the rate of flow of the expanded gas leaving each coil are mutually dependent factors, the proper operative coordination of which determines the cooling efficiency of the expansion coils. That is to say the maximum cooling efficiency of each coil is attained when the quantity of refrigerant delivered to such coil corresponds to its heat exchange requirement and when such heat exchange requirement is maintained substantially constant, for a particular operating condition, by a proper extraction of the gas from the coil at a rate proportional to its formation within the coil. A build up of pressure within the coil by the expanded gas is thus avoided and the incoming liquid refrigerant is permitted to flow freely into the coil.

In the present preferred illustration the evaporator 32 is shown (Fig. 2) as formed of four coil assemblies 35, 36, 39 and 40, each of which is comprised of a set of four serpentine coils, suitably disposed in corresponding parallel alignment as shown in Fig. 2. Since each coil assembly is substantially similar in operation and structure only one assembly, say 35, will now be described in detail. For the purpose of convenience of description, the four coils in the assembly 35 will be designated as 43, 44, 46 and 47 respectively.

Let it be assumed that the air to be cooled by the evaporator flows through the evaporator in a direction from right to left as indicated by an arrow. With the air flow as shown in Fig. 2, it is seen that the coil 43 which is the farthest from the compressor will be the first to come in contact with the passing air while the coil 47 which is the nearest to the compressor will be the last to contact the passing air. The coil 43 therefore would extract more heat from the air than coil 47 since the air in passing each coil 43, 44, 46 and 47 becomes gradually cooler and the temperature difference between each coil and the passing air becomes decreasingly smaller as the air moves from coil 43 to coil 47. However it is to be noted that since the coil 43 is the greatest distance away from the compressor, the compressor draw or pull on the outlet of coil 43 will be less than that on the outlet of coil 47, whereby the velocity of flow in coil 47 will tend to be greater than the velocity of flow in coil 43. It is to be noted also that if there were no metering valves 37 and all the coils were to receive an equal quantity of refrigerant, the coil 47 after a period of operation, would be much cooler than the coil 43 and the refrigerant from the distributor 24 would tend to feed through the coil 47, leaving the remaining coils 43, 44 and 46 partially or totally starved. The operating temperature of the refrigerant in each coil and hence the quantity of refrigerant in each coil as controlled by the valve 37 is therefore dependent upon the combined effects of the amount of heat absorbed from the passing air and the magnitude of the compressor draw or pull on the coil outlet.

It is preferred in the present example to maintain the cross sectional areas of the coil inlets 48, 50, 51 and 52 substantially equal and to vary the cross-sectional areas of the coil outlets 54, 55, 56 and 58 in direct proportion to the heat exchange requirement of each coil 43, 44, 46 and 47 and to the distance each coil is from the compressor or source of suction. The cross-sectional areas of the coil outlets 54, 55, 56 and 58 are varied by inserting therein bushings 59 (Fig. 2) which are provided with different sized ports or internal bores. It is seen that the coil 43, which performs more work and is farther from the source of suction than any of the other coils in the assembly 35, has an outlet 54 proportionately larger than the outlet 55 which in turn is proportionately larger than the outlet 56; the outlet 58 being the smallest of the coil outlets.

It has been noted that a suction or draw of variable pressure exists at each coil outlet and that corrections have been allowed for this condition. However since the area of each coil outlet 54, 55, 56 and 58, and hence the rate of flow in each coil 43, 44, 46 and 47 is dependent upon the particular suction pressure acting on such outlet, it is necessary to provide for a distribution of the suction pressure whereby the entire area of each coil outlet will be subjected to the action of the suction pressure. That is to say there must be a full draw or pull on the entire area of each coil outlet to obtain the predetermined metered quantity of liquid to flow through each coil. The proper pull on each coil outlet occurs when the suction header 60, in operative association with the coil assembly 35, is provided with a cross-sectional area substantially equal to or greater than the summation of the coil outlet areas or port areas in the bushings 59. There is thus attained in each coil, of the coil unit 35, a removal of the expanded gas therefrom at a rate corresponding to the metered quantity of refrigerant delivered to such coil whereby a short circuiting of the refrigerant through certain of the coils is substantially eliminated and a high cooling efficiency of the evaporator coils is attained.

The proper quantity of refrigerant flowing in the coils of the coil units 36, 39 and 40 is provided for in a substantially similar manner. Since the air conditions about each coil unit are the same, each coil unit will perform a substantially equal amount of work, whereby the quantity of refrigerant flowing through each coil assembly per unit of time will be substantially the same.

It is seen that the coil assembly 35 is the farthest from the compressor and that the coil assembly 40 is the nearest to the compressor, whereby the suction pressure acting on the outlets of the coils in assembly 40 will be greater than the pressure acting on the outlets of the coils of assembly 35. The velocities of the refrigerant flowing in the coil assembly 40 will therefore tend to exceed the velocities of the refrigerant flowing in the coil assembly 35, but since the coil assemblies are to pass substantially the same quantity of refrigerant per unit of time, the ports of the bushings 62, which are inserted in the coil outlets of the coils of unit 40, will be proportionally smaller than the ports in the corresponding bushings 59 of the unit 35 so as to compensate for the higher velocities of flow. It will be seen therefore that the coil units 36 and 39 which are located between the coil units 35 and 40 are provided with bushings 63 and 64, respectively, having openings proportionally smaller in size than the corresponding openings in bushings 59, and proportionally larger in size than the corresponding openings in bushings 62. Thus as is clearly shown in Fig. 2, each coil assembly 35, 36, 39 and 40 is provided with coil outlets having areas graduated in proportion to the heat ex-

change requirements of each coil and to the distance each coil is from the source of suction, whereby each coil unit will perform substantially the same amount of work. As hereinbefore noted the proper pull on each coil outlet in a coil unit is attained when the suction header, in operative association with the coil unit, is provided with a cross-sectional area substantially equal to or greater than the summation of the respective coil outlet areas. Therefore since the corresponding coil outlet areas or port areas of the bushings **59**, **62**, **63** and **64** of the coil units **35**, **36**, **39** and **40** are graduated respectively in a descending order, due to their approaching nearer to the compressor, the suction headers **60**, **66**, **67** and **68** in operative association with the respective coil units **35**, **36**, **39** and **40** are graduated in a corresponding descending order (Figs. 1 and 2).

Where a single coil assembly forms the total number of coils in the evaporator, it will appear evident that the cross sectional area of the suction header will be equal to the cross sectional area of the main suction header or line connecting the suction header with the compressor. However where an evaporator is comprised of a plurality of coil units such as **35**, **36**, **39** and **40** of the present case, the cross sectional area of each such suction header **60**, **66**, **67** and **68**, forms only a proportional part of the cross sectional area of the main suction header or line **70**. The cross sectional area of the main suction header is substantially equal to or greater than the summation of the cross sectional areas of the respective headers. The suction headers **60**, **66**, **67** and **68** are graduated so that their capacities are in proportion to the distance that each header is from the source of suction pressure. Since the quantity of refrigerant flowing through each header per unit of time is substantially the same, it will be further seen that the velocity of flow in each varies directly with the suction pressure acting on such header.

To assure a full capacity and metered flow of the refrigerant through all of the coils and suction headers of the evaporator it is necessary to prevent the formation of oil traps in the coils and suction headers. Where a refrigerant, such as freon for example, is used in the cooling system, an affinity exists between the liquid freon and the liquid oil, and the refrigerant has a tendency to entrain oil particles and carry the same through the entire system. When the liquid refrigerant is formed into a gas, in the manner hereinabove noted, the oil suspended in the liquid undergoes no material change and remains in the liquid state. The affinity between the gas so formed and the oil is less than the affinity between the liquid refrigerant and the oil, whereby that portion of the oil not taken up by the gas separates from the gas. Since the oil so separated has a greater density than the gas and oil mixture, it tends to flow slower than the mixture and collect wherever possible. If this oil is permitted to accumulate in the coils or suction headers, a condition will be reached, after a period of operation, where the flow of the gas will be impeded to the extent of seriously interfering with the cooling efficiency of the evaporator and in some instances the refrigerant flow in the coils or suction headers may be shut off entirely. In order to maintain at all times a high cooling efficiency in the evaporator, it is necessary therefore to provide for a constant drainage of the separated oil from the coils and suction headers whereby to substantially prevent the formation of objectionable oil accumulations. This is accomplished by arranging the coils of the evaporator to effect a gravitational flow of oil from each coil **42**, into the suction headers **60**, **66**, **67** and **68** and thence through the main suction header **70** into the compressor **10**.

In many air cooling installations it is desirable to have the coils mounted in a vertical plane, as shown in Fig. 5. From the preferred arrangement of the coils as shown in Figs. 2 and 5 it will appear evident that the evaporator will effect a proper drainage of the oil when the coils are mounted in either a horizontal or vertical plane.

A preferred embodiment of the present invention has been illustrated and fully described, but it is to be understood that certain structural changes may be made in the organization herein set forth without departing from the spirit and full intendment of the invention as defined in the appended claims.

I claim:

1. In an air cooling system, an air duct, an evaporator comprising a plurality of independent coils extending transversely in said duct and arranged sequentially in the path of air flow whereby said coils are contacted consecutively by the air flowing through said duct, a distributer common to said coils for supplying liquid refrigerant thereto, an exhaust header at the discharge end of said coils, and means at the discharge end of each of said coils for controlling the rate of flow of vaporized refrigerant therefrom to said exhaust header.

2. In an air cooling apparatus including an air duct, an evaporator comprising a plurality of independent coils extending transversely of, and arranged sequentially in the path of air flowing through said duct whereby said coils are contacted consecutively by the moving air, a distributer common to said coils for supplying liquid refrigerant thereto, an exhaust header for vaporized refrigerant connected to the discharge end of said coils, said coils having discharge ports, graduated in size, opening into said header, the coil first to contact the moving air having the largest discharge port.

3. In an air cooling apparatus including an air duct, an evaporator comprising a plurality of independent coils disposed in said duct and arranged to be contacted sequentially by the air flowing therethrough, a distributer for supplying liquid refrigerant to said coils, means associated with each of said coils for controlling the rate at which refrigerant is supplied thereto, a suction header at the discharge end of said coils for relieving the coils of vaporized refrigerant and means at the discharge ends of said coils for controlling the flow of vaporized refrigerant therefrom to said suction header, said supply and discharge control means jointly serving to graduate the rate of refrigerant flow through said coils so that the coil first contacted by the oncoming air has the greatest rate of refrigerant flow and the coil last contacted by the oncoming air has the lowest rate of refrigerant flow.

4. In an air cooling apparatus, an air duct, an evaporator comprising a plurality of independent coils arranged sequentially in the path of air flow through said duct whereby said coils are contacted consecutively by the moving air, a distributer connected to the inlet end of said coils for supplying liquid refrigerant thereto, an exhaust header connected to the outlet ends of coils for

receiving vaporized refrigerant therefrom, means for controlling individually the supply of refrigerant to said coils, the outlet openings of said coils being graded in size, the foremost coil having the largest outlet opening, and a conduit for conducting vaporized refrigerant formed in said distributor directly to said exhaust header.

5. In an air cooling apparatus, an air duct, an evaporator comprising a series of independent coils arranged sequentially in the path of air flowing through said duct, a distributer for supplying liquid refrigerant to said coils, an exhaust header, said coils having discharge openings at their outlet ends of graduated size communicating with said exhaust header, the coil disposed foremost in the path of the oncoming air having the largest discharge opening, said exhaust header having an outlet opening equal to or greater than the combined areas of the coil discharge openings.

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